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Reilly Tar Site / Meadowbrook Ground Water Model Expansion

Minnesota Pollution Control Agency
St. Paul, Minnesota

STS Project 99330-XF
June 30, 2006

EPA Region 5 Records Ctr.
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THE INFRASTRUCTURE IMPERATIVE

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June 30, 2006

Mr. Nile Fellows
Minnesota Pollution Control Agency
520 Lafayette Road
St. Paul, MN 55155

Re: Reilly Tar Site/Meadowbrook Ground Water Model Expansion;
STS Project 99330-XF

Dear Mr. Fellows:

We are pleased to present you with the Reilly Tar Site / Meadowbrook Ground Water Model Expansion Report. The work was conducted as outlined in STS Proposal 13137PP submitted to the MPCA on December 16, 2005, with slight modifications as dictated by the progressing modeling work. The proposal was approved as stated in the Contract Work Order STST0613 issued by MPCA on December 21, 2005. That Work Order was effective on December 21, 2005 and expires on June 30, 2006.

This report presents and documents the expanded model set-up, calibration, limited number of predictive simulations and discussion of the simulation results. Finally, it includes assessment of the model usefulness to assist with the remedial action evaluations and decisions as related to the Reilly Tar Site and other environmental projects in the area.

If you have any questions, please contact Peter Rzepecki at 763-315-6345 or Bob DeGroot at 763-315-6317.

Sincerely,

STS CONSULTANTS, LTD.

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1.0 INTRODUCTION, PURPOSE OF THE PROJECT

This report presents the sub-regional Reilly Tar Site / Meadowbrook Ground Water Model (the Model) that was set-up, calibrated and used to run a limited number of predictive simulations as specified in STS Proposal 13137PP. This proposal was submitted to the MPCA on December 16, 2005. Slight modifications of this work scope have been implemented in response to the progressing modeling work.

This project expanded the earlier developed ground water model by adding additional model layers that represent Glenwood, Platteville and Drift formations, in addition to St. Peter and Prairie du Chien – Jordan (OPCJ) formations represented in the initial model (STS, 2005b). The expanded model is a tool that can be used to better understand the ground water flow regime around the Reilly Tar Site and to help evaluate different pumping strategies to control the migration of the Reilly Tar Site related ground water contaminants. The model can also be used to evaluate possible sources and pathways of contaminants detected in the City of Edina municipal wells.

The Reilly Tar Site and the surrounding area encompasses several areas where contaminated soils and/or aquifers have been identified. These areas have been subject to numerous previous investigations and studies. Many of these studies included ground water modeling as summarized in the STS technical memorandum submitted to the Minnesota Pollution Control Agency (MPCA) in December 2003 (STS, 2003).

STS undertook an effort to identify and process an extensive amount of existing regional and site area-specific geological, hydrogeological, hydrological information including historical water level data as well as pumping and aquifer test data to support the model development. That data gathering and processing work is described in three STS reports submitted to MPCA in June and October 2004, and in January 2006 (STS, 2004a; STS, 2004b, STS, 2006a).

Several aquifer tests were conducted in the past within the area of the model domain for the OPCJ formations aquifer system. Many of these tests reported a range of transmissivity values, in addition to the preferable or best fit solution value. This range

reflects a measure of uncertainty associated with the test results. Summit Envirosolutions Inc. conducted a series of aquifer tests on Platteville / Drift wells near the Reilly Tar Site and provided the results to STS for use with the expanded model set-up. These test results also show a range of values obtained from different monitoring wells and using different analytical models (Theis, Cooper-Jacob Time-Drawdown and Neuman). As in the case of the Prairie du Chien – Jordan tests, this range represents uncertainties associated with the test results.

The STS ground water flow model was developed using the United States Geological Survey (USGS) Modular Finite difference ground water flow model MODFLOW v2000 and Visual Modflow, Ver. 4.1 platform. Two basic versions of the flow model were developed to explore the uncertainties as to the transmissivity values and their effects on the model predictions. The first version uses the lower range and the second version uses the upper range of the reported aquifer transmissivity values.

Both versions of the ground water flow model underwent initial manual calibration, followed by an automated calibration using the PEST optimization program. The model was calibrated to heads observed in the wells located within the 5-mile radius around the Reilly Tar Site. In addition to heads, four other measures of the model calibration were used in the process. Compared to the head based calibration, these measures are more qualitative in nature:

- Model simulated discharge through boundaries representing the Mississippi and Minnesota Rivers;
- Continuous water level measurements in Meadowbrook Golf Course Well (W119) and seasonal water level data from other wells near the Reilly Tar Site;
- Ground water age data obtained via low-level tritium analysis of the samples collected from the wells near the Reilly Tar Site; and
- Extent of ground water contamination.

While both model versions were calibrated to heads in monitoring wells within the 5-mile radius around the Reilly Tar Site, the high transmissivity model was unable to simulate the magnitude of measured seasonal water level fluctuations in the Prairie du Chien

Jordan wells. Also, it predicts particle transport far beyond the area of the documented ground water contamination around the Reilly Tar Site. In addition, the high transmissivity model's simulated discharge to rivers is high compared to literature provided ground water flux estimates. Therefore, the low transmissivity model was judged to be a more accurate representation of the ground water flow system under investigation, compared to the high transmissivity model. Consequently, most of the predictive simulations (conducted with the use of MODPATH particle tracking program) were conducted using the low transmissivity model. Also, the STS presented conclusions as to the operation of gradient control system are based on the low transmissivity model version.

2.0 CONCEPTUAL HYDROGEOLOGIC MODEL

This section presents the Conceptual Hydrogeologic Model of ground water flow in the southeastern portion of Hennepin County. That area encompasses the Reilly Tar Site which is the focus of this ground water modeling study. The conceptual model discussed below serves as a basis for the set-up and development of the seven-layer, three-dimensional Reilly Tar Ground Water Model.

2.1 Hydro-stratigraphic Units and Boundaries of the Reilly Tar Model

The Reilly Tar Site source and gradient control wells are completed in glacial Drift, Platteville (OPVL), St. Peter (OSTP) and Prairie du Chien / Jordan (OPCJ) aquifers. Therefore the Conceptual Hydrogeologic Model encompasses each of these aquifers and the aquitards that separate these units. Specifically, the model simulated confining layers or aquitard layers correspond to the following: the basal St. Peter confining unit, the Glenwood Shale and glacial till horizons that separate the sand and gravel aquifers within the Drift formation.

Two more major aquifer systems are present below the OPCJ Aquifer in Hennepin County: the deep Franconia-Ironton-Galesville Aquifer and still deeper Mt. Simon-Hinckley Aquifer. However, the St. Lawrence Formation that separates the OPCJ and Franconia-Ironton-Galesville aquifers is relatively impermeable and was assumed in this model to act as an aquaclude (see discussion in STS, 2003 – Section 4.2.2).

2.1.1 Drift Aquifer System – Hydro-stratigraphy

The Drift formation represents a complex system of water table and confined sand aquifers separated by a glacial till and other lower permeability strata. This Quaternary hydrogeology is also described as the water-table system and buried glacial aquifer (this last one present mainly in the western portion of Hennepin County - Kanivetsky, 1989). Five hydro-stratigraphic units have been described near the Reilly Tar Site: Upper Drift Aquifer, Upper Confining Unit, Middle Drift Aquifer, Lower Confining Unit, and Lower Drift

Aquifer (Lindgren, 1995). Lower Confining Unit is represented as Model Layer 1. Lower Drift Aquifer is represented as Model Layer 2.

2.1.2 Decorah-Platteville-Glenwood Confining Unit – Hydro-stratigraphy

The Drift formation overlies the Decorah-Platteville-Glenwood confining unit. Although the Platteville Limestone is regionally considered part of the confining unit, it yields water to wells in the Site area and is locally considered to act as an aquifer. Studies of the Platteville Formation under shallow bedrock conditions demonstrated the presence of discrete intervals with relatively well developed secondary porosity, separated by intervals with much lower porosity (Runkel et al., 2003). Platteville Limestone is represented as Model Layer 3.

The Decorah Shale has been extensively weathered, eroded and reduced to rubble. In the area near downtown Minneapolis it is present as erosional remnants of the continuous geologic unit which was originally deposited. The Glenwood Shale is consistently present throughout much of the Reilly Tar Site area and constitutes a confining unit. It is represented in the model as Layer 4. This regional confining unit is dissected by erosion where the buried bedrock valleys are present. One small branch of such bedrock valley extends one mile southeast of the Site. The eroded bedrock valleys were subsequently filled with glacial drift. Most of that drift is described in well logs of the area as a glacial till or "clay". However, part of the drift is likely present as sands and gravels which create a potential for increasing vertical movement of ground water and contaminants between the aquifers.

2.1.3 St. Peter Aquifer - Hydro-stratigraphy

St. Peter Sandstone constitutes the next deeper regional aquifer and is represented by Model Layer 5. It is present throughout most of the southeast portion of Hennepin County including the area around the Site. It is missing east of the Site where it was eroded away along the course of the buried bedrock valley (running south-north through Lake Harriet - "Chain of the Lakes"). The bedrock valleys were subsequently filled with

glacial drift. Analysis of boring logs included in the County Well Index reveal that the buried bedrock valleys near the Site were filled mostly with glacial till.

St. Peter Sandstone is composed of well sorted, fine- to medium-grained quartzose sandstone. Several indicators for the St. Peter aquifer in shallow bedrock conditions suggest that fracture flow may be regionally significant. Fractures in the St. Peter Sandstone are known to at least locally provide conduits through which ground water can move much more rapidly than rates predicted under the assumption of inter-granular flow only (Runkel, et al., 2003). It is not clear, however, if the St. Peter Formation around the Reilly Tar Site can be classified as fitting shallow or deep bedrock conditions described by Runkel, et al. (2003). These conditions differ by a degree of the presence of solution enhanced cavities and voids.

The basal portion of the St. Peter represents a confining unit, which consists of 5 to 15 feet of siltstone and shale. This confining unit overlies the OPCJ aquifer, which consists of dolomite and sandstone. The Basal St. Peter is represented in the model as a separate layer (Model Layer 6).

2.1.4 Prairie du Chien / Jordan Aquifer System (OPCJ) - Hydro-stratigraphy

Some investigators have recently postulated that the OPCJ aquifer should be divided into a Shakopee Aquifer (upper member of the Prairie du Chien Group) and Jordan Aquifer with Oneota Dolomite (the lower member of the Prairie du Chien Group, particularly the lower portion of it) serving as a confining unit. Ground water flows through the Shakopee Aquifer and the top portion of Oneota Dolomite chiefly through fractures and solution features having moderate to extremely high values of hydraulic conductivity. This migration pattern is quite different from ground water flow within the Jordan Sandstone (Runkel, et al., 2003). However, most of the Prairie du Chien and Jordan wells near the Reilly Tar Site are opened to both of these aquifers, providing hydraulic connection between these two natural hydro-stratigraphic units. Since most of the wells are opened to most or the entire OPCJ formation, there is no data to compare water levels and vertical hydraulic gradients between the Shakopee and Jordan Aquifers. As such, the OPCJ is modeled as a single layer (Model Layer 7).

2.2 Ground Water Level Patterns, Trends, Flow Directions, Recharge and Discharge Zones

2.2.1 City of St. Louis Park Water Level Database

The City of St. Louis Park (Mr. Scott Anderson – Superintendent of Utilities) provided STS with a database of 1650 water level measurements collected by the City from 119 wells during the period of June 1992 through August 2003. STS reviewed and processed these data to derive the basic statistical characteristics summarized below. STS also used the provided data to create a set of hydrographs for qualitative analysis and for transient model calibration. Following is the discussion of our findings:

- The City of St. Louis Park database does not include any data collected during winter time. This is most likely because during winter, the well padlocks are frozen and access to the wells is more difficult. Therefore, the summary presented below likely does not fully characterize seasonal fluctuations in water levels.

- Comparison of the average water levels in the four bedrock aquifers (Table 2-1, column 4, Figures 2-2 through 2-6) clearly demonstrates the presence of consistent downward vertical gradients from shallow to deeper aquifers. The greatest difference in water levels exists between the St. Peter and OPCJ aquifers. To a large extent, these head differences are caused by extensive pumping from the OPCJ aquifer and the relatively low hydraulic conductivity of the Basal St. Peter confining unit. The second strongest vertical gradient or head difference is present between the Platteville and St. Peter aquifers. This gradient is also caused by pumping from the underlying OPCJ aquifer (which, despite the presence of the Basal St. Peter confining unit, lowers water level in the St. Peter aquifer), and by the presence of the relatively impermeable confining Glenwood Shale. Water levels in the Platteville wells are only slightly lower compared to water levels in the Drift aquifer wells. These two shallowest aquifer systems are in much closer hydraulic communication than with deeper aquifers.

- The greatest fluctuations in water levels can be observed in the OPCJ wells (Table 2-1, columns 5 and 6) – maximum fluctuation was recorded in St. Louis Park Municipal Well No. 10 (SLP10) – 71.40 feet. Water levels in the other OPCJ wells, some distance from pumping centers, fluctuate on the order of 30 to 40 feet (780 to 820 feet). All hydrographs constructed for OPCJ wells show remarkable correlation (see Figure 2-2). The diverging hydrograph for well W70 most likely is caused by damage to the well seal. Such damage may be causing water leakage from the St. Peter Sandstone to OPCJ, thus resulting in increased groundwater elevations.

- Water level fluctuations are much smaller in shallower aquifers. The only fluctuations observed in the St. Peter and Platteville wells comparable to fluctuations in the OPCJ wells are recorded in the Platteville pumping wells – W421 and W434. Figure 2-3 demonstrates an interesting correlation between hydrographs of the St. Peter well W410 and the Platteville wells W434 and especially W421. Gradual decline in water levels measured in these three wells over the years 1992 and 2002 most likely is caused by a similar schedule of pumping from each of them – these wells are part of the Reilly Tar Site Gradient Control System. Close similarity between the hydrographs for wells W410 and W421 indicate hydraulic connection between the two wells. That connection is additionally implicated by the fact that well W421 is highly contaminated with VOCs, and the down-gradient well W410 is also contaminated with VOCs, though the detected concentrations are much lower. No hydrograph correlation can be observed between the hydrographs for W410 and the OPCJ well W48 (Methodist Hospital).

- Correlation between the hydrographs of the pumping Platteville wells, W421 and W434, and the other St. Peter wells in the area is not very strong (see Figure 2-4). However, a general decline in water levels in St. Peter wells can be correlated with the pumping from W421 and W434. A similar moderate correlation can be observed between the W421 and W434 and other Platteville and Drift wells' hydrographs (see Figures 2-5 and 2-6). A lack of hydrograph

correlation between some wells like W421 and W18, or W434 and W428, indicates a poor hydraulic connection between these wells within the Platteville aquifer. This is to be expected in a fractured formation.

- Water levels during the warmer half of the year (May to October) are higher in Drift and Platteville aquifers (greater recharge) and lower in St. Peter and OPCJ aquifers (greater pumping from OPCJ wells) compared to the average annual water levels (Table 2, column 9). This pattern is even more pronounced when considering only the summer data (July to September – Table 2-1, column 18). During the colder half of the year (November to April) the trend is opposite – water levels are lower in Drift and Platteville aquifers (less recharge during winter) and higher in St. Peter and OPCJ aquifers (lesser water demand and pumping from OPCJ wells) compared to the average annual water levels (Table 2, column 12).

- Based on review of the hydrographs, it is apparent that the vertical groundwater flow direction remains consistently downward, however the steepness of the gradient (i.e., rate of flow) may vary depending on the season. As shown by the hydrographs, the water levels in most of the wells in a given aquifer change in a similar pattern. Consequently, ground water and dissolved contaminants tend to travel in a similar direction, regardless of the season. The hydrographs suggest that the rate of vertical flow increases in downward direction during summer season. This is because during that time water levels in shallow aquifers are the above annual average reflecting increased recharge while water levels in deep aquifers are below average, reflecting the increased pumpage.

2.2.2 Drift Aquifer System - Hydrogeology

Very limited regional hydrograph data exist for Drift aquifer wells to evaluate seasonal and long term water level trends. Available data indicate that water table elevations show some correlation with the precipitation patterns. Water level in the buried drift artesian aquifer wells generally decreased in years 1945-2002, however, no clear seasonal pattern could be discerned.

The Drift aquifer system is recharged by infiltrating portion of precipitation throughout the entire Hennepin County. Ground water flows in general toward the Crow, Mississippi and Minnesota Rivers, away from the ground water divide that is located in the west-central portion of the County, north of Lake Minnetonka. It discharges to the rivers and to local streams and lakes. The Drift aquifer also recharges deeper, bedrock aquifers.

2.2.3 St. Peter Aquifer - Hydrogeology

Very limited regional hydrograph data exist for St. Peter aquifer wells to evaluate seasonal and long term water level trends. Available data indicate no clear long-term trends. In some locations water levels decreased over the years, at other locations they increased. A seasonal pattern is usually present with summer drawdowns from 2 to 20 feet as measured in actively discharging or pumped wells. In monitoring wells that are not pumping wells, summer drawdown is generally 1 to 2 feet.

Ground water in the St. Peter aquifer generally flows from west to east/southeast under the influence of a regional hydraulic gradient of about 10 feet/mile. This gradient increases, however, near the Mississippi and Minnesota Rivers.

The St. Peter aquifer is recharged by leakage from the overlying units. Recharge rates to this aquifer are influenced by, among other things, the hydraulic properties of the overlying units, which can range from very permeable glacial outwash materials to relatively impermeable shale and limestone formations (Seaberg and Hansen, 2000). Discharge from the aquifer is to unconsolidated sediments in the valleys of the Minnesota and Mississippi Rivers, to production wells completed in the aquifer, and through leakage to underlying aquifers (Lorenz and Stark, 1990). Larsen-Higdem and others (1975) estimated that the average vertical leakage from the St. Peter aquifer to the underlying OPCJ aquifer, in Hennepin County, is about 3.5 inch/year and that about one inch of additional leakage may occur as the result of increased summer pumping and resulting drawdown in the OPCJ aquifer (i.e., increased vertical gradients between the two units).

2.2.4 Prairie du Chien / Jordan Aquifer System – Hydrogeology

Detailed hydrographs are available for several OPCJ wells within Hennepin County. Analyses of these hydrographs reveal that ground water elevation increased in the Minneapolis area since the early 1990s, decreased in the St. Louis Park area and was stable near Lake Minnetonka. A seasonal pattern was present in all wells with summer drawdown varying with time and area, and ranging from 1 to 90 feet. However, it was noticed that most of the available OPCJ hydrographs are from pumping wells. Only five non-pumping, observation wells' hydrographs are available to document seasonal water level fluctuations at a distance from the pumping wells. Summer drawdown for these wells ranged from zero to 7 feet and average approximately 2.55 feet. Due to well efficiency and construction related variables, the observation well drawdown values are more representative of the seasonal water level fluctuations within the aquifer system than the 30, 60 or more feet of summer drawdown measured in pumping wells. However, data collected from the Municipal Well Edina 7 show that water level in July 2004 was 29 feet lower compared to January 2005. This summer drawdown may be typical of a major, concentrated municipal supply well field, like the one in Edina.

Ground water in the OPCJ aquifer flows in the eastern, southeastern and southern direction, towards the Mississippi and Minnesota Rivers.

Recharge to the OPCJ aquifer system occurs as leakage from the overlying bedrock units and from the glacial drift where the OPCJ formation sub-crops beneath it. As in the case of the shallower aquifer systems of the area, the OPCJ aquifer ground water discharges to surface water bodies, primarily the major river systems that physically dissect the aquifer (i.e., the Mississippi and Minnesota Rivers). However, unlike the shallower systems, a significant portion of the discharge from this aquifer occurs through ground water pumping. Leakage through the underlying St. Lawrence Formation, a regional confining unit, is considered negligible (see discussion in STS, 2003 - Section 4.22).

2.3 Ground Water Production Rates, Patterns and Trends

Ninety-six wells that are pumping at an average annual rate of 100 gpm, or more, were identified within the 10-mile radius of the Reilly Tar Site. This equates to one well per three square miles, on average. However, the distribution of high capacity wells over the area is very uneven. These high capacity wells account for over 90% of the water withdrawn from all wells of the area.

Over 90% of ground water pumped within the 10-mile radius of the Reilly Tar Site comes from the OPCJ aquifer system. Most of the water produced from OPCJ is pumped by the municipal wells. Only a small increase in ground water production has taken place within the last 15 years (1988-2002). A slightly increasing trend in ground water production can be observed for all the City of St. Louis Park municipal wells. However, production from the neighboring City of Edina municipal wells shows a slightly decreasing trend.

Maximum ground water production for most of the Edina and St. Louis Park OPCJ wells occurs in May through October. On average, about 59% of the annual ground water production takes place during this period. Very few wells diverge from that pattern.

A more detailed discussion of ground water production rates, patterns and trends can be found in the October 2004 and January 2006 STS reports (STS, 2004b, Section 3.3; STS, 2006a, Section 4).

2.4 Approximate Water Budget

A preliminary water balance for the model domain was developed using several assumptions, data and equations as explained below.

Assuming no significant changes in aquifer system storage with time, general water balance of the proposed Reilly Tar Site Model can be described using the following equation:

$$Rech_{precip} + Rech_{surf\ wat\ bod} + Q_{inflow\ horiz} = Disch_{surf\ wat\ bod} + Q_{exflow\ horiz} + Leakage_{St\ Lawrence} + Q_{wells}$$

Where:

$Rech_{precip}$	– recharge from precipitation;
$Rech_{surf\ wat\ bod}$	– recharge from surface water bodies;
$Q_{inflow\ horiz}$	– horizontal ground water inflow across the artificial model boundaries (west and northwest model boundaries – see discussion in Subsection 5.1.2 – Model Boundaries);
$Disch_{surf\ wat\ bod}$	– discharge to surface water bodies;
$Q_{exflow\ horiz}$	– horizontal ground water outflow across the southern artificial model boundary;
$Leakage_{St\ Lawrence}$	– leakage of ground water from OPCJ aquifer downward through St. Lawrence formation;
Q_{wells}	– discharge of ground water from production wells.

The following considerations were taken into account in order to simplify the above equation:

- The most significant recharge from surface water bodies is that which is coming from Lake Minnetonka;
- Most of the ground water outflow is taking place across the line of artificial southern model domain boundary, discharging to the Minnesota River;
- The model domain's northern boundary approximately coincides with the regional ground water flow path lines – therefore ground water movement across this boundary is assumed to be insignificant;
- Vertical downward leakage from the OPCJ aquifer through the St. Lawrence formation is considered insignificant compared to other elements of the water balance.

Using the above assumptions, an approximate water balance for the model domain can be represented with a simpler equation:

$$Rech_{precip} + Rech_{Lake\ Minnetonka\ and\ ground\ water\ horizontal\ inflow\ from\ the\ west\ and\ northwest} = Disch_{surf\ wat\ bod} + Q_{wells}$$

Table 2-2 presents the approximate water balance for the area of the model domain. Recharge from precipitation (Table 2-2, row 3) is taken from regional data (Norvitch et al.,

1974). Discharge to major rivers (Table 2-2, row 6) is taken from regional data (Schoenberg, 1990). Ground water pumping (Table 2-2, row 7) was calculated as average production in years 1988-2002 from all MDNR permitted wells within a 7-mile radius of Reilly Tar Site. This ground water pumping rate is likely to be over-estimated, since many of the wells within the 7-mile radius of the Site may be outside of the model domain. The model domain's shape is more of a rectangle than a circle. Recharge from Lake Minnetonka and horizontal ground water inflow across the arbitrary western and northwestern model boundaries was lumped together (Table 2-2, row 4) and calculated using the other three water balance terms.

Row 8 of Table 2-2 presents the calculation of vertical ground water leakage rate from the OPCJ aquifer down through the St. Lawrence Formation. That calculation involves leakage rate estimation provided by Hansen and Seaberg (2000). The calculated leakage rate is about two orders of magnitude smaller than any of the four elements of the summary water balance. Thus, the assumption of an impermeable bottom of the OPCJ (and the lowest model layer) seems to be reasonable.

The regional value for recharge from precipitation provided by Norvitch et al. (1974), 0.1626 m/year, falls within the range of values used in the MPCA Metro Model (Seaberg and Hansen, 2000) for polygons coinciding with the Reilly Tar Model domain area. The net recharge within this area ranges from 0.3556 m/year to minus 0.1524 m/year (minus sign indicating net discharge from aquifer rather than recharge to aquifer). However, the average recharge for these polygons (without considering varying areas of the polygons) is smaller than the Norvitch value – 0.1291 m/year. It is important to note that Helgeson and Lindholm (1977, p. 16) estimated recharge to the unconfined drift aquifer underlying the Anoka Sand Plain in the northern part of the Minneapolis-St. Paul Metropolitan Area to be considerably larger, 0.2819 m/year (information included in Lindgren, 1995). Considerable portions of the Reilly Tar Site Model domain consist of highly permeable outwash and terrace deposits – areas with surface geologic conditions similar to the Anoka Sand Plain. On the other hand, most of the model domain area is urban and suburban in character and, therefore, relatively high surface runoff can be expected.

The regional value for discharge to major rivers provided by Schoenberg (1990), 2.2 m^3 per day per one meter of river, is somewhat lower than discharges calculated by the MPCA Metro Model (Seaberg and Hansen, 2000 – Table 5 – Modeled Discharge to Curvilinear Line-Sinks, Northwest Province). Modeled discharge to curvilinear line-sinks representing Mississippi and Minnesota Rivers in the Metro Model range from 3.3 to 13.5 m^3 per day per one meter of the Mississippi River and from 3.9 to 4.5 m^3 per day per one meter of the Minnesota River. As opposed to the Mississippi River valley, the Minnesota River valley dissects the OPCJ Formation. Therefore, ground water discharge to the Minnesota River should be considerably higher than discharge to the Mississippi River. The discharges simulated by the Metro Model show the opposite trend, thus pointing to this model's potential shortcoming. This is an important consideration for the Reilly Tar Site model. The Metro Model set-up tends to simulate more easterly ground water flow direction near the Site, resulting in less likely interception of the St. Louis Park area contaminants by the Edina wells – the Edina wells are south to southeast of St. Louis Park. It is important to note that ground water contamination was detected in the Edina municipal wells number 2, 7, 13 and 15.

3.0 MODEL SET-UP

3.1 Modeling Software

The Reilly Tar Site Model was developed using MODFLOW v2000 program. The decision to use MODFLOW was based on the following considerations:

- MODFLOW can accommodate a great level of detail like inhomogeneities and other structural features (see discussion in Barr, 1999);

- MODFLOW allows transient condition simulations - such simulations represent more realistically the dynamic, seasonally changing ground water flow conditions around the Reilly Tar Site;

- MODFLOW is public domain software - completed model files can be accessed by general public. MODFLOW represents the most popular program among ground water modelers and hydrogeologists, and the model files are portable; model set-up is easy to understand, verify and modify by various users (governmental agencies, consultants, citizen organizations, etc.).

The model was developed using the Visual MODFLOW v. 4.1 pre- and post-processing platform. Model calibration was accomplished in three phases:

- Phase I - manual parameter adjustments;
- Phase II - automatic calibration with the use of the parameter estimation program, PEST;
- Phase III - inspection of the PEST output and final manual adjustments; this phase involved the use of MODPATH particle tracking program.

The model was calibrated using head data, regional water budget estimates discussed in Section 2.4 above, ground water age dating data and seasonal water level fluctuation data (see discussion in Sections 4.0 and 5.0).

The calibrated model was used to run a limited number of predictive simulations to evaluate the effects of various gradient control pumping well configurations. The effects of these different gradient control configurations were evaluated with the help of the particle tracking program MODPATH. Particles were "released" and tracked "forward" from within the known locations of PAH and phenolics plumes (see discussion in Section 6.0).

3.2 Model Domain and Boundaries

The model domain is centered on the Reilly Tar Site (see Figure 3-1). It is extending in each direction from the site, six to over ten miles encompassing 423 square kilometers (163 square miles). It extends in a western direction to Lake Minnetonka, encompassing Grays Bay, Wayzata Bay, Robinson Bay and the eastern portion of Brown Bay. The eastern part of Lake Minnetonka is considered a major recharge area to the OPCJ Aquifer. Norvitch and others, 1974, showed the Grays Bay area of the lake area to be a stable feature with a constant piezometric level throughout the year.

The northern and southwestern boundaries of the domain are set parallel to a regional ground water flow direction as shown on the water table map in the Geologic Atlas of Hennepin County (Kanivetsky, 1989, Plate 5). The eastern boundary of the model domain coincides with the position of the Mississippi River and the eastern boundary of the MPCA Metro Model - Northwest Province (Seaberg and Hansen, 2000).

The southern model boundary is set along Highway 494, north of the Minnesota River, as an artificial, prescribed head boundary. The area near the Minnesota River was excluded from the model domain. This way the need to model highly complex geologic and hydrogeologic features present in that area was avoided. The simulation of deep buried bedrock valleys that cut through the OPCJ formation south of Highway 494 or the consideration of seepage of ground water from the aquifers that terminate in that area would greatly add to the complexities of this modeling project without offering any significant benefit. The purpose of the model is to simulate the ground water flow around the Reilly Tar Site. As such, the defined model southern boundary is sufficiently far away

from the important areas of the project that the southern boundary was deemed to exert no significant influence.

Model external boundaries are represented as both no-flow boundaries and prescribed head boundaries. The head values for the boundaries were taken from the water levels measured in the wells located along the boundaries. The water level data were taken from the calibration database developed for this project. This database was developed using several sources as briefly described in Section 3.6.

For the model Layer 1 representing the Lower Drift Confining Unit, the southern model boundary, where groundwater migrates toward the Minnesota River, was set as prescribed head boundary. All the other boundaries in that layer were set as no-flow boundaries (see Figure 3-2).

For the model Layer 2 representing the Lower Drift Aquifer, the southern model boundary was set as prescribed head boundary, like in the Layer 1. However, the northwestern boundary was also set as prescribed head boundary to simulate influx of water from up-gradient direction – the central portion of the Hennepin County, where the center of the regional recharge zone is located (see Figure 3-3).

Boundaries for the model Layer 3 representing Platteville Formation (where it is present) were set the same as for Layer 1 (see Figure 3-4).

All boundaries of the model Layer 4 representing Glenwood Formation were set as no-flow boundaries. This is because this unit serves as a regional confining unit and ground water migrates through it mainly in the vertical direction (see Figure 3-5).

For the St. Peter aquifer, represented as model Layer 5, the northwestern, northeastern, eastern and southern boundaries are set as prescribed head boundaries (see Figure 3-6). A short segment of the eastern boundary near downtown Minneapolis is set as no-flow boundary - this is the area coinciding with the presence of Platteville and Glenwood Formation overlying St. Peter and separating it from the Mississippi River (Olsen and Bloomgren, 1989). Discharge of the St. Peter aquifer ground water in that area to the

river is significantly restricted. The northern and southwestern model boundaries parallel the regional ground water flow direction in St. Peter aquifer and were set as no-flow boundaries since little flux occurs across the regional flow line which established the model boundary.

All boundaries of the model Layer 6 representing Basal St. Peter Formation were set as no-flow boundaries. This is because this unit, similar to Glenwood Shale represented by model Layer 4, serves as a regional confining unit and ground water migrates through it mainly in the vertical direction (see Figure 3-7).

For the OPCJ aquifer system, the northwestern and southern boundaries are set as prescribed head boundaries (see Figure 3-8). The northern, eastern and southwestern boundaries are set as no-flow boundaries. The northern and southwestern model boundaries parallel the regional ground water flow direction - thus there is little flux across this model boundary such that they may behave as a no-flow boundary. The eastern boundary represents a regional discharge zone at the Mississippi River. This discharge zone is represented as a no-flow boundary. Such boundary is forcing water to go up to the Model Layer 5 which represents St. Peter aquifer.

3.3 Model Grid Design

The model grid is superimposed upon this 423 square kilometers (163 square miles) area of the model domain. The 100 square kilometer area centered on the Reilly Tar Site (within the five kilometers east, west, north, south from the Site - little over three miles) is represented by a uniform grid spacing of 75 x 75 meter squares. This dense, central portion of the grid consists of 133 columns and 133 rows. Beyond this central area of uniform refinement, the grid expands at a ratio of 1.1 to 1 (1.1 indicates a 10% increase in the size of each adjacent cell). Portions of the grid located beyond the horizontal model domain boundaries are set inactive (see Figure 3-9).

The model domain grid consists of 185 columns and 171 rows to form a total of 31,635 cells per model layer. Three model layers were set as described in the next section. The entire model grid consists of 221,445 cells. Many of these cells are excluded from the

model domain and are set inactive, as discussed above. The areas within the shallow layers set inactive were determined by comparing the bottom elevation of these layers with water levels in the Metro Model database ("w1-cal3") – buried drift wells.

The grid provides a model that is manageable, not excessively large, while at the same time offering sufficient level of space discretization and refinement to simulate the pumping wells' cones of depression near the Site.

3.4 Model Layers

The following seven layers were set in the model:

- Lower Drift (Lower Confining Unit near the Reilly Tar Site) – Model Layer 1;
- Lower Drift (Lower Drift Aquifer near the Reilly Tar Site) – Model Layer 2;
- Platteville Limestone (OPVL) – Model Layer 3;
- Glenwood Shale (OGWB) – Model Layer 4;
- St. Peter Aquifer (OSTP) – Model Layer 5;
- Basal St. Peter Formation (aquitard) – Model Layer 6; and
- Prairie du Chien – Jordan Aquifer System (OPCJ) – Model Layer 7(see Figure 3-10 and 3-11).

The model layers allow simulation of a fully three-dimensional flow between the aquifer systems. The deeper model layers are used to simulate confined ground water flow conditions, while shallower layers may simulate unconfined flow conditions, particularly close to the eastern and southern boundaries of the model where water level drops near the Mississippi and Minnesota Rivers.

Since in MODFLOW aquifer transmissivity is assigned to a confined layer directly, selection of the layer's top and base elevations for the three deeper model layers (Layers 5, 6 and 7) is not critical, as long as heads do not drop below the top of the layer elevation (that would convert the layer from confined to unconfined or water table condition). Therefore, elevations of the tops and bottoms of these deep model layers are set to coincide with the elevation of bedrock formations in the area between the Reilly Tar

Site and the northern portion of the City of Edina. The following top and base elevations are used for these deep layers:

- Layer 5 (St. Peter aquifer): top - 242 m MSL, bottom - 199 m MSL
- Layer 6 (Basal St. Peter Formation): top - 199 m MSL, bottom - 194 m MSL
- Layer 7 (OPCJ) - 128 m MSL: top - 194 m MSL, bottom - 128 m MSL

The top four model layers (Layers 1, 2, 3 and 4) were added on top of the original model layers described above. The new layers were designed to represent Drift, Platteville and Glenwood formations. Thickness of these formations varies from place to place and, at some locations, water table resides within them creating unconfined condition. For these reasons, setting the constant top and bottom elevation for the layers representing these formations was not appropriate. Therefore, the top and bottom elevations of the shallow layers were assigned using the digital elevation models. STS developed these models using stratigraphic information that is included in the Minnesota County Well Index database (CWI). The top and bottom elevations of Glenwood and Platteville formations were found by querying the c4st table of the CWI database and processing the extracted information. The ground elevations for the wells near the Reilly Tar Site were verified using the results of surveying conducted as part of the St. Louis Park W437 Chlorinated Solvent Source Investigation (STS, 2006b).

It was assumed that the first two top layers of the model, Layers 1 and 2 representing the lower portion of the Drift formation, are 5 meters thick. This assumption was based on review of geological cross-sections provided by Lindgren (1995). It was observed that the Lower Drift Aquifer near the Reilly Tar Site is in many places roughly 5 meters thick. The modeler decided to represent only the 5 meter thick bottom portion of the Lower Confining Unit, which in many places is thicker than 5 meters. Consequently, the top and bottom elevations of these two top layers were calculated by adding 5 and 10 meters to the elevations of the top of the Platteville Formation. Thus, the two top layers are both 5 meters thick (on average – interpolation algorithm somewhat modified the elevations throughout the model grid) and are mimicking the top of Platteville surface as represented in the model.

Next, the datasets of stratigraphic contact elevations for each of the shallow layers were imported into Visual MODFLOW using "Import Elevation" feature. The imported elevation points were interpolated and projected onto the model grid. Visual MODFLOW automatically checks and corrects the interpolated values to assure that the resulting thickness of each new layer is more than 0 meters. The created layers were visually inspected by the modeler and a few corrections were made to reduce the excessive differences between the elevation of layers in the neighboring grid cells – a situation that often occurs when the original elevation data is not very precise and/or when the interpolating algorithm (Krigging) creates unlikely outputs. The resulting layers are illustrated by Figures 3-10 and 3-11 that show vertical cross-sections of the model, cutting through the middle of the model domain.

3.5 Pumping Wells Represented in the Model

Pumping data for high volume pumping wells within the model domain were obtained from the Minnesota Department of Natural Resources (MDNR) "State Water Use Data System" (SWUDS). Data can be downloaded from the MDNR website - http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html).

Data obtained from the SWUDS database were screened using the following procedures:

- The records for all permitted pumping wells within Hennepin County were retrieved (542 wells remained in the database);
- The wells located more than 10 miles away from the Reilly Tar Site were screened out (350 wells remained in the database);
- The average reported pumping in the years 1998 – 2002 was calculated. All the wells with average annual pumping rate less than 100 gpm were screened out (116 wells remained in the database – data for other wells with lower production wells were retained in case it is needed later in the project);
- The wells were grouped by the aquifer (using the information included in the "Resource Name" field of the SWUDS database);
- All the wells opened to aquifers deeper than Jordan Sandstone were screened out (108 wells remained in the database).

- All the wells opened to aquifers shallower than St. Peter were screened out (98 wells remained in the database).

Fifteen Hennepin County wells discharging at an average rate of more than 100 gpm were not included in the database because no coordinates (Northing and Easting) were available. However, inspection of the permittee names indicated that all of these wells are likely far away from the Reilly Tar Site area. Pumping from these wells should not significantly influence the ground water flow field near the Reilly Tar Site, which is the focus area of this model.

In total, 98 pumping wells were included in the model database. These are the wells within a 10-mile radius of the Reilly Tar Site that are pumping at an average annual rate of 100 gpm or more. Pumping rates for these wells were calculated as average annual production rate for years 1988-2002. Out of these wells, only the wells that are at least one mile away from these boundaries are represented in the model. The influence of the wells that are one mile away from the boundary, or less, is reflected by the prescribed heads set at the boundary.

There are hundreds of wells within the area of model domain that are pumping at an average rate of less than 100 gpm. Such wells are not represented in the model. However, these lower capacity wells pump only a few percent of the total production of the high capacity wells that are included in the model. Therefore, for the purpose of this model, these wells have been considered to exert a relatively insignificant influence on the regional ground water flow. However, some of these lower production wells that are close to the Site area could exert significant influence on contaminant pathways. For this reason, some additional wells discussed below have been added to the model simulations.

Out of the 98 wells in the original database, only 50 wells were found to be located within the model domain and, if within the domain, more than one mile away from the model domain boundaries. Eight additional wells were added to the model. These are six source and gradient control wells that were operating in 2005 and two other wells that are currently not pumping but may initiate pumping in the future. Pumping rates for the six

active wells were taken from the Annual Progress Report for 2005 (ENSR, 2006a) and are summarized below:

- Republic Creosote (W23): the OPCJ Site source control well that is pumping continuously at an average rate of 46.4 gpm;
- W410: the St. Peter (OSTP) aquifer gradient control well that is pumping at an average rate of 85.1 gpm;
- W420: the Deep Drift Aquifer gradient control well that is pumping at an average rate of 33.2 gpm;
- W439: the Deep Drift Aquifer gradient control well that is pumping at an average rate of 48.6 gpm;
- W421: the Platteville (OPVL) aquifer gradient control well that is pumping at an average rate of 29.7 gpm;
- W434: the Platteville (OPVL) aquifer gradient control well that is not active now but was pumping in 2005 at an average rate of 32.4 gpm;

Two more wells that are not currently pumping were also added to the model:

- Meadowbrook Golf Course Well (W119): the OPCJ well that is not pumping now but may be pumped in the future;
- Methodist Hospital Well (W48): the OPCJ well that is not pumping now but may be pumped in the future.

Based on the above discussions, a total of 58 wells are represented by the model. One well is completed in the Deep Drift Aquifer and is represented in model Layer 2. Three wells, W421, W434 and W439, are completed in the OPVL aquifer and are represented in model Layer 3. One well, W410, is completed in the OSTP aquifer and is represented in model Layer 5. Most of the wells, 53, are completed within the OPCJ aquifer and are represented in model Layer 7. Since two pairs of the wells share the same model cell (Abbot 1 & 2 and Richfield 1 & 2), the MODFLOW simulates only 56 wells (see Figure 3-12 and Table 3-1). In this case, Visual MODFLOW automatically assigned a combined discharge to the model cell.

3.6 Water Level Monitoring Points Used in the Model Calibration

All collected water level data were grouped into four categories of data from the highest quality, best documented and most detailed, group 1 data, to the lowest precision, reliability and poorest documented, group 4 data.

- Group 1 Dataset

High quality water level data collected as part of the MDNR administered Observation Well (ObWell) program were downloaded from the MDNR website - http://climate.umn.edu/obwell/ObWlCh.asp

Twenty-four of these Group 1 dataset wells were identified within the model domain which are opened to OPCJ aquifer or shallower aquifers. Water level records for each of these wells include measurements taken several times a year, for many years.

- Group 2 Dataset

City of St. Louis Park provided STS with water level data collected for 127 wells in 2001, 2002 and 2003. The water level data for these wells were collected two times a year, in late April and late September. Fourteen of these monitoring wells are St. Peter wells, and twenty-six are OPCJ aquifer wells.

City of St. Louis Park also provided STS with another database of 1650 water level measurements collected by the City from 119 wells during the period of June 1992 through August 2003. Twenty wells from that database that were recently surveyed and have multiple water level measurements were selected from that database for inclusion into the Group 2 Dataset. Three of these are Drift wells, nine are OPVL, five are OSTP wells and three are OPCJ wells.

City of Edina provided STS with static and pumping water level data collected over the years for nineteen of the Edina municipal water supply wells.

- Group 3 Dataset

In addition to the data from the current ObWell program, STS obtained data for 101 other wells that were part of this program in the past. These data were provided to us on CD by Justin Blum, the co-author of the ground water Multiple Layer Analytic Element Model (MLAEM) regional model ground water flow within the OPCJ aquifer in Hennepin County. That model was developed in the mid-1990s by Jim Piegat (Hennepin County) and Justin Blum (MPCA). STS refers to this model as the "MDH Model". Apparently no documentation was ever published for the MDH model. The CD includes electronic files with water levels measured in 114 wells in summer and winter of 1993 and 1994. Only three of these wells are currently utilized by the ObWell program.

- Group 4 Dataset

Three additional calibration datasets were obtained from the MPCA. The three calibration datasets from the Northwest Province of the Metropolitan Area Ground water Model (Metro Model) were downloaded from the MPCA web site - http://www.pca.state.mn.us/water/ground water/metromodel.html. Water level elevations in these datasets are approximate, ±5 feet (Streitz, 2003). It was assumed that they represent the average water level at that location, and that this water level is not changing with time.

The three Group 4 datasets are stored in three electronic files:

- Dataset stored in the file "w1-cal3" contains water levels measured in 900 buried drift wells – layer 1 of the Metro Model.
- Dataset stored in the file "w2-cal3" contains water levels measured in 544 St. Peter Sandstone wells – layer 2 of the Metro Model.
- Dataset stored in the file "w3-cal3" contains water levels measured in 754 Prairie du Chien-Jordan wells – layer 3 of the Metro Model.

All these datasets and groups were processed to retain only the 170 Drift/Platteville wells, 314 St. Peter wells and 103 OPCJ wells. These are non-pumping wells within the model

domain that are at least 200 meters away from any well pumping at an average rate of 100 gpm or more. All the Drift / Platteville observation wells were assigned to the model Layer 2.

If a given well was included in more than one of the above discussed Group Datasets, the duplicate records were removed if it was also contained in another dataset. In such cases, only water levels from the highest quality Group Dataset available were retained for the model calibration.

In total, 587 observation wells are included in the model (see Figure 3-13 and Table 3-2).

3.7 Recharge to Top of Layer 1 Set-up

The model domain was divided into 13 zones to allow a spatial variation in recharge rates (see Figure 3-14). The initial values for recharge were set based on the values of infiltration used in the MPCA's Model (Seaberg and Hansen, 2000). These recharge values resulted in about 20–25% of the annual precipitation infiltrating the soil as groundwater recharge. The final values of recharge used for the model are the result of a manual and automatic model calibration (see discussion in Sections 4.1 and 4.2).

3.8 Aquifer Properties Set-up

The model domain was divided into 50 hydraulic conductivity zones and 51 storage zones to allow a spatial variation of aquifer properties (see Table 3-3 and Figures 3-15 through 3-21). The drift formation is represented in six model layers (L 1, 2, 3, 4, 5 and 6) using 24 conductivity and 26 storage zones. The Drift is present in deeper model layers where buried valleys cut through bedrock formations. The Platteville (OPVC) formation is represented in one model layer (L3) using four conductivity and storage zones. The Glenwood (OGWD) formation is represented in one model layer (L4) also using four conductivity and storage zones (these two formations, Platteville and Glenwood, most often are encountered together). The St. Peter (OSTP) is represented in model layer 5 (L 5) using four conductivity and storage zones. Basal St. Peter formation is represented in one model Layer (L7) using six conductivity and five storage

zones. Prairie du Chien – Jordan (OPCJ) formation is represented in one model layer using eight conductivity and storage zones.

The lateral extent of the Drift, Platteville and Glenwood formations was set based on review of available geological information, including the Geological Atlas of Hennepin County (MGS, 1989), Plate 2 (Bedrock Geology – Bloomgren, Cleland and Olsen) and Plate 3 (Surficial Geology – Meyer and Hobbs).

STS extended an effort to delineate the lateral and vertical extent of glacial tills and outwash sands in the deeper portion of the Drift formation near the Reilly Tar Site. These drift units and associated outwash aquifers are represented by the model layers L1 and L2. STS reviewed geological cross-sections and maps included in the relevant published articles covering this area (Ehrlich, et al., 1982; Hult and Schoenberg, 1984; and Lindgren, 1995). It is apparent that the authors of these publications were in possession of geological logs from many boreholes that are not included in the CWI database. STS has made an attempt to find these logs in the archives of the Minnesota District of the United States Geological Survey. With the help of Geoff Delin, we located many folders that could potentially contain the logs of interest to our study. However, searching all these folders would require level of effort beyond the budget of this project. STS retrieved the well information presented by Hult and Schoenberg (1984, Table 1) on the depths to all geologic units penetrated by each well's borehole. This data allowed calculation of the top and bottom elevation of each of these bedrock units. However, the Drift formation was not differentiated by lithology, which limited the value of this information for the purposes of our analysis (STS, 2006b).

The boundaries of the lithological units (glacial till and outwash sands) within the deep Drift formation near the Reilly Tar Site were set in the model layers L1 and L2 based on the information provided by Lindgren (1995 – Figures 3, 4, 5, 9 and 10).

3.8.1 Hydraulic Conductivity

Model Layers 1 through 5 were set to MODFLOW layer code LAYCON 3 which indicated a convertible layer that might be confined or unconfined depending on the head relative to the declared top of aquifer elevation. These convertible layers were represented by assigning a hydraulic conductivity value to each model cell. Model Layers 6 and 7 were set as MODFLOW layer code LAYCON 0 (always confined) thus constant (for the entire simulation) transmissivity and storage coefficients were required for the simulation of these layers. The transmissivity was calculated based on the product of the saturated thickness and hydraulic conductivity. The storage coefficient may alternate between confined and unconfined values by switching between a primary storage coefficient which represents confined aquifer conditions and a secondary storage coefficient which represents unconfined conditions.

Visual MODFLOW pre-processor requires input of hydraulic conductivity rather than transmissivity. The values of hydraulic conductivity for Drift, Platteville, Glenwood and St. Peter formations were initially set as discussed below and then adjusted in the process of the model calibration, as discussed in the following sections of this report. The model pre-processor then calculates the transmissivity values where necessary (i.e., for Layers 6 and 7) based on the aquifer or layer thickness and the hydraulic conductivity.

The summary of aquifer property zones set in the model is provided in Table 3-3 and on Figures 3-15 through 3-21.

3.8.1.1 Hydraulic Conductivities Assigned to the Drift, Platteville and Glenwood Formations

Hydraulic conductivity values for Drift, Platteville and Glenwood formations were initially set using regional information. STS compiled that information from the reports and literature and presented it in the Phase II evaluation report (STS 2004b, Tables 8, 9 and 10). Hydraulic conductivity values for many zones were then adjusted in a process of the first phase, manual model calibration.

Another source of information used to set hydraulic conductivities for Platteville and Lower Drift Aquifer near the Reilly Tar Site is aquifer test results provided to STS by Summit Envirosolutions Inc. The results of these tests are provided in Table 3-4. The hydraulic conductivity for Platteville and Lower Drift aquifers near the Reilly Tar Site was set $1x10^{-2}$ cm/sec in the Low Transmissivity Model version and $2x10^{-2}$ cm/sec in the High Transmissivity Model version. These values were not changed during the model calibration.

3.8.1.2 Hydraulic Conductivities Assigned to the St. Peter Aquifer

Layers 5 and 6 (St. Peter and Basal St. Peter) of the model were divided into zones coinciding with the aerial extent of St. Peter Sandstone and the areas of buried bedrock valleys, where it was absent. The hydraulic conductivity (K) of St. Peter Sandstone near the Reilly Tar Site was set to values representing the low and the high range of the literature quoted hydraulic conductivities (STS, 2004b) for the two different model cases (see discussion in Sections 4.1 and 4.2). The low transmissivity case assumed an aquifer hydraulic conductivity of $5x10^{-3}$ cm/sec and the high transmissivity model version assumed a hydraulic conductivity $7x10^{-3}$ cm/sec.

Based on the review of the CWI well logs, it was concluded that bedrock valleys are filled primarily with glacial till and these areas were assigned K = $5x10^{-4}$ cm/sec. Vertical hydraulic conductivity was assumed to be 1/10 of the horizontal hydraulic conductivity for all zones within the Model Layer 1. This range of anisotropy is typically observed for sedimentary strata, although regional anisotropy on the order of 1/100 is not uncommon (Freeze and Cherry, 1979). The vertical hydraulic conductivity values and thicknesses were used by the MODFLOW pre-processor to calculate the vertical cell leakance rates or VCONT (term used by MODFLOW documentation for vertical leakance).

3.8.1.3 Hydraulic Conductivities Assigned to the Basal St. Peter

Vertical hydraulic conductivity for the Basal St. Peter Formation (Model Layer 6) was set to values representing the lower range of the literature reported values - $5x10^{-7}$ cm/sec (see STS, 2004b, Table 7). One particularly low value reported by Lindgren (1995) was

disregarded. The horizontal K was set to a value equal to 100 times the vertical K. This assumption of a relatively high vertical anisotropy is based on the presence of siltstone and shale layers imbedded into this formation.

3.8.1.4 Hydraulic Conductivities Assigned to the OPCJ Aquifer System

Hydraulic conductivities for the OPCJ aquifer system (model layer 7) were set and were not subject to adjustment or variation during the model calibration. The values were set in the model based on the results of the seventeen OPCJ aquifer tests reported within the model domain or near the model domain boundaries (see Table 3-5). The reported transmissivities were divided by the uniform thickness of Model Layer 3 (OPCJ), which is 66 meters, to provide the hydraulic conductivity inputs for the Visual MODFLOW that were used to construct the model.

The calculated values are relatively consistent throughout the model domain ranging from 1.18×10^{-2} cm/sec to 5.86×10^{-2} cm/sec, except for the two tests (Minnetonka #6A and Eden Prairie #7) where the hydraulic conductivity was estimated in the range of 4×10^{-3} cm/sec. The model domain for Layer 3 was assigned into eight zones and each zone was assigned the minimum values for the low transmissivity model version (see Table 3-5, Columns 8 and 16) and maximum values for the high transmissivity model version (see Table 3-5, Columns 8 and 12). The range of these transmissivity values was based on the range of values reported from the aquifer tests. Vertical hydraulic conductivity (K_v) was set equal to 1/100 of horizontal hydraulic conductivity K_h. This assumption of a relatively high vertical anisotropy is based on the presence of bedding planes and dissolution cavities that are likely following these planes and the presence of the low permeability massive Oneota formation separating the Shakopee Formation and Jordan Sandstone (Runkel, et al., 2003).

The final values of hydraulic conductivities assigned to the zones in low and high transmissivity model versions after completion of a calibration process (discussed in Sections 4.1 and 4.2) are presented in Table 3-6.

3.8.2 Aquifer Storage Properties

The values of specific storativity, specific yield, effective porosity and total porosity used in the model are presented in Table 3-7. The same values were assigned to low and high transmissivity model versions. Within the convertible layers (Laycon 3), the secondary storage coefficient (storage coefficient under unconfined conditions) is assumed to be equal to the specific yield and the effective porosity.

3.8.2.1 Specific Storage

Specific storage values for Drift, Platteville and Glenwood formations were set using generic values typical for a given type of geologic formation.

Specific storage for the St. Peter formation was set to 2.33×10^{-6} [1/meter]. This value was calculated based on the aquifer thickness used in the model, 43 meters, and storativity value of 1×10^{-4} quoted from Barr (1976) and Stark and Hult (1985).

Specific storage for the Drift formation that is filling buried bedrock valleys within the model domain was set to 5.00×10^{-4} [1/meter]. This is the median value in a range of values listed for glacial till in the Enviro-Base Pro (2005).

Specific storage for the Basal St. Peter formation was set to 2×10^{-6} [1/meter]. This value was calculated based on the aquitard thickness used in the model, 5 meters, and storativity value of 1×10^{-5} quoted from Stark and Hult (1985).

Specific storage for the OPCJ formation was set to 1.5×10^{-6} [1/meter]. This value was calculated based on the aquifer thickness used in the model, 66 meters, and storativity value of 1×10^{-4} quoted from ERT (1983). This represents the lower range of values quoted in the regional reports and literature sources for this formation.

3.8.2.2 Specific Yield

Specific yield values for Drift, Platteville and Glenwood formations were set using generic values typical for a given type of geologic formation.

Specific yield for the St. Peter formation was set to 0.21. This is the value listed for fine sandstone in the Enviro-Base Pro (2005).

Specific yield for the Drift formation that is filling buried bedrock valleys within the model domain was set to 0.07. This is the median value in a range of values listed for glacial till in the Enviro-Base Pro (2005).

Specific yield for the Basal St. Peter formation was set to 0.08. This is the value listed for silts by van der Leeden et al. (1990).

Specific yield for the OPCJ formation was set to 0.04. This is the average value listed for fractured dolomite and limestone in the Enviro-Base Pro (2005).

3.8.2.3 Effective Porosity

Effective porosity values for Drift, Platteville and Glenwood formations were set using generic values typical for a given type of geologic formation.

Effective porosity is used by MODPATH to calculate the imaginary ground water particle travel velocity. No data from the area reports and literature could be found. In general, literature provides very scarce generic data on this parameter. Since effective porosity has been systematically measured to be lower than total porosity, for the purpose of this modeling study, it was assumed that effective porosity is approximately equal to specific yield.

3.8.2.4 Total Porosity

Total porosity values for Drift, Platteville and Glenwood formations were set using generic values typical for a given type of geologic formation.

Total porosity for the St. Peter formation was set to 0.30, based on the value quoted by Barr (1977) and Hickok and Associates (1981b).

Total porosity for the Drift formation that is filling buried bedrock valleys within the model domain was set to 0.30. This is the value used in the Metro Model for the Drift formation (Seaberg and Hansen, 2000).

Total porosity for the Basal St. Peter formation was set to 0.23. This is the value listed in the Enviro-Base Pro (2005) for sandstone with silt and clay.

Total porosity for the OPCJ formation was set to 0.15, which is the value quoted by Hickok and Associates (1981b) and ERT (1984).

4.0 STEADY-STATE MODEL DEVELOPMENT AND CALIBRATION

4.1 Low Transmissivity Model (Re7LLKSS) Development and Calibration

After the preliminary model set-up was completed, the model was run using WHS Solver that employs a Bi-Conjugate Gradient Stabilized acceleration routine. The first run resulted in abnormal termination and non-convergence. The modeler increased the initially set low values of recharge to several zones (many cells in the top layer ended up dry), increased the maximum allowed number of outer iterations from 50 to 100, and increased head change convergence from 0.01 m to 0.1 m. The next run resulted in a successful model convergence after 55 outer iterations and 93.8 seconds of model run. The heads were too low throughout the model domain. The modeler increased recharge and set the recharge to the uppermost active layer. Some cells in the upper layer and on the perimeter of the model domain were dry. These changes resulted in a successful third run that converged after twelve outer iterations and 22.6 seconds of computer run. The mass balance error was -0.02%.

During calibration process, the modeler utilized the "root mean squared" (RMS) error expressed in meters and normalized RMS expressed as percentage (%) to evaluate the model calibration. RMS stands for the "root mean square error". It is the average of the squared differences in measured and simulated heads. Normalized RMS is RMS over the magnitude of the change in measured heads in the dataset for which RMS is calculated. The RMS is usually thought to be the best measure of error if errors are normally distributed (Anderson and Woessner (1992)).

In addition to observing RMS, the modeler utilized four other, qualitative measures of calibration :

- Regionally estimated discharge rates to the Mississippi and Minnesota Rivers were compared to the model predicted discharge rates;
- Ground water age estimates obtained from tritium analysis were compared to the groundwater flow rates estimated from the model;

- Seasonal water level fluctuations in Prairie du Chien – Jordan Aquifer near the Reilly Tar Site were compared to the model predicted fluctuations; and
- MODPATH calculated pathlines were compared to the documented patterns of ground water contamination in the area around Reilly Tar Site.

Since discharge rates to the rivers and ground water age data are estimates only, these two measures of model calibration are only qualitative in nature. Seasonal water level fluctuations were simulated using transient model, as discussed in the following Sections 5.1 and 5.2.

The most important calibration measure used was an agreement between the model simulated heads and the measured heads, calculated as RMS. In total, 587 monitoring wells with measured head were included in the model - 170 of these wells are completed either in Drift or Platteville aquifers, 314 wells in St. Peter, and 103 wells in the Prairie du Chien – Jordan aquifer. Based on the objectives of the modeling scope, the model calibration focused on the use of water levels measured within the 5 mile radius of the Reilly Tar Site. The use of all the monitoring points to calibrate the model was not deemed appropriate for this project since large clusters of wells are located in close proximity to the simulated model boundaries with prescribed heads in the western and northwestern portion of the model domain. Due to the distance from the Reilly Tar focus area, the water levels in the non-proximal wells are less important than water levels in the wells closer to the Site.

Four observation well groups were created to assist with the model calibration: "5 mile Drift and Platteville" (93 wells within a five-mile radius around the Reilly Tar Site), "5 mile radius St. Peter" (167 wells within a five-mile radius around the Reilly Tar Site), "5 mile radius OPCJ" (32 wells within a five-mile radius around the Reilly Tar Site), and a group called "Near" that includes twenty observation wells located near the Reilly Tar Site. Twelve (12) of these near wells are completed in the Drift and Platteville aquifers, five are completed in the St. Peter aquifer, and three are completed in the Prairie du Chien – Jordan aquifer. The model included wells and the respective observation groups are presented in Table 3-2.

In the next 47 runs, the solution converged each time within 10 to 14 seconds and six to eight outer iterations. During these manual calibration runs the modeler adjusted the recharge values, hydraulic conductivity values, added additional recharge zones to allow better representation of spatially varying recharge rates, and added hydraulic conductivity zones to allow better representation of spatially varying hydraulic properties of aquifers and confining units within the model domain.

Following the initial runs and manual parameter adjustments, further model calibration was performed with the use of the parameter estimation and predictive analysis program, PEST-ASP, Version 5.5. The PEST program was allowed to adjust recharge values in all the model recharge zones (except zone 1 which is not used in the model domain - zone 1 represents recharge values that were developed for an earlier version of the model - see Figure 3-14). Initially, unsuccessful PEST simulations required the elimination of recharge to zone 3 from the parameter estimation process. Additional analyses indicated that the model was insensitive to this parameter. Changing values of insensitive parameters does not significantly affect the model behavior - the objective function cannot change significantly (objective function is the sum of squared deviations between the model-generated observations and the designated experimental observations). The final PEST optimization was accomplished after 6 optimization iterations and 206 model calls.

The successfully completed PEST optimization revealed that the three most sensitive parameters were recharge to zones 2 and 10. The correlation coefficients between any of the optimized parameters were always less than 0.63, which indicates that these parameters were not too strongly correlated. The frequency distribution of residuals is not skewed and approximates a normal distribution – this is one indication of a proper calibration. This PEST parameter optimization, like previous manual calibration, was conducted using the three 5-mile radius observation well groups shown in Table 3-2. The PEST optimized recharge values for the low and high transmissivity simulations are presented in Table 4-1.

Following the PEST optimization, the Visual MODFLOW model was updated (the PEST derived parameter values were imported into the model) and ran to verify if the

optimization resulted in an improved model calibration. As shown by Table 4-2 (columns 2-5), the PEST model optimization simulations were able to decrease the RMS error in the Layer 7 and "near well Group by 2% to 3% to 11.65% and 9.88%, respectively. The reason the calculated value of RMS cannot be lowered more is the fact that the calibration data are of limited precision – most of the wells are not surveyed, top-of-casing elevations were usually estimated from topographic maps, etc. The consequence is a random distribution of residuals, closely following normal distribution.

Figures 4-1, 4-2 and 4-3 present an aerial distribution of residuals (differences between the model computed and measured heads) for Model Layers 2 (Drift and Platteville wells), 5 (St. Peter wells) and 7 (OPCJ wells), respectively. Red circles (bubbles) represent the model computed heads higher than measured heads. Blue circles represent the model computed heads lower than measured heads.

The calibrated model (i.e., low transmissivity case) budget was inspected to find out how the simulated discharge rates to the Mississippi and Minnesota Rivers compare to the estimates found in regional literature. The simulated discharge to the Mississippi River is found by inspecting the water balance for the budget zone No. 3 (see Figure 4-11). As data in Column 11 of Table 4-2 shows, simulated discharge is about 0.91 cubic meters per day per linear meter of river (m^3/day/m). This is much lower discharge than the 3.3 to 13.5 m^3/day in the Metro Model. Discharge to the Minnesota River is judged to be greater than discharge to the Mississippi River, because the Minnesota River dissects through the OPCJ. Conversely, the Basal St. Peter has not been removed along much of the Mississippi River.

The simulated discharge to the Minnesota River is found by inspecting the water balance for the budget zones No. 2 and 7 (see Figures 4-7 through 4-12). As data in Column 13 of Table 4-2 shows, simulated discharge is about 2.85 m^3/day/m of river. This discharge is comparable to values quoted in literature (2.2 m^3/day/m according to Schoenberg, 1990; 3.9 to 4.5 m^3/day/m simulated by the Metro Model, Seaberg and Hansen, 2000 - see discussion in STS, October 2004, page 17). STS believes that this model's representation of discharge to major rivers is more realistic compared to the representation provided by the Metro Model since more water is discharging to the

Minnesota River than to the Mississippi River. This result is considered an improvement since it addresses the concern voiced by Justin Blum (see discussion in STS, 2003, page 13; a summary of that discussion is presented in the previous paragraph).

Compared to the pre-model estimated water budget presented in Table 2-2, a larger percentage of the total inflow of water into the model system (77% vs. 61%) comes from recharge. The simulated recharge represents about 31% of the annual precipitation. Judging by data presented by other investigators (Novitch 1974), this result is reasonable. Simulated discharge to major rivers is similar to the initially estimated discharge rates presented in Table 2-2.

The PEST calibrated model was used to run the MODPATH program as part of the model predictive simulations that are discussed in Section 6. The MODPATH simulations were conducted to evaluate the effectiveness of the gradient control system of pumping wells around the Reilly Tar Site (i.e., evaluate capture), but also to check if particles introduced in the top model layer could travel to some of the Prairie du Chien – Jordan (OPCJ) wells within 40 to 50 years (verify observed aquifer recharge rates). Tritium dating of ground water samples collected from the Edina Well No. 7 indicates that some of the water reaching that well is no older than 40 to 50 years. MODPATH simulations demonstrated that the particles introduced in the model Layer 1 can indeed reach the OPCJ wells within that time frame. Thus, one of the objectives of the model calibration (simulation of observed travel times in this case) has been met.

The travel time estimates are highly dependent on the effective porosity estimates utilized. The effective porosity for the OPCJ was set in the model as 0.04, which is the lower end of the porosity estimates quoted in the regional literature (STS, 2004b). Using this low value of effective porosity is believed to be justified in the view of the findings of the Edina Well No. 7 (ED-7) study (STS, 2005a; STS 2005c). This study found indications that most of the water is entering the ED-7 well through a narrow fracture zone in the Shakopee Formation (the upper member of the Prairie du Chien Formation). Video inspection of another OPCJ well, Meadowbrook Golf Course Well, also shows water entrance through a narrow fracture zone. It appears that much of the ground water is likely moving through that formation via a network of fractures and dissolution cavities

that occupy only a small fraction of the formation's volume. Because highly interconnected fractures provide a low effective porosity conduit that results in higher groundwater flow velocities, it is apparent that these discontinuities may appreciably affect groundwater flow and contaminant migration. This may be an explanation why contaminants can apparently move long distances over relatively short periods of time.

The model MODPATH simulations (see discussion in later sections) indicated that the contaminant plumes present near the Reilly Tar Site may be intercepted by several municipal wells: Hopkins 4, 5 and 6, Edina 2, 4, 7, 13, 15, Minnetonka 6, St. Louis Park 4, 6, 10, 14. And indeed, VOC and PAH contamination was already found in most of these wells (Hopkins 4, Edina 2, 7, 13, 15, St. Louis Park 4, 6, 10, 14).

4.2 High Transmissivity Model (Re7LHKSS) Development and Calibration

The calibrated low transmissivity model named "Re7LLKSS" was copied to another folder under a different name – "Re7LHKSS" and was utilized to conduct simulations to evaluate the model sensitivity to transmissivity. The hydraulic conductivity values for the zones representing the OPCJ, OSTP, OPVL and Drift aquifer systems were changed. Hydraulic conductivity values for the OPCJ zones were changed from the minimum values provided by the area's aquifer tests (as listed in Table 3-5, Column 15) to the maximum values (as listed in Table 3-5, Column 11). Hydraulic conductivity values for the OSTP zones were increased relative to the low range of the literature quoted values (see STS, 2004b, Table 7). Hydraulic conductivity values for OPVL and Drift aquifers were increased relative to the low range of the values provided by Summit Envirosolutions Inc. (see Table 3-4).

This high transmissivity version of the model was then calibrated using the same procedures as described above for the low transmissivity version of the model. The values of the hydraulic conductivity and recharge parameters set in the calibrated high transmissivity version are presented in Tables 3-6 and 4-1.

The head calibration results are similar to the results accomplished for the low transmissivity version of the model. The selected results of the calibration and budget

elements of this high transmissivity version of the model are presented in Table 4-2. The simulated discharge to the Mississippi River is found by inspecting the water balance for the budget zone No. 3 (see Figure 4-11). As data in Column 11 of Table 4-2 shows, the simulated discharge is about 2.62 m^3/day/m of river. This discharge rate is slightly lower than the discharge rate presented in the Metro Model (3.3 to 13.5 m^3/day).

The simulated discharge to the Minnesota River is found by inspecting the water balance for the budget zones No. 2 and 7 (see Figures 4-7 through 4-12). As data in Column 13 of Table 4-2 shows, simulated discharge is about 5.64 m^3/day/m of river. This discharge is somewhat greater than the values quoted in literature (2.2 m^3/day/m according to Schoenberg, 1990; 3.9 to 4.5 m^3/day/m simulated by the Metro Model, Seaberg and Hansen, 2000 - see discussion in STS, October 2004, page 17).

The simulated percentage of the total inflow of water into the model system coming from recharge is similar to the pre-model estimated water budget presented in Table 2-2 (60% vs. 61%). The simulated recharge represents about 39% of the annual precipitation. This percentage is judged to be high, considering the prevailing land use within the model domain and considerable runoff and the following water balance estimates: The average runoff from the general area of the City of St. Paul is estimated to be about 40% (Pat Byrne, City of St. Paul Sewer Utility - personal communication). A similar estimate was obtained for the residential areas within the City of Minneapolis (Barr Engineering Company, December 1992. Minneapolis Chain of Lakes Clean Water Partnership Project - Stormwater Monitoring Study - Hydrologic/Nutrient Budgets for 1991 prepared for Minneapolis Park and Recreation Board). If the model simulated recharge is 39%, the estimated runoff is 40%, then evapotranspiration would be about 21%, which is judged unrealistically low.

Simulated discharge to major rivers is somewhat higher compared to the pre-model estimated value presented in Table 2-2.

The MODPATH calculated particle pathlines indicate that contaminants may escape capture zones of not only the Reilly Tar Gradient Control System wells, but also capture zones of several municipal wells within St. Louis Park and Edina. The calculated

pathlines reach all the way to the Mississippi and Minnesota Rivers, east and southeast of the Reilly Tar Site. These predictions do not appear to be supported by the available ground water quality data.

Figures 4-4, 4-5 and 4-6 present an aerial distribution of residuals (differences between the model computed and measured heads) for Model Layer 2 (OPVL and Drift), 5 (OSTP) and 7 (OPCJ), respectively.

5.0 TRANSIENT MODEL DEVELOPMENT AND SIMULATIONS

Existing data indicate that seasonal water level fluctuations are a prominent feature of the Prairie du Chien – Jordan aquifer system (see Figures 2-1 and 2-2). Continuous water level monitoring conducted by STS in the Meadowbrook Golf Course Well and random measurements conducted in the other OPCJ wells document 30 to 40 foot water level differences between the winter and summer seasons. These water level differences are often observed at wells located far away from the pumping wells. Judging from the limited data available to STS, no such prominent seasonal variations in water level can be observed in any of the shallower aquifers in the area (see Figures 2-4, 2-5 and 2-6).

Transient simulations were conducted to test if the low and high transmissivity models can recreate the wide water level fluctuations observed in the OPCJ aquifer. The transient models were developed for both versions of the steady state models by creating 12 stress periods representing twelve months (May 2005 through April 2006). Next, pumping rates and prescribed head elevations were varied between these stress periods. Monthly ground water production for that period was obtained from the City of Edina and the City of St. Louis Park. It was assumed that all the other municipalities within the model domain vary production in a similar fashion to the City of Edina. Average pumping rates prescribed to all the pumping wells represented in the model were adjusted using this City of Edina production pattern. Water levels at the prescribed head model boundaries were assumed to vary in a similar manner to water levels measured in the Meadowbrook Golf Course Well, however the magnitude of these changes were assumed to be two times smaller.

Figure 5-1 presents the transient model calculated heads at the location of the Meadowbrook Golf Course Well and the observed average monthly water levels calculated for that well from a database of continuous water level monitoring. Water levels were measured every 15 minutes throughout the entire simulation period – May 2005 through April 2006. As can be seen, the low transmissivity model version closely recreates the observed water level fluctuations, while the high transmissivity model does not. This result indicates that the low transmissivity model represents a better approximation of real ground water system, compared to the high transmissivity model.

While developing the original, three layer version of this model (STS, 2005b), STS set-up transient model simulating 80 years of ground water flow and using 160 stress periods. Each pair of stress periods for one year represented warmer and colder half of the year. Changes in production with this warmer/colder half-year were assumed to follow the water production pattern observed in the recent five-year production well records for the City of Edina. These transient simulations involved MODPATH particle tracking and showed that the model calculated particle pathlines do not differ from the pathlines calculated by steady-state models. This result is not surprising, as pumping patterns are similar throughout the model domain and horizontal hydraulic gradients do not change significantly with season. Therefore, STS decided against developing a revised version of a transient model for the long-term predictive simulations.

6.0 PREDICTIVE MODEL SIMULATIONS - MODPATH RUNS

One of the principal intended purposes of this project was to develop a tool that could help in evaluating the Reilly Tar Site's gradient control system. The gradient control wells are operated to capture the Reilly Tar Site related contaminant plumes and to prevent the contaminants from spreading. To evaluate the capture zones, 456 forward moving imaginary particles were introduced in the model to areas where the PAH and phenolics' plumes have been documented (ENSR, 2006b). The particles were set to be released at the beginning of the simulation. MODPATH, a semi-analytical particle-tracking program was then used to calculate the pathlines of these particles. MODPATH uses the output from the MODFLOW to develop groundwater velocities. Graphical representation of pathlines calculated by the model allows visual inspection of the pumping wells' capture zones and evaluation if these capture zones indeed capture all the particles. The particle tracking plots can be used to determine whether some of the particles are likely to bypass the gradient control system and be captured by another well or enter the regional flow system. The particles represent not only water particles but also non-reactive dissolved contaminants moving with water. This representation of contaminant transport is imperfect as several fate and transport phenomena, such hydrodynamic dispersion, contaminant retardation and degradation, are not accounted for. However, pathline tracking is considered a good first-cut approximation of contaminant transport that is often conservative. Within porous media, the particle tracking results are often conservative (i.e., predict contaminant movement faster and further than found in a real system), however phenomenon such as dispersion and fracture pathways can result in potential contaminant transport at rates that exceed the estimates provided from the particle tracking simulations. Particle tracking also provides a practical approach, since simulation of fate and transport processes within a potentially fractured bedrock environment requires information that most often is not readily available, such as fracture size and geometry, contaminant degradation rates or the magnitude of retardation.

The results of the transient model simulations discussed in the previous Section 5 indicate that the low transmissivity model appears to be a better representation of the ground water flow system, compared to the high transmissivity model. Therefore the model predictive simulations evaluating gradient control well performance focused on

using the low transmissivity model version. Although, for comparative purposes, one simulation was also conducted using the high transmissivity model.

Five gradient control system scenarios were selected for simulation from numerous possible scenarios:

a. Current gradient control system configuration, plus well W434 pumping at the rate of 32.5 gpm (177 m^3/day);
b. Current gradient control system configuration (W434 turned off);
c. Current gradient control system configuration (W434 turned off), plus Methodist Hospital Well (W48) pumping at the rate of 300 gpm (1,635 m^3/day);
d. Current gradient control system configuration (W434 turned off), plus Meadowbrook Golf Course Well (W119) pumping at the rate of 300 gpm (1,635 m^3/day);
e. Current gradient control system configuration (W434 turned off), plus St. Louis Park Municipal Well No. 6 (SLP6) pumping at the rate of 762 gpm (4,157 m^3/day).

As previously mentioned, each of these scenarios was analyzed using the low transmissivity version of the model. The results of these simulations are presented on Figures 6-1 through 6-4 (a, b, c, d and e). One more simulation was run using the high transmissivity version of the model. This simulation considered the current gradient control system configuration, plus W434 pumping at the rate of 32.5 gpm (177 m^3/day), and the St. Louis Park Municipal Well No. 6 (SLP6) pumping at the rate of 762 gpm (4,157 m^3/day). The results of this simulation are presented on Figure 6-5. The particle track pathlines presented on these figures are fixed with 10-year time markers – the distance between two adjacent time markers on a pathline shows the distance a given particle will travel within 10 years.

The following provides a brief discussion of the results of these simulations. For illustrative purposes, the discussion includes a more detailed analysis of the scenario "a", followed by comparison of the results of other scenarios with the first scenario "a". Thus, scenario "a" has been used as a baseline to provide a comparison for the other

scenarios. Inspection of Figures 6-1 through 6-5 allow the reader a more detailed analysis of the results of these other simulated scenarios.

Scenario "a"

The Scenario a simulation indicates that the particles released within the Drift aquifer (Model Layer 2) will be intercepted by the Drift, Platteville, St. Peter and Prairie du Chien – Jordan wells (W420, W421, W343, W439, W410, Republic Creosote (W23), SLP10 and SLP14 – see Figure 6-1a). One particle arrives at SLP14 - that well does not belong to the gradient control system, but the travel time exceeds 50 years (trace contamination with 1,2-dichloroethene was recently detected in that well).

Almost all of the particles released within the Platteville aquifer (Model Layer 3) will be intercepted by the Platteville, St. Peter and Prairie du Chien – Jordan wells (W421, W343, W439, W410, Republic Creosote (W23), SLP4, SLP10 and SLP14 – see Figure 6-2a). Some particles arrive at SLP14 but the travel time exceeds 50 years. One particle escapes capture zones of the gradient control system and discharges southwest of downtown Minneapolis, but the travel time exceeds 50 years.

Most of the particles released within the St. Peter aquifer (Model Layer 5) will be intercepted by the St. Peter and Prairie du Chien – Jordan wells (W410, Republic Creosote (W23), SLP4, SLP10 and SLP14 – see Figure 6-3a). Some particles arrive at SLP14 but the travel time exceeds 50 years. Several particles migrate far in the eastern direction to discharge west of downtown Minneapolis, but the travel time exceeds 50 years. However, this is not confirmed by the monitoring data, possibly because the well W70 creates ground water mounding that prevents contaminants migrating in the eastern direction. This well W70 is likely feeding OPCJ aquifer with St. Peter water due to leaking casing sealing (see Figure 2-2). Since that leaking occurred beginning from 1999, it is not represented in the model. If the well W70 is sealed, to prevent mixing waters between aquifers, this mounding effect will have been lost allowing some contaminants to escape in eastern direction.

Most of the particles released within the Prairie du Chien - Jordan aquifer (Model Layer 7) will be intercepted by the St. Peter and Prairie du Chien – Jordan wells (W410, Republic Creosote (W23), SLP4, SLP10, SLP14 and SLP16, Hopkins 4, 5 and 6, Minnetonka 6 and 7, and Edina 2, 4 and 13 – see Figure 6-4a). Some particles arrive at SLP14 but the travel time exceeds 50 years. Several particles escape capture zones of the gradient control system and discharge west of downtown Minneapolis within 50 years. Several of these wells do not belong to the Reilly Tar Site Gradient Control System.

Scenario "b"

The results of simulating scenario "b" are presented on Figures 6-1b, 6-2b, 6-3b and 6-4b. Turning off W434 appears to have little influence on the overall pattern of pathways.

Scenario "c"

The results of simulating scenario "c" are presented on Figures 6-1c, 6-2c, 6-3c and 6-4c. Turning on the Methodist Hospital Well (W48) and pumping from that well at the rate of 300 gpm appears to influence the ground water flow system noticeably. Particles released from the Drift aquifer are not reaching SLP14, like in scenario "a". but are reaching SLP4. Unlike scenario "a", no particles released in Platteville aquifer escape capture zones of the gradient control system traveling toward Minneapolis. Pumping from W48 also reduces the number of particles released within St. Peter and Prairie du Chien – Jordan aquifers that travel toward Minneapolis.

Scenario "d"

The results of simulating scenario "d" are presented on Figures 6-1d, 6-2d, 6-3d and 6-4d. Turning on the Meadowbrook Golf Course Well (W119) and pumping from that well at the rate of 300 gpm appears to influence the ground water flow system in a similar manner to turning on the Methodist Hospital Well (W48). Some differences between scenarios "d" and "c" include the following: one Drift particle travels toward Minneapolis; more St. Peter and Prairie du Chien – Jordan particles travel toward Minneapolis – this is

understandable as W199 is located south of W48 and, therefore, pumping from that well will have lesser effect on particles planted in the northeast part of the contaminant plumes.

Scenario "e"

The results of simulating scenario "e" are presented on Figures 6-1e, 6-2e, 6-3e and 6-4e. Turning on the St. Louis Park Municipal Well No. 6 (SLP6) and pumping from that well at the rate of 762 gpm (the average pumping rate in the years 1988-1992 listed in the Minnesota Department of Natural Resources "State Water Use Data System") has a significant effect on the ground water flow system in the area. Under this scenario, no Drift, Platteville or St. Peter planted particles escape the gradient control system, and only two particles migrate toward Minneapolis. However these two particles migrate only a short distance away from the present plume areas within the next 50 years.

High Transmissivity Model Version Scenario

High transmissivity model version was used to run MODPATH simulation with the current pumping configuration, plus pumping from W434 (which was some time ago turned off) plus pumping from St. Louis Park Municipal Well No. 6. The results of this simulation are presented in Figure 6-5. As this Figure demonstrates, numerous particles will escape capture by the Gradient Control System wells and other high capacity wells in the area around the Reilly Tar Site and will migrate southeast toward the Mississippi and Minnesota Rivers.

7.0 SUMMARY AND RECOMMENDATIONS

Two cases of a steady-state ground water flow model were developed for the Drift, Platteville (OPVL), St. Peter (OSTP) and Prairie du Chien - Jordan (OPCJ) aquifer system in the southeastern portion of Hennepin County, centered on the Reilly Tar Site. The model domain covers 423 square kilometers (163 square miles). In total, 58 pumping wells are represented in the model. Both model cases were calibrated using average pumping rates from the five-year period - 1998-2002, and transmissivity values based on the lower and upper range of the aquifer test analyses. The two versions of the model were developed to explore uncertainties associated with any given single calibrated model. In the report of the previous stage of this model's development, both model cases were considered equally likely representations of the modeled system (STS, 2005b). However, the inability of the high transmissivity version of the model to recreate the seasonal and monthly water level fluctuations observed in the OPCJ aquifer wells (see discussion in Section 5), and predictions of widespread escape of contaminants from the capture zones of the wells near the Reilly Tar Site (not supported by monitoring data) suggests that this high transmissivity model version may be a less reliable representation of the system, compared to the low transmissivity version of the model.

Both model cases predict that contaminants originating in the shallow aquifers (Drift, Platteville) migrate downward through St. Peter Sandstone to Prairie du Chien – Jordan aquifer system. This prediction corresponds to ground water contamination data, which documents that all these aquifers are indeed contaminated, with contaminant plumes more and more laterally extensive with each deeper aquifer. This pattern can be explained by dispersive transport and transport along preferential pathways, with contaminants traveling laterally on top of confining units, before finding vertical pathways leading to the next deeper aquifer. However, it is not certain how much of the contamination observed in the Prairie du Chien – Jordan aquifer system was introduced directly to that aquifer via deep injection well(s) (like the original, multi-aquifer Republican Creosote well used by the Reilly Tar Site to dump waste materials).

The developed model has been used in the currently presented form to analyze the Gradient Control System (GCS) operations and various possible alternative System

configurations. The significant differences between the high transmissivity and low transmissivity particle tracking cases suggest that the results of these analyses should be interpreted with caution. A mere 100% increase in the Layer 7 transmissivity results in a significantly different particle distribution (i.e., many particles escape the gradient control system into the regional flow system). This suggests that the model is very sensitive to transmissivity variations and that the presence of unknown high hydraulic conductivity pathways (i.e., fractures etc.) could appreciably influence the contaminant distribution within the flow system.

The particle tracking results are generally considered to provide conservative estimates of potential contaminant flow paths (i.e., neglect retardation and other attenuation mechanisms). For instance, if the MODPATH calculated pathlines escape beyond the influence of GCS, it only means that the contaminants represented by the imaginary and inert particles have the potential of escaping the System. PAH and phenolic compounds from the Reilly Tar Site related ground water contaminants are strongly retarded and undergo degradation. These and other processes considerably slow down their movement and lower their concentrations.

Predictions of any ground water model are associated with uncertainties. The properly calibrated models often allow better understanding of the system under investigation. However, any remedial decisions influenced by the modeling results should be subject to periodic re-evaluation, based on the new monitoring data and model validation.

The model should be re-evaluated after continuous water level measurements have been conducted in at least three non-pumping OPCJ wells located some distance away from each other and not along one flow line. Such data would allow determination of possible seasonal changes in local hydraulic gradients that drive ground water and contaminant movement near the Reilly Tar Site. One year of such continuous data has been collected from the Meadowbrook Golf Course Well. However other wells are not monitored in a similar fashion.

The Park Theatre Well (W70) was instrumented by the Minnesota Department of Health but water levels in that well are much higher than in other OPCJ wells, suggesting

possible structural problems (i.e., leakage from stratigraphically higher units) with this well. The Edina Well No. 7 was instrumented by a contractor hired by the City of Edina but the data collected to-date are not reliable (Roger Glanzer – personal communication). Manual water level measurements taken at Edina wells number 7 (ED-7) and 13 (ED-13) were provided by the City of Edina and are plotted on Figure 2-1. This new information points out, once more, how important these continuous water level measurements are for the proper model calibration. Comparison of measurements collected from Meadowbrook Golf Course Well (W119) and ED-7 indicates that during summer, water levels in ED-7 are much lower than in W119. If such conclusion is confirmed by comparing continuous water level measurements from both wells, this model will need to be recalibrated and, perhaps, re-set. Southern boundary conditions or model extent in southern direction might need to be changed to allow recreation of such great seasonal water level fluctuations caused by the Edina well field. This field may be under current model configuration too close to the southern boundary.

In addition to PAH and phenolic samples, VOC samples should also be systematically collected. VOC contaminants are generally less retarded and move faster through aquifer systems, compared to PAH compounds. Thus VOCs provide a better indication of the pattern of ground water movement. The extent of the OSTP ground water contamination is not well delineated in most of the directions. The extent of the OPCJ ground water contamination is not well defined in the southern, southwestern and western direction. Additional monitoring wells in these areas would allow an early indication if some of the contaminants migrate beyond the GCS's zone of influence. These wells would also provide a means of monitoring the zone of influence of the gradient control wells (i.e., determination of the divide areas between the gradient control system and the regional flow system).

The presented ground water flow MODFLOW model can be used to develop a more sophisticated contaminant transport model using MT3D or RT3D programs that account for hydrodynamic dispersion, retardation and reactions. Such model would simulate the Reilly Tar Site related and other ground water contaminants' movement much more realistically compared to MODPATH program.

It is possible that contaminant transport within the Prairie du Chien is governed, to a large extent, by fractures and solution cavities that create preferential pathways. Such transport is difficult to represent in a model that is based on an "equivalent porous medium" concept. Application of a model capable of representing a fractured flow would not likely help. Very little is known about the fractures within the Prairie du Chien formation in that area to allow a proper parameterization of such model. It is also very likely that contaminants migrate vertically through the multi-aquifer wells that still exist in the area, or along the improperly installed or age-failing wells' seals. Representing such "short-circuiting" pathways in the model is difficult, particularly if the location of such wells is uncertain. Existence of such wells may have a profound influence upon the contaminant transport and the effectiveness of the GCS.

The final conclusion is that the presented model can be used to simulate various GCS's configurations. However, the results of such analysis will be inevitably associated with uncertainties. Therefore, regardless of the gradient control configuration decided upon to mitigate the migration of the PAH, phenolics and VOCs, water level monitoring should be continued so that the model is periodically revised and the GCS's configuration is adjusted as needed. Such interactive management procedures are believed necessary to account for the influence of geologic, hydrogeologic, climactic, and pump operational uncertainties in the system.

8.0 GENERAL QUALIFICATIONS

STS professional services have been performed, findings obtained, and recommendations prepared in accordance with generally accepted engineering and hydrogeologic principles and standard practices. No other warranty, either expressed or implied, is made. STS assumes no responsibility for data or interpretations made by others. STS accepts no responsibility for application or interpretation of the results by anyone other than the client.

9.0 REFERENCES

Anderson, M.P, W.W Woessner, 1992. Applied Ground water Modeling – Simulation of Flow and Advective Transport. Academic Press, Inc.

Barr, 1976. Soil and Ground Water Investigation – Coal Tar Distillation & Wood Preserving Site, St. Louis Park, Minnesota – Phase I Report, May 1976.

Barr, 1977. Soil and Ground Water Investigation – Coal Tar Distillation & Wood Preserving Site, St. Louis Park, Minnesota. Report to Minnesota Pollution Control Agency by Barr Engineering, June 1977.

Barr 1999. Ramsey County Ground Water Model – Summary Report. February 1999.

Ehrlich, G.G., D.F. Goerlitz, E.M. Godsy, M.F. Hult, 1982. Degradation of Phenolic Contaminants in Ground Water by Anaerobic Bacteria: St. Louis Park, Minnesota. Ground Water, Vo. 20, No. 6.

ENSR, 2006a. Annual Progress Report for 2005 – Reilly Tar & Chemical Corp., N.P.L. Site, St. Louis Park, Minnesota. Submitted on March 15, 2006.

ENSR, 2006b. Annual Monitoring Report for 2005 – Reilly Tar & Chemical Corp., N.P.L. Site, St. Louis Park, Minnesota. Submitted on March 15, 2006.

Enviro-Base Pro, 2005. Integrated Aquifer Properties Reference Database provided by the Waterloo Hydrogeologic as an add-in to the Visual Modflow Pro, Version 4.1.

ERT, 1983. Recommended Plan for a Comprehensive Solution of the Polynuclear Aromatic Hydrocarbon Contamination Problem in the St. Louis Park Area. Environmental Research & Technology, Inc. Document P-B690-161, April 1983.

ERT, 1984. Computer Modeling of the St. Louis Park Area Employing the Modified USGS Ground-Water Flow Model - Report on work completed August 1983 - October

1984, Prepared for Dorsey & Whitney, Minneapolis, Minnesota. Environmental Research & Technology, Inc. Document Number B690-300, November 1984.

Freere, A.R., T.A. Cherry, 1979. Groundwater. Prentice Hall.

Hansen, D.D., J.K. Seaberg, 2000. Metropolitan Area Ground Water Model Project Summary – Lower Aquifers Model, Layers 4 and 5. Version 1.00, November 2000. (document posted on MPCA Website - http://www.pca.state.mn.us/water/groundwater/mm-overview.html)

Helgeson, J.O., G.F. Lindholm, 1977. Geology and Water-Supply Potential of the Anoka Sand-Plain Aquifer, Minnesota: Minnesota Department of Natural Resources, Technical Paper No. 6, 17 p.

Hickok and Associates, 1981b. Study of Ground Water Contamination in the St. Louis Park Area – Final Report (Appendices A – H), November 1981.

Hult, M.F., M.E. Schoenberg, 1984. Preliminary Evaluation of Ground-Water Contamination by Coal-Tar Derivatives, St. Louis Park Area, Minnesota. U.S. Geological Survey Water-Supply Paper 2211.

Kanivetsky, R., 1989. Bedrock Hydrogeology. In: Geologic Atlas, Hennepin County, Minnesota – Atlas C-4. N.H. Bababan, Editor. Plate 6 of 9.

Larsen-Higdem, D.C., S.P. Larsen, R.F. Norvitch. 1975. Configuration of the Water Table and Distribution of Downward Leakage to the Prairie du Chien-Jordan in the Minneapolis-St. Paul Metropolitan Area, Minnesota. USGS Open-File Report 75-342.

Lindgren, R.J., 1995. Hydrogeology and Ground-Water Flow of the Drift and Platteville Aquifer System, St. Louis Park, Minnesota. USGS Water-Resources Investigations Report 94-4204.

Lorenz, D.L. and J.R. Stark, 1990. Simulation of Ground-Water Flow in the St. Peter Acuifer in an Area Contaminated by Coal-Tar Derivatives, St. Louis Park, Minnesota. USGS Water-Resources Investigations Report 90-4150.

MGS, 1989. Geologic Atlas – Hennepin County, Minnesota. County Atlas Series, Atlas C-4. N. H. Balaban – Editor. Minnesota Geological Survey.

Norvitch, R.F., T.G. Ross, A. Brietkrietz, 1974. Water Resources Outlook for the Minneapolis – Saint Paul Metropolitan Area, Minnesota. USGS – Metropolitan Council of the Twin Cities Area, 1974.

Olsen, M.B., B.A. Bloomgren, 1989. Bedrock Geology. In: Geologic Atlas, Hennepin County, Minnesota – Atlas C-4. N.H. Bababan, Editor. Plate 2 of 9.

Runkel. A.C., R.G. Tipping, E.C. Alexander, Jr., J.A. Green, J.H. Mossler, S.C. Alexander, 2003. Hydrogeology of the Paleozoic bedrock in southeastern Minnesota. Minnesota Geological Survey – Report of Investigations 61.

Seaberg, J.K., D.D. Hansen, 2000. Metropolitan Area Ground Water Model Project Summary – Northwest Province, Layers 1, 2, and 3 Model. Version 1.00, July 2000. (document posted on MPCA Website - http://www.pca.state.mn.us/water/ ground water/mm-overview.html)

Schoenberg, M.E., 1990. Effects of Present and Projected Ground-Water Withdrawals on the Twin Cities Aquifer System, Minnesota. USGS Water Resources Investigations Report 90-4001, prepared in cooperation with Minnesota Department of Natural Resources, and Metropolitan Council of the Twin Cities.

Stark, J.R. and M.F. Hult, 1985. Ground-Water Flow in the Prairie du Chien-Jordan Aquifer Related to Contamination by Coal-Tar Derivatives, St. Louis Park, Minnesota. USGS Water-Resources Investigations Report 85-4087.

Streitz, A.R., 2003. Preparation of Supporting Databases for the Metropolitan Area Ground water Model - Metropolitan Area Ground water Model Project. Version 1.00, August 2003.

Streitz, A., J. Seaberg, D. Hansen. Metro Ground Water Model – Site Applications. (document posted on MPCA web site: http://www.pca.state.mn.us/water/ ground water/mm-mgwa.pdf)

STS, 2003. Well Evaluation for Meadowbrook Golf Course – Review of the Past Ground Water Modeling Work and Recommendation of Further Work. STS December 9, 2003. A study conducted for the Minnesota Pollution Control Agency. STS Project 99330-XA;

STS, 2004a. Reilly Tar Site/Meadowbrook Ground Water Model, St. Louis Park, Minnesota – Model Database Summary Report. STS June 30, 2004. A study conducted for the Minnesota Pollution Control Agency. STS Project 99330-XB; and

STS, 2004b. Reilly Tar Site/Meadowbrook Ground Water Model, St. Louis Park, Minnesota - Project Phase II Report. STS October 20, 2004. A study conducted for the Minnesota Pollution Control Agency. STS Project 99330-XC.

STS, 2005a. City of Edina Well No. 7 Study, July 2004 to March 2005. STS March 3, 2005. A study conducted for the Minnesota Pollution Control Agency. STS Project 99613-XA.

STS, 2005b. Reilly Tar Site / Meadowbrook Groundwater Model Set-up and Calibration Report. A study conducted for the Minnesota Pollution Control Agency. STS May 31, 2005. STS Project 99330-XD.

STS, 2005c. City of Edina Well No. 7 Study – Phase II Report, March 2005 to June 2005. STS June 30, 2005. A study conducted for the Minnesota Pollution Control Agency. STS Project 99613-XA.

STS, 2006a. Reilly Tar Site/Meadowbrook Ground water Model – Collection of Additional Data for the Model. A study conducted for the Minnesota Pollution Control Agency. January 31, 2006. STS Project 99330-XE.

STS, 2006b. St. Louis Park W437 Chlorinated Solvent Source Investigation. A study conducted for the Minnesota Pollution Control Agency. March 13, 2006. STS Project 99330-XE.

Van der Leeden, F., F.L. Troise, D.K. Todd, 1990. The Water Encyclopedia, Second Edition. Lewis Publishers.

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Table 2-1 Statistical Summary of the SLP Water Level Data
Collected from 119 wells during the period of June 1992 through August 2003

Reilly Tar Site /
Meadowbrook Ground Water Model
STS Project No. 99330-XF

Column Numbers:																				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Aquifer	No. of Wells	Annual Water Levels				Warm Half-Year (May - October)			Cold Half-Year (November - April)			Spring			Summer			Fall		
		Number of Water Level Measur.	Average	Maximum Annual Amplitude of Water Levels in any Single Well	Average Annual Amplitude of Water Levels in the Wells (1)	Number of Water Level Measur.	Average	Difference between Annual Average and Warm Half-Year Average	Number of Water Level Measur.	Average	Difference between Annual Average and Cold Half-Year Average	Number of Water Level Measur.	Average	Difference between Annual Average and Spring Average	Number of Water Level Measur.	Average	Difference between Annual Average and Summer Average	Number of Water Level Measur.	Average	Difference between Annual Average and Fall Average
Drift	44	510	880.72	12.90	4.68	419	880.92	0.20	91	879.82	-0.90	221	880.23	-0.49	147	881.30	0.58	142	880.89	0.17
Platteville	35	612	879.26	41.45 (2)	7.64 (3)	493	879.46	0.19	119	878.46	-0.80	266	878.81	-0.46	173	879.27	0.01	173	879.96	0.69
St. Peter	14	228	865.38	35.16 (4)	9.21 (5)	183	865.35	-0.03	45	865.50	0.12	100	865.01	-0.37	66	864.56	-0.82	62	866.86	1.48
Prairie du Chien - Jordan	22	230	794.26	71.40	37.80	184	792.43	-1.83	46	801.56	7.30	106	794.92	0.67	68	789.81	-4.44	56	798.39	4.13
Unknown	4	71																		

Notes:

(1) - Calculated only using data for wells with a minimum of five water level measurements
(2) - 13.45 feet if W421, W434 (pumping wells) and W435 excluded
(3) - 4.52 feet if W421, W434 (pumping wells) and W435 excluded
(4) - 14.66 feet if W410 excluded
(5) - 6.62 feet if W410 excluded

Table 2-2 Estimate of the Model Water Budget

Reilly Tar Site / Meadowbrook Ground Water Model STS Project No. 99330-XF

1	Area of the Model Domain	=	160	[square miles]
		=	4.14E+08	[m^2]
2	Length of E and S boundaries (representing major rivers)	=	35	[miles]
			56327	[m]
3	Recharge from precipitation	=	6.4	[inch/year] (Norvitch et al., 1974)
		=	0.1626	[m/year]
			6.74E+07	[m^3/year/model domain area]
		=	184560	[m^3/day/model domain area]
4	Recharge from Lake Minnetonka and horizontal ground water inflow across the artificial model western and northwestern boundaries	=	1.10E+08	[m^3/year/model domain area] (calculated as total discharge minus recharge from precipitation)
		=	300840	[m^3/day/model domain area] (calculated as total discharge minus recharge from precipitation)
5	**Recharge Total**	=	**1.10E+08**	**[m^3/year/model domain area]**
		=	**301346**	**[m^3/day/model domain area]**
6	Discharge to Rivers	=	4.3	[inch/year] (Schoenberg, 1990)
		=	0.1092	[m/year]
		=	4.53E+07	[m^3/year/model domain area]
		=	8.04E+02	[m^3/year/m river]
		=	2.20	[m^3/day/m river]
7	Ground Water Pumping	=	17102	[MGY] (average production in years 1988-2002 from all MDNR permitted wells within 7-mile radius of Reilly Tar Site)
		=	6.47E+07	[m^3/year/model domain area]
		=	177344	[m^3/day/model domain area]
8	Leakage Leakage of ground water from PDCJ aquifer through St. Lawrence Formation	=	0.0015	[m/year - 0.06 inch/year - Hansen and Seaberg, 2000)
		=	6.32E+05	[m^3/year/model domain area] (calculated as total discharge minus recharge from precipitation)
9	**Discharge Total**	=	**1.10E+08**	**[m^3/year/model domain area]**
		=	**301346**	**[m^3/day/model domain area]**

Table 3-1 Puming Wells Represented in the Model

Reilly Tar Site /
Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	MN Unique No.	UTME	UTMN	Screen ID	Top of Screen (m)	Bottom of Screen (m)	Screen Radius (m)	Casing Radius (m)	Stop time (days)	Pumping Rate (m^3/day)
ABBOTT_NW_HOSP_1	00201082	479284	4977987	1	190	130	0.1	0.1	36500	-2065
ABBOTT_NW_HOSP_2	00201083	479316	4978023	1	190	130	0.1	0.1	36500	-1199
ABBOTT_NW_HOSP_3	00112248	479357	4977968	1	190	130	0.1	0.1	36500	-539
EDINA_13	00203613	468828	4974188	1	190	130	0.1	0.1	36500	-2450
EDINA_16	00203101	469482	4970571	1	190	130	0.1	0.1	36500	-3678
EDINA_17	00200914	473563	4971458	1	190	130	0.1	0.1	36500	-572
EDINA_2	00208399	473163	4973279	1	190	130	0.1	0.1	36500	-2694
EDINA_4	00200561	472788	4971862	1	190	130	0.1	0.1	36500	-1959
EDINA_6	00200564	472600	4971537	1	190	130	0.1	0.1	36500	-3990
EDINA_7	00206474	471863	4972656	1	190	130	0.1	0.1	36500	-3032
GM_1	00224098	468695	4980440	1	190	130	0.1	0.1	36500	-1566
GM_3	00226208	468692	4980554	1	190	130	0.1	0.1	36500	-870
GM_4	00161405	468697	4980747	1	190	130	0.1	0.1	36500	-779
GM_OP_1	00223780	469156	4982350	1	190	130	0.1	0.1	36500	-212
HINES_1	00201007	478633	4980399	1	190	130	0.1	0.1	36500	0
HONEYWELL_INC_1	00203892	471370	4982906	1	190	130	0.1	0.1	36500	-1662
HONEYWELL_INC_2	00203878	471512	4983298	1	190	130	0.1	0.1	36500	-703
HOPKINS_1	00204573	467416	4974181	1	190	130	0.1	0.1	36500	0
HOPKINS_4	00204068	466990	4975893	1	190	130	0.1	0.1	36500	-7822
HOPKINS_5	00204570	467294	4975820	1	190	130	0.1	0.1	36500	-1097
HOPKINS_6	00112228	467675	4975792	1	190	130	0.1	0.1	36500	-1790
MINNETONKA_10	00204140	463477	4976644	1	190	130	0.1	0.1	36500	-1773
MINNETONKA_10A	00150356	463474	4976738	1	190	130	0.1	0.1	36500	-1647
MINNETONKA_11	00208014	463643	4972738	1	190	130	0.1	0.1	36500	-2411
MINNETONKA_11A	00439797	463604	4972839	1	190	130	0.1	0.1	36500	-2888
MINNETONKA_12	00203717	464596	4979633	1	190	130	0.1	0.1	36500	-2663
MINNETONKA_12A	00191939	464621	4979538	1	190	130	0.1	0.1	36500	-2452
MINNETONKA_13	00205165	465661	4971682	1	190	130	0.1	0.1	36500	-3612
MINNETONKA_13A	00132263	465602	4971607	1	190	130	0.1	0.1	36500	-2795
MINNETONKA_14	00204537	464647	4974689	1	190	130	0.1	0.1	36500	-976
MINNETONKA_14A	00160021	464582	4974637	1	190	130	0.1	0.1	36500	-612
MINNETONKA_3	00204470	460973	4975336	1	190	130	0.1	0.1	36500	-421
MINNETONKA_3A	00171021	461016	4975374	1	190	130	0.1	0.1	36500	-783
MINNETONKA_6	00204054	467254	4977553	1	190	130	0.1	0.1	36500	-2898
MINNETONKA_7	00208012	467217	4977553	1	190	130	0.1	0.1	36500	-1734
NSP_XCEL_EN_1	00200362	478701	4980718	1	190	130	0.1	0.1	36500	-805
PLYMOUTH_12	00508300	463598	4983191	1	190	130	0.1	0.1	36500	-2320
PLYMOUTH_13	00462918	462850	4983141	1	190	130	0.1	0.1	36500	-3101
PLYMOUTH_7	00184882	463214	4983147	1	190	130	0.1	0.1	36500	-2903
REPUBLIC_CEROSOTE_(W23)	00216050	470787	4976659	1	190	130	0.1	0.1	36500	-253
RICHFIELD_1	00206353	478075	4970720	1	190	130	0.1	0.1	36500	-2629
RICHFIELD_2	00206353	478075	4970582	1	190	130	0.1	0.1	36500	-1758
RICHFIELD_3	00206361	478940	4970729	1	190	130	0.1	0.1	36500	-2374
RICHFIELD_4	00206276	478967	4970415	1	190	130	0.1	0.1	36500	-2080
RICHFIELD_6	00206279	479506	4970069	1	190	130	0.1	0.1	36500	-1782
SLP_10	00206442	470979	4977506	1	190	130	0.1	0.1	36500	-3456
SLP_14	00227965	471881	4979130	1	190	130	0.1	0.1	36500	-3567
SLP_16	00203187	468730	4978917	1	190	130	0.1	0.1	36500	-2747
SLP_4	00200542	473203	4975132	1	190	130	0.1	0.1	36500	-4881
SLP_6	00206457	472079	4974462	1	190	130	0.1	0.1	36500	-4157
SLP_8	00203678	468215	4979510	1	190	130	0.1	0.1	36500	-5319
W410	00434042	471380	4976072	1	235	230	0.1	0.1	36500	-464
W420	00434045	471004	4976262	1	255	253	0.1	0.1	36500	-181
W421	00434044	471060	4976262	1	251	248	0.1	0.1	36500	-161
W439	?	471108	4976683	1	253	251	0.1	0.1	36500	-264
W434	00463012	471784	4976180	1	249	247.5	0.1	0.1	36500	-177
MEADOWBROOK_W119	00216009	471316	4974878	1	190	130	0.1	0.1	36500	0
METHODIST_W48	00216067	471504	4975536	1	190	130	0.1	0.1	36500	0

Table 3-2 Observation Wells Included in the Model

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	UTME (m)	UTMN (m)	Screen ID	Screen Elevation (m)	Observ. Time (days)	Head (m)	Model Layer	Observation Groups: 5 mile OPCJ	5 mile OSTP	5 mile OPVL / Drift	Near Reilly
DRIFT-W1-100	467125	4982460	1	257.0	1	271.0	2			x	
DRIFT-W1-101	466133	4977473	1	253.0	1	271.3	2			x	
DRIFT-W1-102	467663	4979368	1	252.5	1	271.3	2			x	
DRIFT-W1-103	466330	4982324	1	257.0	1	271.3	2			x	
DRIFT-W1-106	466028	4973488	1	252.5	1	272.5	2			x	
DRIFT-W1-110	464236	4979229	1	253.0	1	272.8	2			x	
DRIFT-W1-114	467021	4973695	1	253.0	1	273.4	2			x	
DRIFT-W1-115	467928	4979245	1	252.0	1	273.4	2			x	
DRIFT-W1-118	465903	4981786	1	256.0	1	273.7	2			x	
DRIFT-W1-119	464035	4972647	1	248.5	1	274.3	2			x	
DRIFT-W1-122	464935	4977431	1	257.0	1	274.3	2			x	
DRIFT-W1-123	465444	4980941	1	256.0	1	274.3	2			x	
DRIFT-W1-130	465389	4973840	1	253.0	1	275.2	2			x	
DRIFT-W1-137	465477	4973595	1	253.0	1	275.8	2			x	
DRIFT-W1-142	466190	4978213	1	259.0	1	275.8	2			x	
DRIFT-W1-143	465600	4979763	1	264.0	1	275.8	2			x	
DRIFT-W1-145	465305	4974342	1	253.0	1	276.5	2			x	
DRIFT-W1-150	463142	4978918	1	258.0	1	276.8	2			x	
DRIFT-W1-158	463923	4979385	1	253.0	1	277.4	2			x	
DRIFT-W1-160	466681	4978551	1	249.5	1	277.7	2			x	
DRIFT-W1-176	463929	4979322	1	251.0	1	280.4	2			x	
DRIFT-W1-183	463056	4977358	1	260.0	1	282.5	2			x	
DRIFT-W1-2	474133	4969289	1	233.0	1	243.5	2			x	
DRIFT-W1-23	475066	4969745	1	233.0	1	250.9	2			x	
DRIFT-W1-27	476076	4970587	1	239.0	1	252.4	2			x	
DRIFT-W1-28	469588	4969339	1	240.0	1	253.0	2			x	
DRIFT-W1-29	475021	4970142	1	235.0	1	253.0	2			x	
DRIFT-W1-30	471278	4970546	1	244.0	1	253.0	2			x	
DRIFT-W1-31	475774	4970566	1	238.0	1	253.9	2			x	
DRIFT-W1-32	473121	4969456	1	233.0	1	254.5	2			x	
DRIFT-W1-33	472396	4983506	1	254.0	1	254.5	2			x	
DRIFT-W1-35	470891	4969051	1	237.0	1	256.0	2			x	
DRIFT-W1-36	468672	4969411	1	241.0	1	256.0	2			x	
DRIFT-W1-37	470812	4970998	1	247.5	1	256.0	2			x	
DRIFT-W1-38	472158	4983632	1	255.0	1	256.0	2			x	
DRIFT-W1-39	471298	4970517	1	244.0	1	256.9	2			x	
DRIFT-W1-40	469643	4969729	1	241.5	1	257.6	2			x	
DRIFT-W1-42	470882	4969021	1	237.0	1	259.7	2			x	
DRIFT-W1-43	471340	4970986	1	247.0	1	259.7	2			x	
DRIFT-W1-44	469814	4982697	1	255.0	1	259.7	2			x	
DRIFT-W1-45	472280	4982363	1	253.5	1	260.3	2			x	
DRIFT-W1-46	471289	4970668	1	245.0	1	260.6	2			x	
DRIFT-W1-47	471207	4970739	1	245.5	1	260.6	2			x	
DRIFT-W1-48	471351	4971078	1	247.0	1	260.6	2			x	
DRIFT-W1-49	472300	4983120	1	253.0	1	260.6	2			x	
DRIFT-W1-5	480770	4970180	1	239.0	1	245.1	2			x	
DRIFT-W1-50	469446	4984186	1	252.5	1	260.6	2			x	
DRIFT-W1-52	471869	4970302	1	241.5	1	261.5	2			x	
DRIFT-W1-54	473418	4979165	1	251.0	1	261.8	2			x	
DRIFT-W1-56	471054	4970937	1	247.0	1	262.1	2			x	
DRIFT-W1-57	473026	4971224	1	247.0	1	262.1	2			x	
DRIFT-W1-58	471912	4971241	1	246.0	1	262.1	2			x	
DRIFT-W1-59	469285	4984116	1	253.0	1	262.1	2			x	
DRIFT-W1-60	470938	4983877	1	252.0	1	263.0	2			x	
DRIFT-W1-61	473167	4980114	1	251.0	1	263.3	2			x	
DRIFT-W1-62	470744	4980549	1	252.5	1	263.3	2			x	
DRIFT-W1-65	471973	4971584	1	247.0	1	263.7	2			x	
DRIFT-W1-66	469824	4981989	1	255.5	1	263.7	2			x	

Table 3-2 Observation Wells Included in the Model

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	UTME (m)	UTMN (m)	Screen ID	Screen Elevation (m)	Observ. Time (days)	Head (m)	Model Layer	Observation Groups: 5 mile OPCJ	5 mile OSTP	5 mile OPVL / Drift	Near Reilly
DRIFT-W1-67	469406	4982041	1	256.0	1	263.7	2			x	
DRIFT-W1-68	470741	4982560	1	253.0	1	263.7	2			x	
DRIFT-W1-69	470877	4982716	1	253.5	1	263.7	2			x	
DRIFT-W1-70	470351	4983825	1	252.0	1	263.7	2			x	
DRIFT-W1-72	470136	4984026	1	252.0	1	264.9	2			x	
DRIFT-W1-73	471700	4980242	1	252.5	1	265.2	2			x	
DRIFT-W1-74	470375	4983709	1	252.0	1	265.2	2			x	
DRIFT-W1-75	470327	4983918	1	252.0	1	265.2	2			x	
DRIFT-W1-76	468079	4983945	1	256.0	1	265.2	2			x	
DRIFT-W1-78	470176	4983848	1	252.0	1	265.8	2			x	
DRIFT-W1-79	470001	4981221	1	252.5	1	266.1	2			x	
DRIFT-W1-80	468577	4982088	1	256.0	1	266.7	2			x	
DRIFT-W1-81	468760	4982229	1	256.0	1	266.7	2			x	
DRIFT-W1-82	468357	4983831	1	254.0	1	266.7	2			x	
DRIFT-W1-84	470681	4982568	1	255.0	1	267.0	2			x	
DRIFT-W1-86	465815	4970316	1	246.0	1	267.3	2			x	
DRIFT-W1-87	470103	4974376	1	252.0	1	268.2	2			x	
DRIFT-W1-88	467686	4978704	1	249.0	1	268.2	2			x	
DRIFT-W1-89	465530	4981162	1	256.0	1	268.2	2			x	
DRIFT-W1-90	468574	4983016	1	256.0	1	268.2	2			x	
DRIFT-W1-93	468662	4982949	1	256.0	1	268.8	2			x	
DRIFT-W1-95	467871	4979338	1	252.0	1	269.7	2			x	
DRIFT-W1-98	466991	4982660	1	257.5	1	270.4	2			x	
R-DRIFT-P308	471361	4976350	1	253.0	1	268.8	2			x	x
R-DRIFT-W116	472369	4976102	1	252.0	1	266.7	2			x	x
R-DRIFT-W128	471935	4975565	1	250.0	1	266.8	2			x	x
R-OPVL-W1	471161	4977287	1	249.0	1	268.1	2			x	x
R-OPVL-W100	470411	4977185	1	249.0	1	271.1	2			x	x
R-OPVL-W120	471748	4976012	1	249.0	1	267.3	2			x	x
R-OPVL-W124	473067	4976108	1	246.0	1	265.0	2			x	x
R-OPVL-W131	471685	4976665	1	249.5	1	268.4	2			x	x
R-OPVL-W18	470976	4976016	1	249.0	1	268.9	2			x	x
R-OPVL-W27	470866	4976343	1	249.0	1	269.2	2			x	x
R-OPVL-W428	471702	4975607	1	246.8	1	268.4	2			x	x
R-OPVL-W438	471505	4976198	1	249.0	1	268.4	2			x	x
DRIFT-W1-10	475329	4969035	1	233.0	1	246.6	2				
DRIFT-W1-104	468829	4984743	1	252.0	1	271.3	2				
DRIFT-W1-107	459383	4974861	1	243.0	1	272.5	2				
DRIFT-W1-109	459429	4976355	1	241.2	1	272.8	2				
DRIFT-W1-111	457525	4980859	1	262.0	1	272.8	2				
DRIFT-W1-112	463001	4973194	1	248.0	1	273.4	2				
DRIFT-W1-113	462901	4973509	1	248.0	1	273.4	2				
DRIFT-W1-12	474912	4968842	1	231.0	1	246.9	2				
DRIFT-W1-121	459269	4976253	1	241.2	1	274.3	2				
DRIFT-W1-124	457912	4981138	1	267.0	1	274.6	2				
DRIFT-W1-125	456923	4984157	1	267.0	1	274.6	2				
DRIFT-W1-127	465707	4984343	1	265.0	1	274.9	2				
DRIFT-W1-128	460865	4984809	1	268.0	1	274.9	2				
DRIFT-W1-13	477242	4970225	1	237.0	1	246.9	2				
DRIFT-W1-131	459520	4975611	1	242.0	1	275.2	2				
DRIFT-W1-132	459937	4984587	1	263.6	1	275.2	2				
DRIFT-W1-133	461571	4975344	1	251.5	1	275.5	2				
DRIFT-W1-134	459128	4976301	1	241.2	1	275.5	2				
DRIFT-W1-135	457494	4980537	1	257.5	1	275.5	2				
DRIFT-W1-136	462606	4972788	1	243.5	1	275.8	2				
DRIFT-W1-139	461166	4976028	1	249.0	1	275.8	2				
DRIFT-W1-14	475054	4969543	1	233.0	1	247.5	2				
DRIFT-W1-140	458764	4976103	1	242.5	1	275.8	2				

Table 3-2 Observation Wells Included in the Model

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	UTME (m)	UTMN (m)	Screen ID	Screen Elevation (m)	Observ. Time (days)	Head (m)	Model Layer	Observation Groups: 5 mile OPCJ	5 mile OSTP	5 mile OPVL / Drift	Near Reilly
DRIFT-W1-141	460562	4976692	1	249.0	1	275.8	2				
DRIFT-W1-144	463030	4984749	1	271.0	1	275.8	2				
DRIFT-W1-146	460914	4975894	1	250.5	1	276.5	2				
DRIFT-W1-147	458820	4976422	1	244.0	1	276.5	2				
DRIFT-W1-148	459118	4975710	1	242.0	1	276.8	2				
DRIFT-W1-149	460659	4975932	1	243.0	1	276.8	2				
DRIFT-W1-151	462870	4973510	1	248.0	1	277.1	2				
DRIFT-W1-152	462587	4973120	1	244.0	1	277.4	2				
DRIFT-W1-155	461727	4975287	1	253.0	1	277.4	2				
DRIFT-W1-156	461655	4975373	1	253.0	1	277.4	2				
DRIFT-W1-157	461401	4977267	1	256.0	1	277.4	2				
DRIFT-W1-159	462997	4984701	1	271.0	1	277.4	2				
DRIFT-W1-16	475364	4969229	1	233.0	1	248.4	2				
DRIFT-W1-161	461649	4978864	1	260.0	1	278.0	2				
DRIFT-W1-162	457570	4980874	1	262.0	1	278.3	2				
DRIFT-W1-163	456909	4981054	1	262.5	1	278.3	2				
DRIFT-W1-164	458346	4983256	1	273.0	1	278.3	2				
DRIFT-W1-165	461220	4977245	1	257.0	1	278.6	2				
DRIFT-W1-166	456723	4980819	1	260.0	1	278.6	2				
DRIFT-W1-167	460011	4976378	1	242.5	1	278.9	2				
DRIFT-W1-168	460671	4977239	1	249.5	1	278.9	2				
DRIFT-W1-169	461256	4977246	1	258.0	1	278.9	2				
DRIFT-W1-170	456838	4981407	1	263.0	1	278.9	2				
DRIFT-W1-171	459021	4981889	1	265.0	1	278.9	2				
DRIFT-W1-173	461608	4977310	1	257.0	1	280.1	2				
DRIFT-W1-174	456513	4983883	1	267.0	1	280.1	2				
DRIFT-W1-175	458985	4975302	1	242.5	1	280.4	2				
DRIFT-W1-177	462608	4981224	1	270.0	1	280.4	2				
DRIFT-W1-178	459549	4983755	1	265.0	1	281.0	2				
DRIFT-W1-179	459074	4976460	1	241.0	1	281.3	2				
DRIFT-W1-180	458843	4975854	1	243.0	1	281.6	2				
DRIFT-W1-181	462501	4981251	1	270.0	1	281.9	2				
DRIFT-W1-182	460370	4980949	1	264.0	1	282.2	2				
DRIFT-W1-184	461641	4977918	1	259.0	1	283.2	2				
DRIFT-W1-185	463013	4981480	1	271.0	1	284.1	2				
DRIFT-W1-186	459862	4984534	1	263.6	1	285.0	2				
DRIFT-W1-19	476333	4969317	1	235.0	1	249.0	2				
DRIFT-W1-22	475531	4969688	1	233.0	1	249.9	2				
DRIFT-W1-24	470973	4967670	1	233.0	1	251.2	2				
DRIFT-W1-26	475732	4969917	1	235.0	1	251.8	2				
DRIFT-W1-34	469073	4968214	1	243.0	1	256.0	2				
DRIFT-W1-41	471855	4985059	1	252.0	1	259.1	2				
DRIFT-W1-51	470921	4970636	1	245.3	1	260.9	2				
DRIFT-W1-53	471359	4970737	1	245.0	1	261.5	2				
DRIFT-W1-55	463727	4969843	1	245.0	1	262.1	2				
DRIFT-W1-63	470473	4984714	1	254.0	1	263.3	2				
DRIFT-W1-64	462610	4970278	1	245.0	1	263.7	2				
DRIFT-W1-71	466372	4984059	1	262.0	1	264.0	2				
DRIFT-W1-9	477116	4969803	1	236.0	1	246.3	2				
DRIFT-W1-91	468020	4983930	1	256.5	1	268.2	2				
DRIFT-W1-92	463049	4969851	1	245.0	1	268.5	2				
DRIFT-W1-96	465736	4983328	1	262.0	1	269.7	2				
DRIFT-W1-97	456687	4980472	1	256.0	1	270.1	2				
DRIFT-W1-99	466095	4983131	1	260.0	1	270.4	2				
00200286	473195	4983092	1	210.0	1	259.7	5		x		
00114472	470994	4975806	1	200.0	1	263.3	5		x		
00133350	465802	4978191	1	200.0	1	274.3	5		x		
00155157	466899	4969996	1	200.0	1	258.8	5		x		

Table 3-2 Observation Wells Included in the Model

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	UTME (m)	UTMN (m)	Screen ID	Screen Elevation (m)	Observ. Time (days)	Head (m)	Model Layer	Observation Groups: 5 mile OPCJ	5 mile OSTP	5 mile OPVL / Drift	Near Reilly
00158080	466966	4982173	1	200.0	1	271.0	5		x		
00158409	466830	4969995	1	200.0	1	262.7	5		x		
00160014	468342	4983454	1	200.0	1	260.6	5		x		
00160018	470928	4975508	1	200.0	1	264.0	5		x		
00164543	466926	4982845	1	200.0	1	267.6	5		x		
00165578	472188	4975291	1	200.0	1	269.7	5		x		
00165584	471026	4977534	1	200.0	1	264.7	5		x		
00168724	474204	4972161	1	200.0	1	254.2	5		x		
00200232	473145	4984338	1	200.0	1	254.5	5		x		
00200234	473069	4984180	1	200.0	1	248.4	5		x		
00200237	473097	4983664	1	200.0	1	251.2	5		x		
00200238	473019	4983653	1	200.0	1	254.5	5		x		
00200245	473426	4983972	1	200.0	1	248.4	5		x		
00200246	473386	4983927	1	200.0	1	248.4	5		x		
00200276	473475	4982821	1	200.0	1	246.0	5		x		
00200279	473401	4983073	1	200.0	1	254.5	5		x		
00200292	472691	4982579	1	200.0	1	247.8	5		x		
00200297	473238	4982278	1	200.0	1	251.8	5		x		
00200300	472930	4981925	1	200.0	1	249.3	5		x		
00200301	473396	4982435	1	200.0	1	244.4	5		x		
00200303	473831	4981310	1	200.0	1	250.5	5		x		
00200306	472937	4981828	1	200.0	1	251.2	5		x		
00200307	473311	4981579	1	200.0	1	253.0	5		x		
00200309	472777	4981758	1	200.0	1	260.3	5		x		
00200323	472840	4980435	1	200.0	1	257.6	5		x		
00200332	473508	4980703	1	200.0	1	253.0	5		x		
00200341	473660	4980388	1	200.0	1	254.8	5		x		
00200552	472871	4973434	1	200.0	1	266.7	5		x		
00200557	473739	4972169	1	200.0	1	256.0	5		x		
00200562	472876	4971320	1	200.0	1	259.4	5		x		
00200571	474721	4972162	1	200.0	1	253.0	5		x		
00200572	474766	4972110	1	200.0	1	248.4	5		x		
00200573	474592	4971897	1	200.0	1	253.6	5		x		
00200581	477034	4972019	1	200.0	1	251.5	5		x		
00200639	477718	4979318	1	200.0	1	237.4	5		x		
00201022	473430	4980245	1	200.0	1	253.6	5		x		
00201025	474059	4979758	1	200.0	1	260.6	5		x		
00201035	472741	4979759	1	200.0	1	255.4	5		x		
00201040	472723	4979661	1	200.0	1	260.9	5		x		
00201051	474032	4979238	1	200.0	1	257.3	5		x		
00201056	473832	4978686	1	200.0	1	254.8	5		x		
00201060	474026	4977579	1	200.0	1	252.7	5		x		
00201061	473623	4978370	1	200.0	1	262.1	5		x		
00203102	468970	4970518	1	200.0	1	255.1	5		x		
00203103	468791	4970432	1	200.0	1	260.6	5		x		
00203105	468651	4970173	1	200.0	1	261.5	5		x		
00203107	468684	4970098	1	200.0	1	248.4	5		x		
00203108	468600	4970105	1	200.0	1	254.5	5		x		
00203112	469261	4969862	1	200.0	1	250.5	5		x		
00203128	469310	4969475	1	200.0	1	259.1	5		x		
00203129	469301	4969442	1	200.0	1	258.8	5		x		
00203130	469679	4969346	1	200.0	1	251.5	5		x		
00203141	466336	4969972	1	200.0	1	258.2	5		x		
00203606	470029	4972425	1	200.0	1	263.7	5		x		
00203612	469567	4973247	1	200.0	1	257.6	5		x		
00203616	469878	4972894	1	200.0	1	254.5	5		x		
00203617	469883	4972851	1	200.0	1	254.5	5		x		
00203618	469280	4973065	1	200.0	1	256.6	5		x		

Table 3-2 Observation Wells Included in the Model

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	UTME (m)	UTMN (m)	Screen ID	Screen Elevation (m)	Observ. Time (days)	Head (m)	Model Layer	Observation Groups: 5 mile OPCJ	5 mile OSTP	5 mile OPVL / Drift	Near Reilly
00203619	469201	4972979	1	200.0	1	259.4	5		x		
00203621	469529	4972953	1	200.0	1	256.9	5		x		
00203622	469708	4972460	1	200.0	1	257.6	5		x		
00203624	469230	4971098	1	200.0	1	264.0	5		x		
00203627	470243	4972260	1	200.0	1	259.4	5		x		
00203629	470186	4972016	1	200.0	1	261.2	5		x		
00203631	470174	4971965	1	200.0	1	254.5	5		x		
00203813	470760	4984343	1	200.0	1	258.5	5		x		
00203859	472258	4983591	1	200.0	1	257.3	5		x		
00203869	471949	4982537	1	200.0	1	258.5	5		x		
00203873	471649	4982266	1	200.0	1	258.8	5		x		
00203893	471347	4982549	1	200.0	1	262.1	5		x		
00203894	471265	4982518	1	200.0	1	253.0	5		x		
00203897	471159	4982598	1	200.0	1	265.2	5		x		
00203901	470998	4982683	1	200.0	1	260.6	5		x		
00203903	470976	4982638	1	200.0	1	262.1	5		x		
00203907	471136	4982545	1	200.0	1	263.0	5		x		
00203908	471105	4982567	1	200.0	1	261.5	5		x		
00203914	470406	4981067	1	200.0	1	260.0	5		x		
00203957	469858	4982712	1	200.0	1	263.7	5		x		
00203960	469891	4982530	1	200.0	1	262.1	5		x		
00204390	466821	4983135	1	200.0	1	266.1	5		x		
00204391	466830	4983115	1	200.0	1	265.2	5		x		
00204566	465546	4974226	1	200.0	1	277.4	5		x		
00204595	464979	4973259	1	200.0	1	265.2	5		x		
00204598	464248	4972821	1	200.0	1	260.6	5		x		
00204736	467172	4982029	1	200.0	1	270.4	5		x		
00204859	472129	4970505	1	200.0	1	260.6	5		x		
00204861	472158	4970190	1	200.0	1	260.9	5		x		
00204862	472063	4970300	1	200.0	1	261.5	5		x		
00204911	471282	4968882	1	200.0	1	249.6	5		x		
00204915	470446	4968740	1	200.0	1	249.9	5		x		
00205008	463380	4973939	1	200.0	1	274.3	5		x		
00205010	463405	4973889	1	200.0	1	276.5	5		x		
00205011	463474	4973883	1	200.0	1	274.3	5		x		
00205014	463329	4973926	1	200.0	1	271.3	5		x		
00205015	463307	4973889	1	200.0	1	277.4	5		x		
00205168	468074	4970837	1	200.0	1	256.0	5		x		
00206397	473194	4969279	1	200.0	1	253.0	5		x		
00206402	472581	4970590	1	200.0	1	256.6	5		x		
00206404	472483	4969977	1	200.0	1	258.8	5		x		
00206427	471539	4979490	1	200.0	1	263.3	5		x		
00206432	470794	4979067	1	200.0	1	258.2	5		x		
00206479	470925	4973958	1	200.0	1	265.5	5		x		
00206480	470816	4973937	1	200.0	1	256.3	5		x		
00206485	470611	4973970	1	200.0	1	265.2	5		x		
00206496	470562	4973197	1	200.0	1	255.1	5		x		
00206554	470672	4972300	1	200.0	1	262.7	5		x		
00206570	470511	4972047	1	200.0	1	253.0	5		x		
00206575	470643	4972126	1	200.0	1	262.1	5		x		
00206579	470572	4972134	1	200.0	1	261.2	5		x		
00206590	471041	4971078	1	200.0	1	262.1	5		x		
00206591	470963	4970994	1	200.0	1	259.4	5		x		
00206593	470768	4971069	1	200.0	1	254.5	5		x		
00206594	470796	4971076	1	200.0	1	256.0	5		x		
00206596	470756	4970994	1	200.0	1	254.5	5		x		
00206598	470774	4970945	1	200.0	1	254.5	5		x		
00206603	470898	4970885	1	200.0	1	258.2	5		x		

Table 3-2 Observation Wells Included in the Model

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	UTME (m)	UTMN (m)	Screen ID	Screen Elevation (m)	Observ. Time (days)	Head (m)	Model Layer	Observation Groups: 5 mile OPCJ	5 mile OSTP	5 mile OPVL / Drift	Near Reilly
00206605	470896	4970848	1	200.0	1	263.0	5		x		
00206622	471372	4970783	1	200.0	1	260.6	5		x		
00207168	468557	4982330	1	200.0	1	263.7	5		x		
00208030	471159	4968925	1	200.0	1	255.4	5		x		
00208033	470878	4968977	1	200.0	1	256.0	5		x		
00208034	470843	4968970	1	200.0	1	256.6	5		x		
00208969	471310	4982005	1	200.0	1	252.4	5		x		
00216049	471020	4975382	1	200.0	1	264.3	5		x		
00218190	470881	4972641	1	200.0	1	256.0	5		x		
00222901	469302	4969417	1	200.0	1	259.4	5		x		
00222902	469216	4969179	1	200.0	1	254.5	5		x		
00222906	469336	4969572	1	200.0	1	260.6	5		x		
00222908	469362	4969198	1	200.0	1	251.8	5		x		
00223683	472906	4984202	1	200.0	1	254.5	5		x		
00223684	472318	4984100	1	200.0	1	253.6	5		x		
00223685	472341	4983793	1	200.0	1	251.5	5		x		
00223691	472134	4983612	1	200.0	1	255.4	5		x		
00223695	472306	4983220	1	200.0	1	255.4	5		x		
00223698	472297	4983621	1	200.0	1	253.0	5		x		
00223700	472326	4983694	1	200.0	1	250.9	5		x		
00223744	463324	4978785	1	200.0	1	271.3	5		x		
00223753	464384	4973474	1	200.0	1	273.4	5		x		
00223757	469272	4969319	1	200.0	1	255.4	5		x		
00223758	469230	4969456	1	200.0	1	250.2	5		x		
00223762	469597	4969461	1	200.0	1	256.0	5		x		
00223766	470347	4972008	1	200.0	1	260.6	5		x		
00223767	470195	4972197	1	200.0	1	262.7	5		x		
00223774	469460	4973242	1	200.0	1	263.0	5		x		
00223781	467528	4982215	1	200.0	1	258.5	5		x		
00223873	465061	4972223	1	200.0	1	256.0	5		x		
00223894	472059	4970064	1	200.0	1	261.5	5		x		
00223898	472678	4970493	1	200.0	1	257.6	5		x		
00223899	472677	4970482	1	200.0	1	254.5	5		x		
00223900	473502	4971672	1	200.0	1	254.2	5		x		
00223901	473830	4978524	1	200.0	1	258.2	5		x		
00223935	473570	4979892	1	200.0	1	259.1	5		x		
00223937	473152	4978375	1	200.0	1	258.8	5		x		
00225887	476486	4981107	1	200.0	1	253.6	5		x		
00226105	474402	4979718	1	200.0	1	260.0	5		x		
00236020	476493	4977064	1	200.0	1	252.4	5		x		
00432034	472170	4975504	1	200.0	1	263.3	5		x		
00432037	473072	4976114	1	200.0	1	265.4	5		x		
R-OSTP-P116	473080	4976135	1	200.0	1	263.4	5		x		x
R-OSTP-W133	471941	4976114	1	200.0	1	263.6	5		x		x
R-OSTP-W33	471261	4976027	1	200.0	1	263.8	5		x		x
R-OSTP-W409	471000	4976385	1	200.0	1	265.2	5		x		x
R-OSTP-W411	471365	4975335	1	200.0	1	263.8	5		x		x
00100115	459564	4975744	1	200.0	1	274.3	5				
00100120	459642	4976007	1	200.0	1	274.6	5				
00100121	459081	4976323	1	200.0	1	275.8	5				
00104862	459446	4975961	1	200.0	1	271.3	5				
00111007	459220	4976084	1	200.0	1	274.3	5				
00111019	459444	4975077	1	200.0	1	268.2	5				
00111041	459151	4976009	1	200.0	1	274.9	5				
00112351	460255	4975970	1	200.0	1	276.8	5				
00114305	464441	4971109	1	200.0	1	256.6	5				
00125924	480593	4971384	1	200.0	1	243.8	5				
00127301	459154	4976065	1	200.0	1	271.6	5				

Table 3-2 Observation Wells Included in the Model

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	UTME (m)	UTMN (m)	Screen ID	Screen Elevation (m)	Observ. Time (days)	Head (m)	Model Layer	Observation Groups: 5 mile OPCJ	5 mile OSTP	5 mile OPVL / Drift	Near Reilly
00127339	459018	4975854	1	200.0	1	274.3	5				
00127384	459192	4975871	1	200.0	1	272.2	5				
00127391	459040	4976634	1	200.0	1	274.6	5				
00127463	459033	4975477	1	200.0	1	268.8	5				
00127475	460286	4977533	1	200.0	1	279.5	5				
00127476	459711	4975149	1	200.0	1	268.2	5				
00127478	459105	4974955	1	200.0	1	268.2	5				
00127479	459072	4975269	1	200.0	1	269.7	5				
00127483	459109	4975845	1	200.0	1	270.7	5				
00127486	459390	4975921	1	200.0	1	272.2	5				
00127488	459099	4975288	1	200.0	1	269.7	5				
00127494	459131	4976373	1	200.0	1	274.3	5				
00127502	459474	4976277	1	200.0	1	272.2	5				
00130758	462688	4970208	1	200.0	1	260.6	5				
00137353	478056	4973025	1	200.0	1	244.4	5				
00157897	459425	4976701	1	200.0	1	279.8	5				
00159032	458823	4976255	1	200.0	1	277.4	5				
00171033	459986	4985472	1	200.0	1	276.1	5				
00171059	458890	4976396	1	200.0	1	273.4	5				
00183678	458159	4981429	1	200.0	1	277.4	5				
00190056	458998	4976113	1	200.0	1	276.5	5				
00190432	459118	4974989	1	200.0	1	274.0	5				
00191332	459290	4976163	1	200.0	1	271.6	5				
00192805	459992	4985064	1	200.0	1	272.8	5				
00200222	473388	4984400	1	200.0	1	250.9	5				
00200223	473464	4984494	1	200.0	1	253.3	5				
00200224	473523	4984311	1	200.0	1	256.0	5				
00200231	473268	4984446	1	200.0	1	251.5	5				
00200233	473268	4984312	1	200.0	1	251.5	5				
00200241	473426	4984277	1	200.0	1	256.6	5				
00200250	474626	4984311	1	200.0	1	248.7	5				
00201084	480020	4977049	1	200.0	1	248.1	5				
00203140	465825	4969275	1	200.0	1	260.6	5				
00203154	462161	4970771	1	200.0	1	262.1	5				
00203761	461322	4979309	1	200.0	1	271.3	5				
00203776	460765	4977327	1	200.0	1	276.5	5				
00204164	461021	4977069	1	200.0	1	275.8	5				
00204175	460850	4976371	1	200.0	1	275.8	5				
00204179	461007	4976077	1	200.0	1	278.3	5				
00204185	460946	4975967	1	200.0	1	278.6	5				
00204189	460850	4975930	1	200.0	1	277.4	5				
00204190	460847	4975889	1	200.0	1	278.9	5				
00204195	461197	4976317	1	200.0	1	271.3	5				
00204293	461312	4984529	1	200.0	1	272.8	5				
00204304	461302	4983898	1	200.0	1	271.3	5				
00204305	461392	4983677	1	200.0	1	274.3	5				
00204307	463070	4984866	1	200.0	1	278.6	5				
00204312	463238	4984798	1	200.0	1	273.4	5				
00204317	463121	4984760	1	200.0	1	271.6	5				
00204322	463068	4984826	1	200.0	1	273.7	5				
00204323	463013	4984842	1	200.0	1	274.6	5				
00204325	462999	4984779	1	200.0	1	271.9	5				
00204331	463054	4984651	1	200.0	1	276.8	5				
00204332	463128	4984614	1	200.0	1	273.7	5				
00204340	463673	4983862	1	200.0	1	272.8	5				
00204396	465266	4983624	1	200.0	1	274.3	5				
00204410	461670	4975808	1	200.0	1	279.5	5				
00204424	460166	4976343	1	200.0	1	277.4	5				

Table 3-2 Observation Wells Included in the Model

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	UTME (m)	UTMN (m)	Screen ID	Screen Elevation (m)	Observ. Time (days)	Head (m)	Model Layer	Observation Groups: 5 mile OPCJ	5 mile OSTP	5 mile OPVL / Drift	Near Reilly
00204446	460241	4975333	1	200.0	1	274.6	5				
00204448	460302	4974949	1	200.0	1	271.3	5				
00204450	458945	4975501	1	200.0	1	271.3	5				
00204457	461948	4975506	1	200.0	1	278.9	5				
00204466	461066	4975231	1	200.0	1	273.1	5				
00204467	460610	4975282	1	200.0	1	274.3	5				
00204468	460709	4975268	1	200.0	1	277.1	5				
00204471	461040	4974052	1	200.0	1	269.7	5				
00204473	461563	4974022	1	200.0	1	268.2	5				
00204626	463491	4981907	1	200.0	1	277.4	5				
00204628	460716	4983599	1	200.0	1	269.7	5				
00204632	460624	4983436	1	200.0	1	271.3	5				
00204633	460764	4983384	1	200.0	1	275.8	5				
00204640	461889	4982250	1	200.0	1	281.0	5				
00204641	461836	4982250	1	200.0	1	285.0	5				
00204658	461818	4981307	1	200.0	1	275.8	5				
00204659	463284	4982021	1	200.0	1	278.9	5				
00204660	463492	4981677	1	200.0	1	280.4	5				
00204678	462704	4981619	1	200.0	1	281.9	5				
00204681	462557	4981398	1	200.0	1	278.9	5				
00204698	462739	4980981	1	200.0	1	281.9	5				
00204702	462319	4981150	1	200.0	1	281.9	5				
00204704	463067	4980978	1	200.0	1	280.4	5				
00204709	464020	4981428	1	200.0	1	275.8	5				
00204949	471030	4967594	1	200.0	1	251.5	5				
00205020	462950	4973685	1	200.0	1	266.7	5				
00205023	462839	4973512	1	200.0	1	263.7	5				
00205025	462818	4973195	1	200.0	1	257.6	5				
00205031	462244	4973682	1	200.0	1	272.8	5				
00205037	462443	4973390	1	200.0	1	264.3	5				
00205059	462848	4973145	1	200.0	1	259.1	5				
00205067	462881	4972414	1	200.0	1	268.2	5				
00205141	463229	4971842	1	200.0	1	259.1	5				
00205887	465107	4968753	1	200.0	1	259.1	5				
00205890	464150	4968840	1	200.0	1	249.9	5				
00205893	466856	4968914	1	200.0	1	260.6	5				
00206318	478030	4970105	1	200.0	1	242.3	5				
00206321	477693	4970176	1	200.0	1	248.4	5				
00206322	477692	4970120	1	200.0	1	247.8	5				
00206323	477696	4970057	1	200.0	1	247.2	5				
00206336	477690	4970263	1	200.0	1	244.8	5				
00206980	465383	4968482	1	200.0	1	248.4	5				
00206990	465517	4968553	1	200.0	1	259.1	5				
00207033	459266	4984075	1	200.0	1	276.8	5				
00207035	459275	4983821	1	200.0	1	276.1	5				
00208848	456904	4982110	1	200.0	1	277.4	5				
00223211	470969	4967699	1	200.0	1	250.5	5				
00223682	473526	4984754	1	200.0	1	251.8	5				
00223750	463335	4971782	1	200.0	1	265.2	5				
00223814	461314	4977310	1	200.0	1	278.9	5				
00223817	461289	4975794	1	200.0	1	278.9	5				
00223970	465573	4969532	1	200.0	1	263.3	5				
00224078	462394	4974079	1	200.0	1	272.5	5				
00224096	466822	4968948	1	200.0	1	262.7	5				
00226841	461007	4974962	1	200.0	1	278.3	5				
00227322	459035	4975585	1	200.0	1	279.2	5				
00233123	460100	4977345	1	200.0	1	274.9	5				
00242218	463539	4972498	1	200.0	1	262.7	5				

Table 3-2 Observation Wells Included in the Model

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	UTME (m)	UTMN (m)	Screen ID	Screen Elevation (m)	Observ. Time (days)	Head (m)	Model Layer	Observation Groups: 5 mile OPCJ	5 mile OSTP	5 mile OPVL / Drift	Near Reilly
00400896	458996	4975632	1	200.0	1	276.8	5				
00405060	460379	4977099	1	200.0	1	279.8	5				
00405081	459145	4975653	1	200.0	1	275.2	5				
00405087	459264	4975764	1	200.0	1	267.6	5				
00405091	459248	4975756	1	200.0	1	269.7	5				
00413357	459248	4975888	1	200.0	1	273.4	5				
00413362	459295	4975223	1	200.0	1	266.7	5				
00415472	460335	4977080	1	200.0	1	276.8	5				
00415485	459730	4975999	1	200.0	1	270.7	5				
00420454	459666	4975934	1	200.0	1	271.9	5				
00420459	459075	4976021	1	200.0	1	269.7	5				
00420475	460343	4976852	1	200.0	1	279.2	5				
00420522	458983	4975925	1	200.0	1	267.9	5				
00420524	458991	4975232	1	200.0	1	275.2	5				
00426527	459278	4975792	1	200.0	1	272.8	5				
00435422	458939	4975965	1	200.0	1	272.8	5				
00435862	458234	4982025	1	200.0	1	275.8	5				
00438251	459718	4976062	1	200.0	1	268.2	5				
00W00098	462180	4981154	1	200.0	1	277.4	5				
00W00126	473008	4984615	1	200.0	1	257.6	5				
00206436	470699	4978378	1	150.0	1	241.8	7	x			
00216067	471401	4975240	1	150.0	1	245.7	7	x			
00200344	475990	4980249	1	130.0	1	232.6	7	x			
00200551	473956	4973103	1	130.0	1	253.9	7	x			
00201039	472509	4979726	1	130.0	1	251.5	7	x			
00201074	478078	4977654	1	130.0	1	237.4	7	x			
00201143	475684	4974835	1	130.0	1	252.1	7	x			
00203135	467705	4969969	1	130.0	1	265.2	7	x			
00203866	472318	4982872	1	130.0	1	251.5	7	x			
00203875	472082	4982080	1	130.0	1	251.5	7	x			
00204387	467124	4982448	1	130.0	1	256.0	7	x			
00204714	464918	4980563	1	130.0	1	270.4	7	x			
00206482	471106	4973348	1	130.0	1	256.0	7	x			
00206502	471483	4973033	1	130.0	1	255.1	7	x			
00206599	470824	4971055	1	130.0	1	254.5	7	x			
00208010	464044	4973815	1	130.0	1	263.0	7	x			
00208011	464056	4974120	1	130.0	1	262.1	7	x			
00213206	471428	4981215	1	130.0	1	248.1	7	x			
00216056	471608	4976210	1	130.0	1	249.3	7	x			
00223714	470849	4983881	1	130.0	1	256.3	7	x			
00223769	470354	4972339	1	130.0	1	253.0	7	x			
00223805	465812	4978775	1	130.0	1	260.6	7	x			
00223987	468468	4969374	1	130.0	1	259.1	7	x			
00227132	467059	4973449	1	130.0	1	254.5	7	x			
00233257	474206	4970078	1	130.0	1	245.1	7	x			
00242300	471139	4973123	1	130.0	1	251.5	7	x			
00431591	477137	4979513	1	130.0	1	240.8	7	x			
00439751	470671	4975759	1	130.0	1	246.0	7	x			
00W00182	469282	4969404	1	130.0	1	249.9	7	x			
MEADOWBROOK	471351	4974886	1	130.0	1	245.5	7	x			x
R-OPCJ-W29	470672	4975759	1	130.0	1	245.3	7	x			x
R-OPCJ-W48	471406	4975248	1	130.0	1	245.2	7	x			x
00100112	459840	4976055	1	130.0	1	270.1	7				
00100183	458438	4982209	1	130.0	1	274.9	7				
00118837	466549	4969116	1	130.0	1	244.8	7				
00118839	458809	4981463	1	130.0	1	276.8	7				
00127344	467721	4967631	1	130.0	1	245.4	7				
00127394	457457	4983594	1	130.0	1	268.2	7				

Table 3-2 Observation Wells Included in the Model

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	UTME (m)	UTMN (m)	Screen ID	Screen Elevation (m)	Observ. Time (days)	Head (m)	Model Layer	Observation Groups: 5 mile OPCJ	5 mile OSTP	5 mile OPVL / Drift	Near Reilly
00127453	458446	4985438	1	130.0	1	270.1	7				
00127519	456778	4982558	1	130.0	1	274.6	7				
00127549	456780	4982703	1	130.0	1	274.0	7				
00131940	456705	4982140	1	130.0	1	277.7	7				
00137351	458981	4975662	1	130.0	1	277.4	7				
00140105	458420	4984803	1	130.0	1	276.5	7				
00155221	458116	4981375	1	130.0	1	272.8	7				
00158070	459161	4976068	1	130.0	1	269.7	7				
00163890	458179	4982071	1	130.0	1	271.3	7				
00164553	458262	4982227	1	130.0	1	274.3	7				
00165621	457024	4980390	1	130.0	1	271.7	7				
00182081	459267	4975802	1	130.0	1	274.0	7				
00200586	480429	4971806	1	130.0	1	241.1	7				
00200602	481989	4975517	1	130.0	1	236.2	7				
00203143	466568	4969192	1	130.0	1	248.7	7				
00203153	464454	4969318	1	130.0	1	256.0	7				
00203155	462438	4970503	1	130.0	1	265.2	7				
00203160	462589	4970195	1	130.0	1	266.7	7				
00203782	461535	4977883	1	130.0	1	259.5	7				
00203809	471192	4984872	1	130.0	1	260.6	7				
00204295	460842	4984661	1	130.0	1	274.3	7				
00204296	460906	4984834	1	130.0	1	274.3	7				
00204298	460872	4984714	1	130.0	1	274.3	7				
00204300	460916	4984542	1	130.0	1	279.8	7				
00204318	463121	4984701	1	130.0	1	271.3	7				
00204431	459959	4975780	1	130.0	1	275.8	7				
00204432	459912	4975784	1	130.0	1	274.3	7				
00204433	459904	4975725	1	130.0	1	280.4	7				
00204435	459870	4975779	1	130.0	1	277.4	7				
00204642	460401	4983609	1	130.0	1	276.8	7				
00204644	459630	4983216	1	130.0	1	275.5	7				
00204646	459296	4982282	1	130.0	1	274.3	7				
00204647	459881	4982086	1	130.0	1	272.8	7				
00204649	459859	4981474	1	130.0	1	273.7	7				
00204654	458973	4981909	1	130.0	1	274.3	7				
00204655	460185	4981066	1	130.0	1	269.7	7				
00204706	462878	4980688	1	130.0	1	272.8	7				
00205032	462101	4973491	1	130.0	1	268.2	7				
00205033	462105	4973359	1	130.0	1	266.7	7				
00205894	466829	4968783	1	130.0	1	253.6	7				
00205895	465313	4968641	1	130.0	1	252.4	7				
00206291	479494	4970587	1	130.0	1	237.1	7				
00206310	475729	4970110	1	130.0	1	246.9	7				
00206358	478573	4970049	1	130.0	1	238.7	7				
00206375	474083	4969368	1	130.0	1	246.6	7				
00206981	465403	4968530	1	130.0	1	248.4	7				
00206982	465460	4968756	1	130.0	1	240.8	7				
00206983	465202	4968763	1	130.0	1	240.8	7				
00206984	465453	4968754	1	130.0	1	246.9	7				
00206986	465247	4968676	1	130.0	1	245.4	7				
00206988	465437	4968598	1	130.0	1	246.9	7				
00206989	465522	4968458	1	130.0	1	251.5	7				
00207008	459428	4982040	1	130.0	1	272.8	7				
00207129	458004	4982901	1	130.0	1	265.8	7				
00207469	461359	4981092	1	130.0	1	271.6	7				
00223874	465402	4968930	1	130.0	1	246.9	7				
00223876	465454	4968993	1	130.0	1	245.4	7				
00224094	465529	4968701	1	130.0	1	240.8	7				

Table 3-2 Observation Wells Included in the Model

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	UTME (m)	UTMN (m)	Screen ID	Screen Elevation (m)	Observ. Time (days)	Head (m)	Model Layer	Observation Groups: 5 mile OPCJ	5 mile OSTP	5 mile OPVL / Drift	Near Reilly
00225886	478882	4979043	1	130.0	1	240.8	7				
00247311	457661	4982170	1	130.0	1	276.5	7				
00417148	457270	4979511	1	130.0	1	269.4	7				
00420513	459218	4977968	1	130.0	1	268.5	7				
00435411	458325	4983895	1	130.0	1	274.6	7				
00436313	457931	4983150	1	130.0	1	266.7	7				
00449184	463608	4983526	1	130.0	1	260.2	7				

Table 3-3 Aquifer Property Zones set in the Model

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

	Hydraulic Conductivity			Storage		
Geologic Formation	Zone Number	Model Layer	Figure No.	Zone Number	Model Layer	Figure No.
Drift	20, 21, 22, 48	1 and 2	3-15a, 3-16a	19, 20, 21	1 and 2	3-15b, 3-16b
	23, 24, 50	2	3-16a	22, 23	2	3-16a
	27, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41	3 and 4	3-17a, 3-18a	26, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40	3 and 4	3-17a, 3-18b
				45, 46, 47, 48	5	3-19b
	2, 3, 4, 5	5 and 6	3-19a, 3-20a	2, 3, 4, 5	6	3-20b
Platteville (OPVL)	25, 26, 28, 29	3	3-17a	24, 25, 27, 28	3	3-17b
Glenwood (OGWD)	42, 43, 44, 45	4	3-18a	41, 42, 43, 44	4	3-18b
St. Peter (OSTP)	1, 46, 47, 49	3, 4, 5	3-17a, 3-18a, 3-19a	1, 49, 50, 51	3, 4, 5	3-17b, 3-18b, 3-19b
Basal St. Peter (OSTP)	6, 7, 8, 9, 10, 19	6	3-20a	6, 7, 8, 9, 10	6	3-20b
Prairie du Chien - Jordan (OPCJ)	11, 12, 13, 14, 15, 16, 17, 18	7	3-21	11, 12, 13, 14, 15, 16, 17, 18	7	3-21

TABLE 3-4
SUMMARY OF AQUIFER TEST RESULTS
Reilly Tar
St. Louis Park, Minnesota
Summit Project No. 0987-007

Well	Test Date	Analysis Method	Conductivity (feet/day)	Conductivity (cm/sec)	Transmissivity ($feet^2$/day)	Storativity	Assumed Aquifer Thickness
W420 Cluster							
W-18	11/10/2005	Theis	38.4	1.35E-02	2,630		68.42
		Cooper-Jacob Time-Drawdown	48.2	1.70E-02	3,300		
		Neuman	38.8	1.37E-02	2,666	1.80E-04	
Average			**41.8**	**1.47E-02**			
W439 Cluster							
W426	12/30/2005	Theis	56.6	2.00E-02	4,240		74.98
		Cooper-Jacob Time-Drawdown	108	3.81E-02	8,120		
		Neuman	44.9	1.58E-02	3,370	1.12E-02	
Average			**69.8**	**2.46E-02**			
W426	2/11/2006	Theis	56	1.98E-02	4,180		74.7
		Cooper-Jacob Time-Drawdown	52.6	1.86E-02	3,930		
		Neuman	50.9	1.80E-02	3,800	1.03E-03	
Average			**53.2**	**1.88E-02**			
W434 Cluster							
P312	11/3/2005	Theis	38.1	1.34E-02	2,720		71.49
		Cooper-Jacob Time-Drawdown	44.1	1.56E-02	3,150		
		Neuman	23.4	8.26E-03	1,680	5.31E-04	
Average			**35.2**	**1.24E-02**			
W120	11/3/2005	Theis	25.1	8.85E-03	1,790		71.49
		Cooper-Jacob Time-Drawdown	36.5	1.29E-02	2,610		
		Neuman	12.9	4.55E-03	920	3.36E-04	
Average			**74.5**	**2.63E-02**			
P312	2/10/2006	Theis	335	1.18E-01	23,900		71.39
		Cooper-Jacob Time-Drawdown	263	9.28E-02	18,800		
		Neuman	261	9.21E-02	18,600	3.25E-02	
Average			**286.3**	**1.01E-01**			
W120	2/10/2006	Theis	273	9.63E-02	19,500		71.39
		Cooper-Jacob Time-Drawdown	237	8.36E-02	16,900		
		Neuman	214	7.55E-02	15,300	3.63E-02	
Average			**241.3**	**8.51E-02**			

Notes:
The results should be used with caution and for comparative purposes as apposed to absolute values because the drift and Platteville aquifers were considered to be a single porous media aquifer. This was done because of the high connectivity that was observed between the aquifers through the transducer data.
The aquifer thickness at each pumping cluster was estimated using the depth of the deepest Platteville well and the static water level at the beginning of the test.

Table 3-5 Aquifer Test Data and Derivation of K Values for the Model Layer 7 Representing the Prairie du Chien / Jordan Aquifer System

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Well Name	MN Unique Well No.	UTME *	UTMN *	PDCJ Thickness (ft)	PDCJ Transmisivity (gpd/ft)	PDCJ Transmisivity (m^2/day)	K cm/sec	PDCJ Transmisivity (gpd/ft)	PDCJ Transmisivity (m^2/day)	K for model input cm/sec	Model Zone	PDCJ Transmisivity (gpd/ft)	PDCJ Transmisivity (m^2/day)	K for model input cm/sec	Model Zone
					Median / Preferred Value			Maximum Value in a Range				Minimum Value in a Range			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
City of Bloomington #2	0000222911	472367	4964588	82	221408	2749	4.82E-02	409156	5081	8.91E-02		147356	1830	3.21E-02	
Hennepin Co. Lake Level #3	0000206924	457161	4981988	88	83600	1038	1.82E-02								
Oakwood Elementary School	0000204636	460644	4982741	129	54978	683	1.20E-02								
Eden Prairie #9	0000424926	462803	4969236	154	51373	638	1.12E-02								
Plymouth 5	0000160023	462962	4983518	169	80784	1003	1.76E-02	129030	1602	2.81E-02	Zone 18	80784	1003	1.76E-02	Zone 18
City of Minnetonka #6A	0000208012	467217	4977553	181	17952	223	3.91E-03	33660	418	7.33E-03	Zone 13	17652	219	3.84E-03	Zone 13
Eden Prairie #7	0000424924	462558	4968554	199	16374	203	3.57E-03								
Northwest Orient (MAC)	0000208324	484006	4969490	205	140000	1739	3.05E-02								
Metro Airport Commission, Well #2	0000208321	483683	4970035	206	115780	1438	2.52E-02								
City of Minnetonka #16A	0000661401	463236	4976840	208	92752	1152	2.02E-02	165532	2056	3.60E-02	Zone 17	46376	576	1.01E-02	Zone 17
Lutheran Bible Inst.	0000203930	471732	4981152	210	54000	671	1.18E-02								
City of Minnetonka #10	0000204140	463477	4976644	213	67245	835	1.46E-02	73828	917	1.61E-02		65749	816	1.43E-02	
Metro Airport Commission, Well #1	0000208322	483690	4970017	218	72850	905	1.59E-02								
Eden Prairie 2	0000205905	463838	4967435	224	88264	1096	1.92E-02	92752	1152	2.02E-02	Zone 16	71284	885	1.55E-02	Zone 16
Eden Prairie #8	0000424925	462875	4968837	225	46329	575	1.01E-02								
City of Edina #3	0000240630	473882	4972728	231	109956	1365	2.39E-02	148029	1838	3.22E-02	Zone 14	18999	236	4.14E-03	Zone 14
City of Edina #6 (STS quick test)	0000200564	472600	4971537	215	269016	3341	5.86E-02	311472	3868	6.78E-02		269016	3341	5.86E-02	

Notes

Modeled thickness of the PDCJ Aquifer is 66 m

Assumptions: Kx = Ky; Kz = 1/100 x Kx

UTME, UTMN - Universal Transferse Merkator coordinate system - Easting and Northing

Table 3-6 Hydraulic Conductivity Values assigned to Model Zones

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

	Low K Model				High K Model		
Zone No	Kx cm/sec	Ky cm/sec	Kz cm/sec	Zone No	Kx cm/sec	Ky cm/sec	Kz cm/sec
1	5.00E-03	5.00E-03	5.00E-04	1	7.00E-03	7.00E-03	7.00E-04
2	2.00E-04	2.00E-04	1.00E-04	2	2.00E-04	2.00E-04	1.00E-04
3	1.21E-03	2.75E-04	7.70E-06	3	1.70E-02	1.70E-02	1.70E-03
4	1.00E-04	1.00E-04	1.00E-04	4	3.00E-03	3.00E-03	3.00E-04
5	1.00E-04	1.00E-04	1.00E-04	5	5.00E-03	5.00E-03	5.00E-03
6	5.01E-05	3.04E-06	2.77E-05	6	5.40E-05	3.00E-06	2.77E-05
7	3.81E-06	2.30E-05	2.00E-07	7	8.90E-06	1.00E-05	2.00E-07
8	1.82E-05	1.98E-05	7.58E-08	8	1.80E-05	3.90E-05	4.30E-08
9	2.15E-05	2.88E-05	1.29E-07	9	2.00E-05	2.60E-05	1.20E-07
10	1.58E-05	3.11E-05	2.32E-07	10	1.10E-05	2.20E-05	1.60E-07
11	1.60E-02	1.60E-02	1.60E-04	11	2.00E-02	2.00E-02	2.00E-04
12	2.75E-02	2.75E-02	2.75E-04	12	3.50E-02	3.50E-02	3.50E-04
13	3.80E-03	3.80E-03	3.80E-05	13	7.30E-03	7.30E-03	7.30E-05
14	4.00E-03	4.00E-03	4.00E-05	14	3.20E-02	3.20E-02	4.32E-03
15	1.20E-02	1.20E-02	1.20E-04	15	3.20E-02	3.20E-02	3.20E-04
16	1.50E-02	1.50E-02	1.50E-04	16	2.00E-02	2.00E-02	2.00E-04
17	1.00E-02	1.00E-02	1.00E-04	17	3.60E-02	3.60E-02	3.60E-04
18	1.80E-02	1.80E-02	1.80E-04	18	2.80E-02	2.80E-02	2.80E-04
19	7.01E-05	1.14E-05	6.80E-06	19	1.80E-04	1.60E-05	7.10E-06
20	3.00E-03	3.00E-03	1.00E-03	20	3.00E-03	3.00E-03	1.00E-03
21	2.00E-04	2.00E-04	7.00E-05	21	2.00E-04	2.00E-04	7.00E-05
22	5.00E-04	5.00E-04	1.00E-04	22	3.47E-03	3.47E-03	3.47E-04
23	5.00E-04	5.00E-04	1.00E-04	23	3.47E-03	3.47E-03	3.47E-04
24	5.00E-04	5.00E-04	1.00E-04	24	3.47E-03	3.47E-03	3.47E-04
25	1.00E-02	1.00E-02	3.00E-03	25	2.00E-02	2.00E-02	6.00E-03
26	1.00E-02	1.00E-02	3.00E-03	26	2.00E-02	2.00E-02	6.00E-03
27	1.00E-02	1.00E-02	3.00E-03	27	2.00E-02	2.00E-02	6.00E-03
28	1.00E-02	1.00E-02	3.00E-03	28	2.00E-02	2.00E-02	6.00E-03
29	1.00E-02	1.00E-02	3.00E-03	29	2.00E-02	2.00E-02	6.00E-03
30	3.00E-04	3.00E-04	1.00E-04	30	3.00E-04	3.00E-04	1.00E-04
31	2.00E-03	2.00E-03	7.00E-04	31	2.00E-03	2.00E-03	7.00E-04
32	2.43E-02	2.43E-02	1.22E-02	32	2.43E-02	2.43E-02	1.22E-02
33	2.00E-03	2.00E-03	7.00E-04	33	2.00E-03	2.00E-03	7.00E-04
34	3.00E-03	3.00E-03	1.00E-03	34	3.00E-03	3.00E-03	1.00E-03
35	3.00E-03	3.00E-03	1.00E-03	35	3.00E-03	3.00E-03	1.00E-03
36	3.00E-03	3.00E-03	1.00E-03	36	3.00E-03	3.00E-03	1.00E-03
37	3.00E-03	3.00E-03	1.00E-03	37	3.00E-03	3.00E-03	1.00E-03
38	5.00E-04	5.00E-04	1.00E-04	38	5.00E-04	5.00E-04	1.00E-04
39	5.00E-04	5.00E-04	1.00E-04	39	5.00E-04	5.00E-04	1.00E-04
40	1.00E-03	1.00E-03	4.00E-04	40	1.00E-03	1.00E-03	4.00E-04
41	3.00E-03	3.00E-03	1.00E-03	41	3.00E-03	3.00E-03	1.00E-03
42	5.00E-06	5.00E-06	2.00E-06	42	5.00E-06	5.00E-06	2.00E-06
43	5.00E-07	5.00E-07	1.00E-07	43	5.00E-07	5.00E-07	1.00E-07
44	5.00E-07	5.00E-07	1.00E-07	44	5.00E-07	5.00E-07	1.00E-07
45	5.00E-06	5.00E-06	2.00E-06	45	5.00E-06	5.00E-06	2.00E-06
46	2.00E-02	2.00E-02	8.00E-03	46	2.00E-02	2.00E-02	8.00E-03
47	5.00E-03	5.00E-03	5.00E-04	47	7.00E-03	7.00E-03	7.00E-04
48	2.00E-04	2.00E-04	7.00E-05	48	2.00E-04	2.00E-04	7.00E-05
49	3.00E-02	3.00E-02	2.00E-03	49	3.00E-02	3.00E-02	2.00E-03
50	1.00E-02	1.00E-02	3.00E-03	50	2.00E-02	2.00E-02	6.00E-03

Table 3-7 Aquifer Storage Properties' Values assigned to Model Zones

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Zone No.	Low K Model				High K Model			
	Specific Storage (1/m)	Specific Yield (-)	Effective Porosity (-)	Total Porosity (-)	Specific Storage (1/m)	Specific Yield (-)	Effective Porosity (-)	Total Porosity (-)
1	2.33E-06	2.10E-01	7.00E-02	3.00E-01	2.33E-06	2.10E-01	7.00E-02	3.00E-01
2	5.00E-04	7.00E-02	7.00E-02	3.00E-01	5.00E-04	7.00E-02	7.00E-02	3.00E-01
3	5.00E-04	7.00E-02	7.00E-02	3.00E-01	5.00E-04	7.00E-02	7.00E-02	3.00E-01
4	5.00E-04	7.00E-02	7.00E-02	3.00E-01	5.00E-04	7.00E-02	7.00E-02	3.00E-01
5	5.00E-04	7.00E-02	7.00E-02	3.00E-01	5.00E-04	7.00E-02	7.00E-02	3.00E-01
6	2.00E-06	7.00E-02	8.00E-02	2.30E-01	2.00E-06	7.00E-02	8.00E-02	2.30E-01
7	2.00E-06	8.00E-02	1.00E-02	2.30E-01	2.00E-06	8.00E-02	1.00E-02	2.30E-01
8	2.00E-06	8.00E-02	8.00E-02	2.30E-01	2.00E-06	8.00E-02	8.00E-02	2.30E-01
9	2.00E-06	8.00E-02	8.00E-02	2.30E-01	2.00E-06	8.00E-02	8.00E-02	2.30E-01
10	2.00E-06	8.00E-02	8.00E-02	2.30E-01	2.00E-06	8.00E-02	8.00E-02	2.30E-01
11	1.50E-06	4.00E-02	4.00E-02	1.50E-01	1.50E-06	4.00E-02	4.00E-02	1.50E-01
12	1.50E-06	4.00E-02	4.00E-02	1.50E-01	1.50E-06	4.00E-02	4.00E-02	1.50E-01
13	1.50E-06	4.00E-02	4.00E-02	1.50E-01	1.50E-06	4.00E-02	4.00E-02	1.50E-01
14	1.50E-06	4.00E-02	4.00E-02	1.50E-01	1.50E-06	4.00E-02	4.00E-02	1.50E-01
15	1.50E-06	4.00E-02	4.00E-02	1.50E-01	1.50E-06	4.00E-02	4.00E-02	1.50E-01
16	1.50E-06	4.00E-02	4.00E-02	1.50E-01	1.50E-06	4.00E-02	4.00E-02	1.50E-01
17	1.50E-06	4.00E-02	4.00E-02	1.50E-01	1.50E-06	4.00E-02	4.00E-02	1.50E-01
18	1.50E-06	4.00E-02	4.00E-02	1.50E-01	1.50E-06	4.00E-02	4.00E-02	1.50E-01
19	2.00E-04	2.80E-01	2.80E-01	3.50E-01	2.00E-04	2.80E-01	2.80E-01	3.50E-01
20	1.00E-05	1.60E-01	1.60E-01	3.50E-01	1.00E-05	1.60E-01	1.60E-01	3.50E-01
21	1.00E-05	1.60E-01	1.60E-01	3.50E-01	1.00E-05	1.60E-01	1.60E-01	3.50E-01
22	1.00E-05	1.60E-01	1.60E-01	3.50E-01	1.00E-05	1.60E-01	1.60E-01	3.50E-01
23	1.00E-05	1.60E-01	1.60E-01	3.50E-01	1.00E-05	1.60E-01	1.60E-01	3.50E-01
24	1.00E-05	2.60E-01	2.60E-01	2.80E-01	1.00E-05	2.60E-01	2.60E-01	2.80E-01
25	1.00E-05	2.60E-01	2.60E-01	2.80E-01	1.00E-05	2.60E-01	2.60E-01	2.80E-01
26	1.00E-05	2.80E-01	2.80E-01	3.50E-01	1.00E-05	2.80E-01	2.80E-01	3.50E-01
27	1.00E-05	2.60E-01	2.60E-01	2.80E-01	1.00E-05	2.60E-01	2.60E-01	2.80E-01
28	1.00E-05	2.60E-01	7.00E-02	2.80E-01	1.00E-05	2.60E-01	7.00E-02	2.80E-01
29	1.00E-05	1.60E-01	1.60E-01	3.50E-01	1.00E-05	1.60E-01	1.60E-01	3.50E-01
30	1.00E-05	2.00E-01	2.00E-01	3.50E-01	1.00E-05	2.00E-01	2.00E-01	3.50E-01
31	1.00E-05	2.80E-01	2.80E-01	3.50E-01	1.00E-05	2.80E-01	2.80E-01	3.50E-01
32	1.00E-05	1.60E-01	1.60E-01	3.50E-01	1.00E-05	1.60E-01	1.60E-01	3.50E-01
33	1.00E-05	2.00E-01	2.00E-01	3.50E-01	1.00E-05	2.00E-01	2.00E-01	3.50E-01
34	1.00E-05	2.00E-01	2.00E-01	3.50E-01	1.00E-05	2.00E-01	2.00E-01	3.50E-01
35	1.00E-05	2.00E-01	2.00E-01	3.50E-01	1.00E-05	2.00E-01	2.00E-01	3.50E-01
36	1.00E-05	2.80E-01	2.80E-01	3.50E-01	1.00E-05	2.80E-01	2.80E-01	3.50E-01
37	1.00E-05	1.60E-01	1.60E-01	3.50E-01	1.00E-05	1.60E-01	1.60E-01	3.50E-01
38	1.00E-05	1.60E-01	1.60E-01	3.50E-01	1.00E-05	1.60E-01	1.60E-01	3.50E-01
39	1.00E-05	2.00E-01	2.00E-01	3.50E-01	1.00E-05	2.00E-01	2.00E-01	3.50E-01
40	1.00E-05	1.60E-01	1.60E-01	3.50E-01	1.00E-05	1.60E-01	1.60E-01	3.50E-01
41	1.00E-05	5.00E-02	5.00E-02	3.50E-01	1.00E-05	5.00E-02	5.00E-02	3.50E-01
42	1.00E-05	5.00E-02	5.00E-02	3.50E-01	1.00E-05	5.00E-02	5.00E-02	3.50E-01
43	1.00E-05	5.00E-02	5.00E-02	3.50E-01	1.00E-05	5.00E-02	5.00E-02	3.50E-01
44	1.00E-05	5.00E-02	5.00E-02	3.50E-01	1.00E-05	5.00E-02	5.00E-02	3.50E-01
45	5.00E-04	7.00E-02	7.00E-02	3.00E-01	5.00E-04	7.00E-02	7.00E-02	3.00E-01
46	5.00E-04	7.00E-02	7.00E-02	3.00E-01	5.00E-04	7.00E-02	7.00E-02	3.00E-01
47	5.00E-04	7.00E-02	7.00E-02	3.00E-01	5.00E-04	7.00E-02	7.00E-02	3.00E-01
48	5.00E-04	7.00E-02	7.00E-02	3.00E-01	5.00E-04	7.00E-02	7.00E-02	3.00E-01
49	2.33E-06	2.10E-01	2.10E-01	3.00E-01	2.33E-06	2.10E-01	2.10E-01	3.00E-01
50	2.33E-06	2.10E-01	2.10E-01	3.00E-01	2.33E-06	2.10E-01	2.10E-01	3.00E-01
51	2.33E-06	2.10E-01	2.10E-01	3.00E-01	2.33E-06	2.10E-01	2.10E-01	3.00E-01

Table 4-1 Recharge Values assigned to Model Zones

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Zone Number	Low K Model Recharge (mm/year)	High K Model Recharge (mm/year)
1	240	240
2	272	272
3	150	150
4	255	255
5	350	350
6	150	150
7	1316	1316
8	-251	-251
9	2	2
10	491	491
11	78	78
12	-931	-931
13	14	14

Table 4-2 Results of Model Calibration and Model Mass Balance

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Calibration Phase	Normalized RMS (%)				Model Mass Balance								
Observation Groups:	L2	L5	L7	Near	Total In	Recharge In	Net Recharge	Wells Pumping Out	Discharge to Mississippi		Discharge to Minnesota		Mass Balance Error
					(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day/m river)	(m^3/day)	(m^3/day/m river)	(%)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Low K Model Vesion													
Preliminary Manual Calibration	11.46	11.70	13.85	12.98	284566	199520	172582	105454	18236	0.87	54189	2.58	-0.07
PEST Optimization	12.90	11.59	11.65	9.88	308071	236344	167092	110272	19023	0.91	58338	2.85	-0.05
% annual precipitation:						31							
High K Model Vesion													
Preliminary Manual Calibration	17.65	14.61	16.28	20.72	440956	318298	278644	110272	51838	2.47	112466	5.36	-0.03
Preliminary Manual Calibration	11.71	11.34	14.7	10.94	506498	302555	259717	110272	54966	2.62	115620	5.64	-0.02
PEST Optimization													
% annual precipitation:						39							

Notes:
L2 - 5-mile Radius Platteville and Drift Wells Observation Group
L5 - 5-mile Radius St. Peter Wells Observation Group
L7 - Near Reilly Tar Site Wells Observation Group

The Infrastructure Imperative

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Figure 2-1. Edina Well No. 7, Edina Well No. 13 and Meadowbrook Golf Course Well (W119) Hydrographs

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

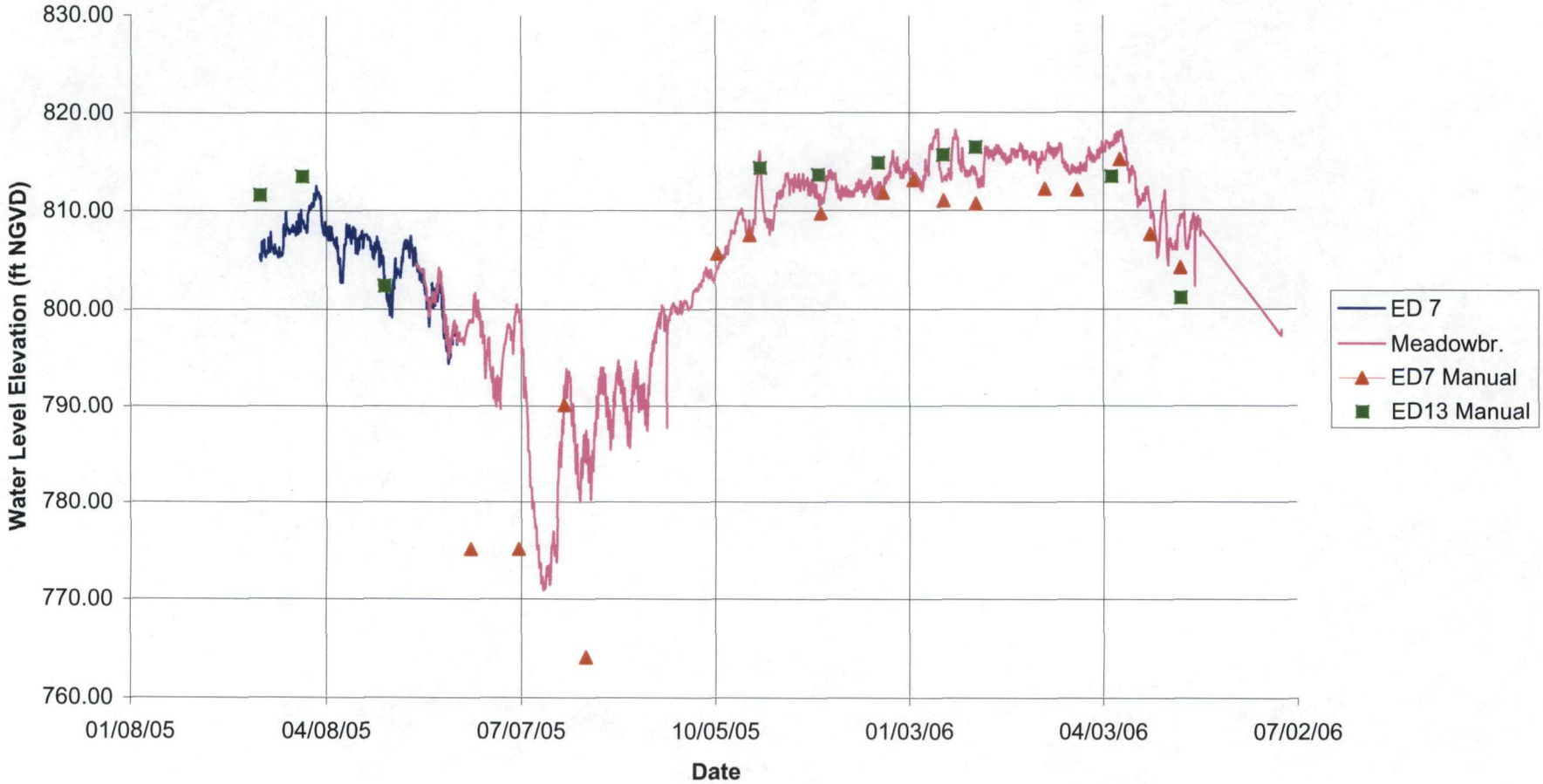

Figure 2-2. Prairie du Chien - Jordan Wells Hydrographs

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

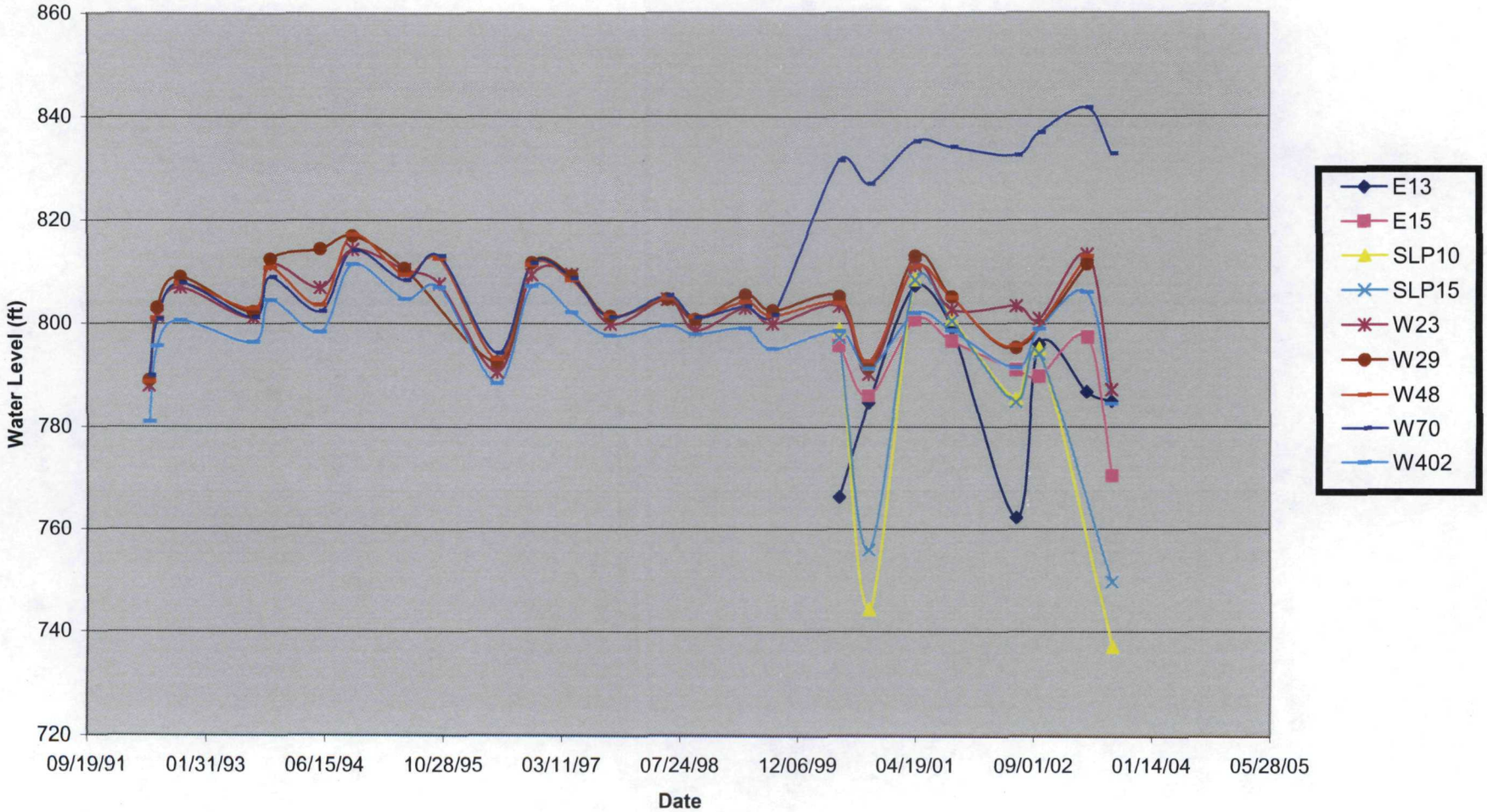

Figure 2-3. Prairie du Chien - Jordan, St. Peter and Platteville Wells Hydrographs

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

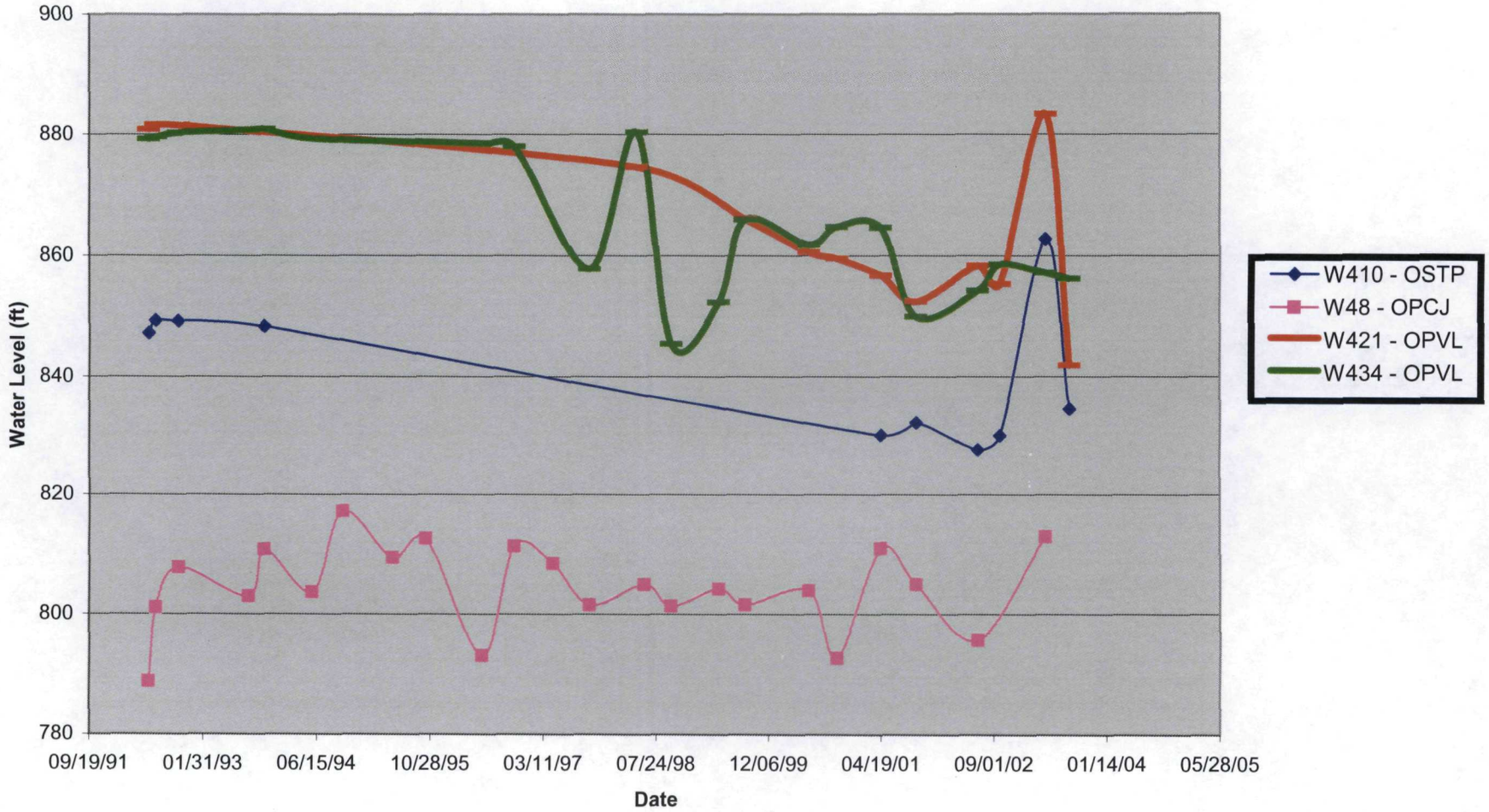

Figure 2-4. St. Peter and Platteville Wells Hydrographs

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

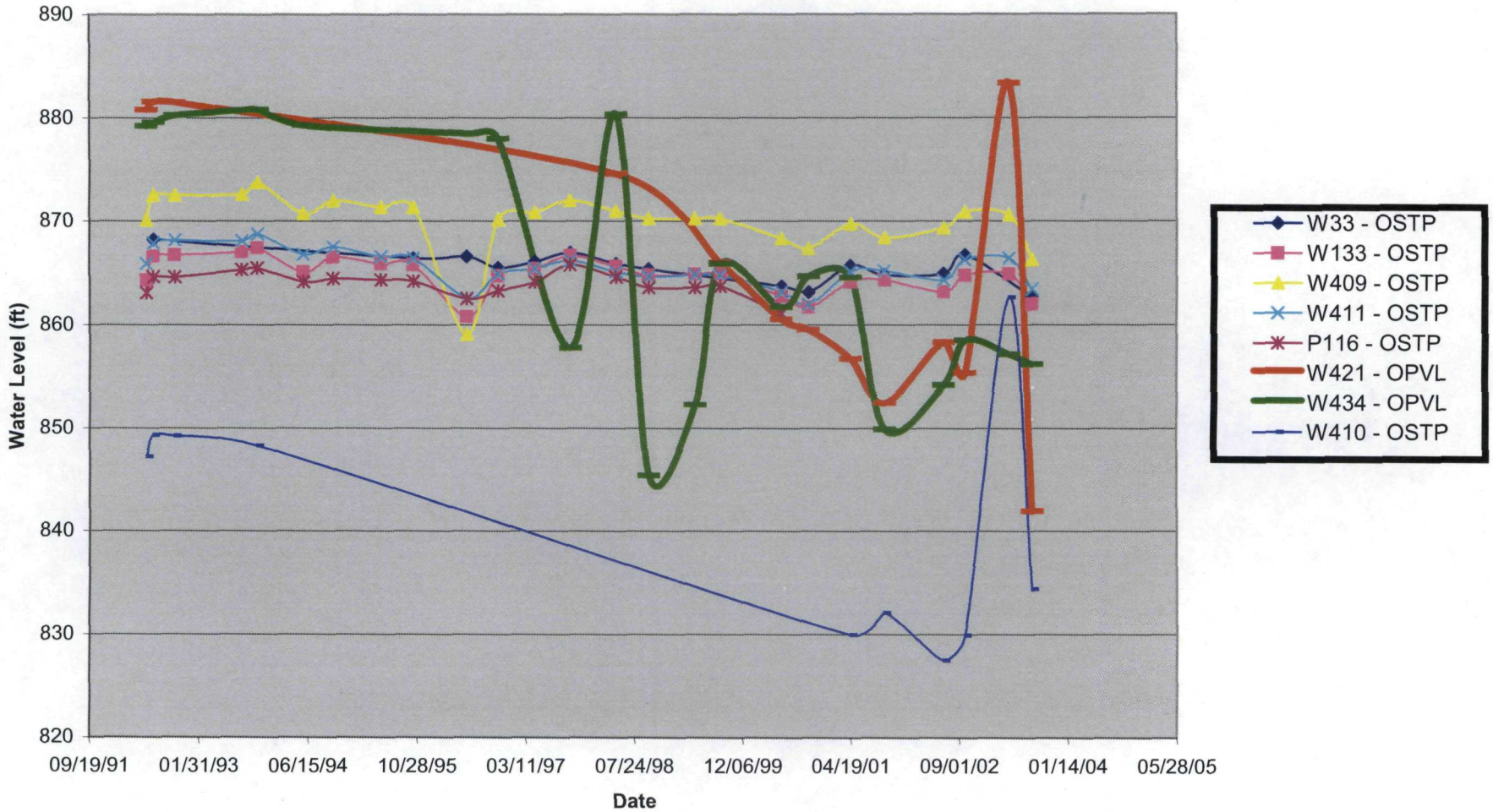

Figure 2-5 Platteville Wells Hydrographs

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

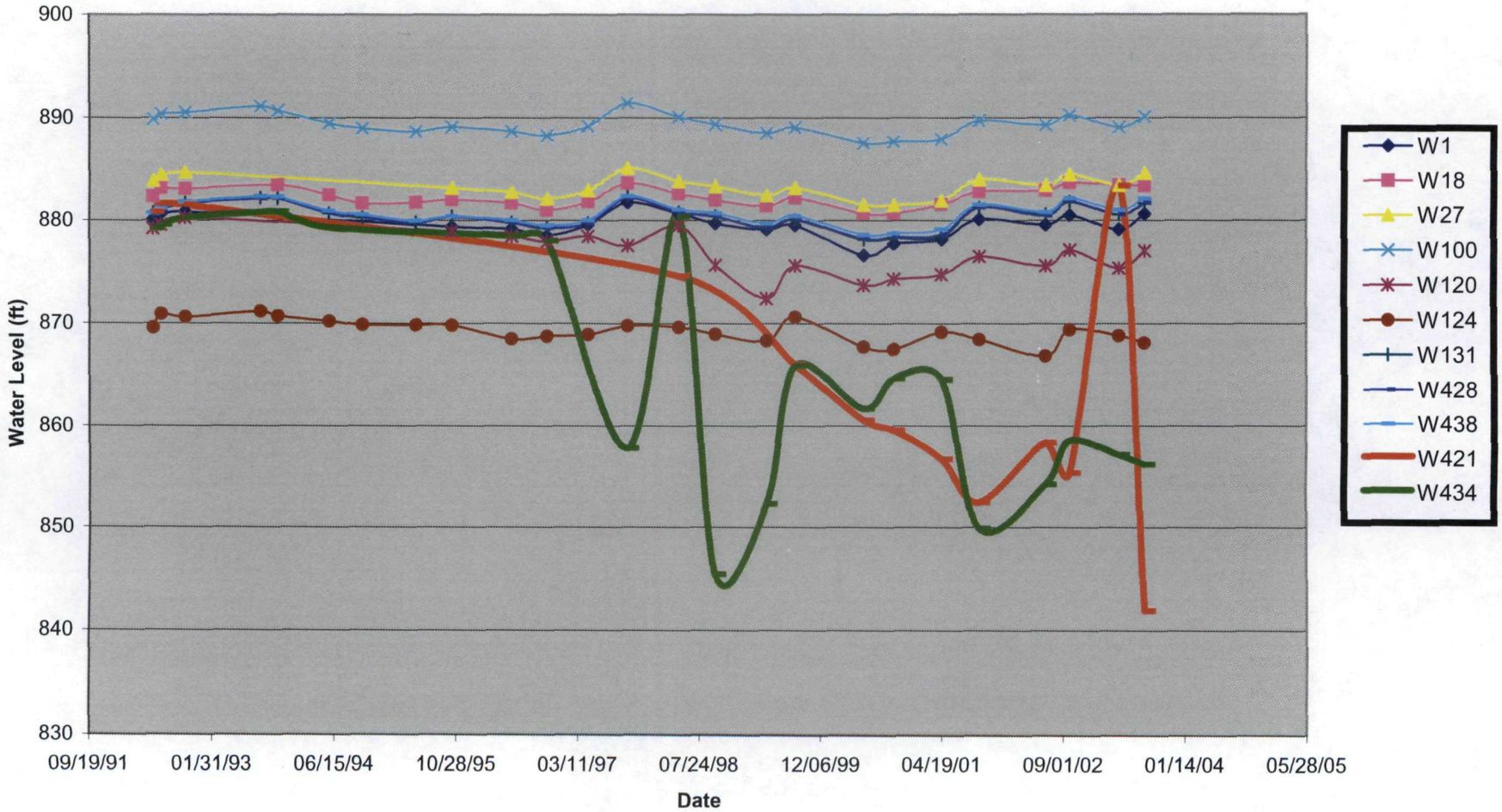

Figure 2-6 Drift Wells Hydrographs

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

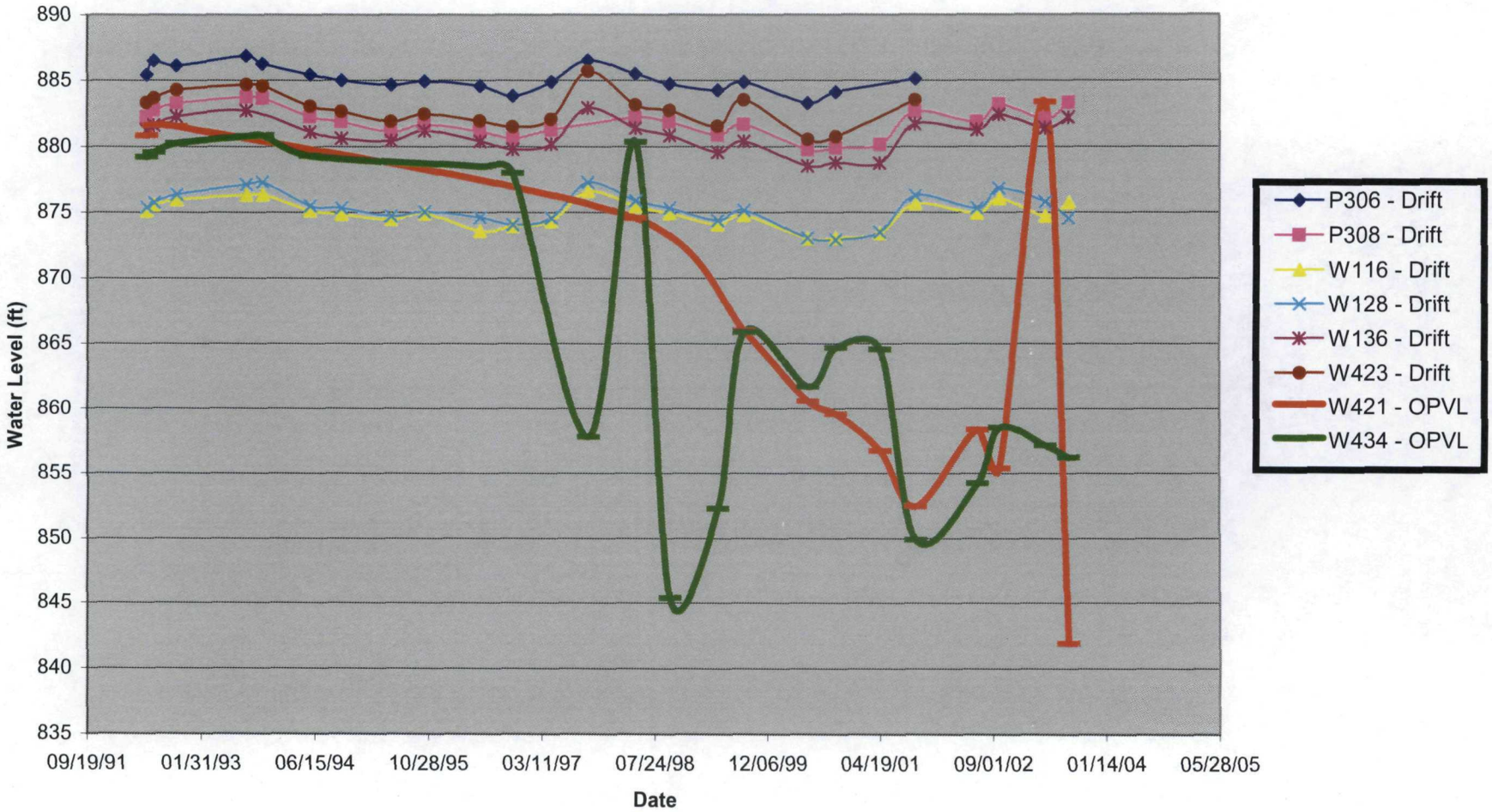

Figure 3-1. Model Domain Area - Reilly Tar Site / Meadowbrook Ground Water Model.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

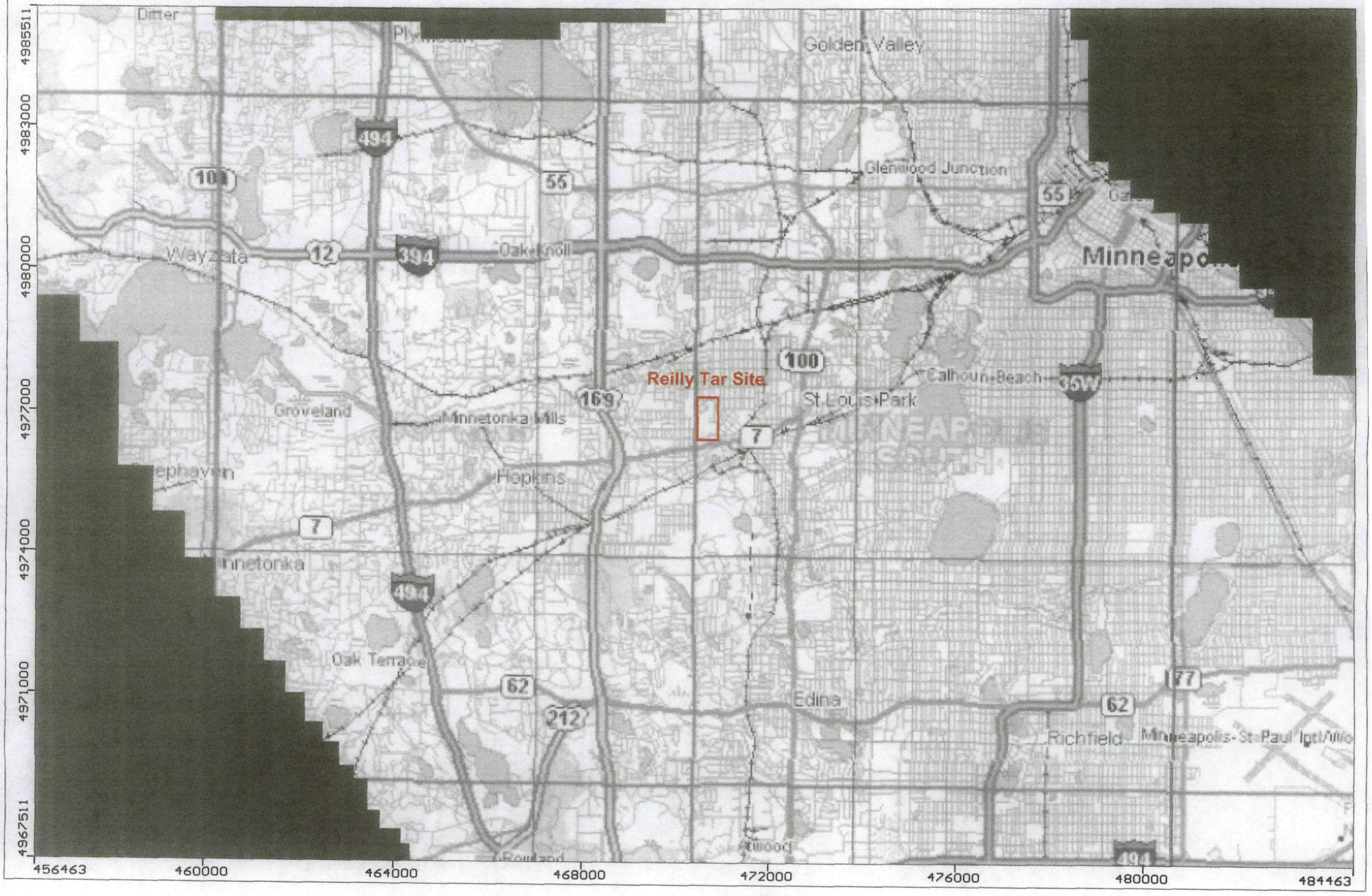

Figure 3-2. Model Domain Area and Prescribed Head Boundaries for the Model Layer 1 Representing the Lower Drift Confining Unit around the Reilly Tar Site.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

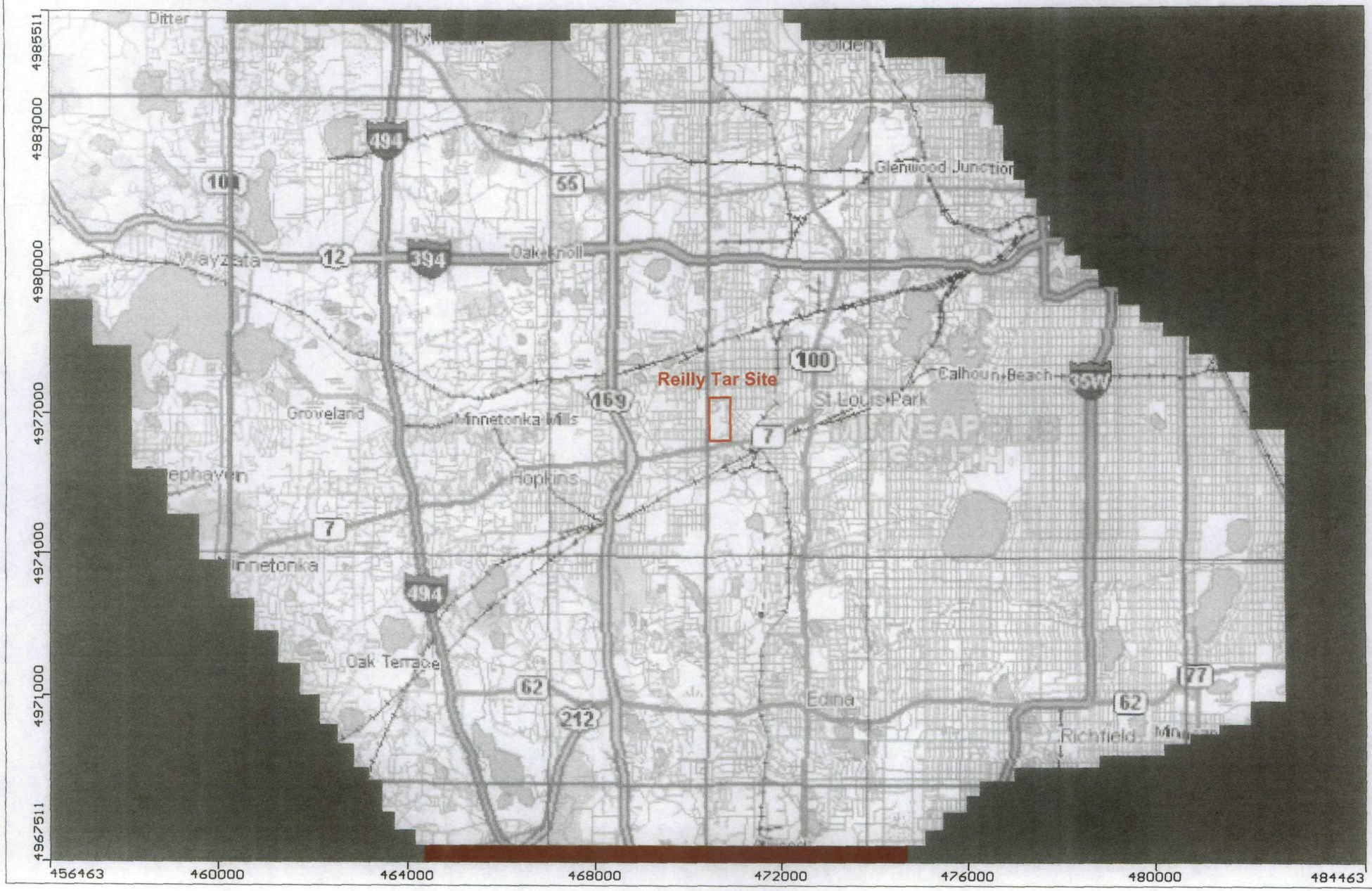

Figure 3-3. Model Domain Area and Prescribed Head Boundaries for the Model Layer 2 Representing the Lower Drift Aquifer around the Reilly Tar Site.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Figure 3-4. Model Domain Area and Prescribed Head Boundaries for the Model Layer 3 Representing the Platteville Formation around the Reilly Tar Site.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

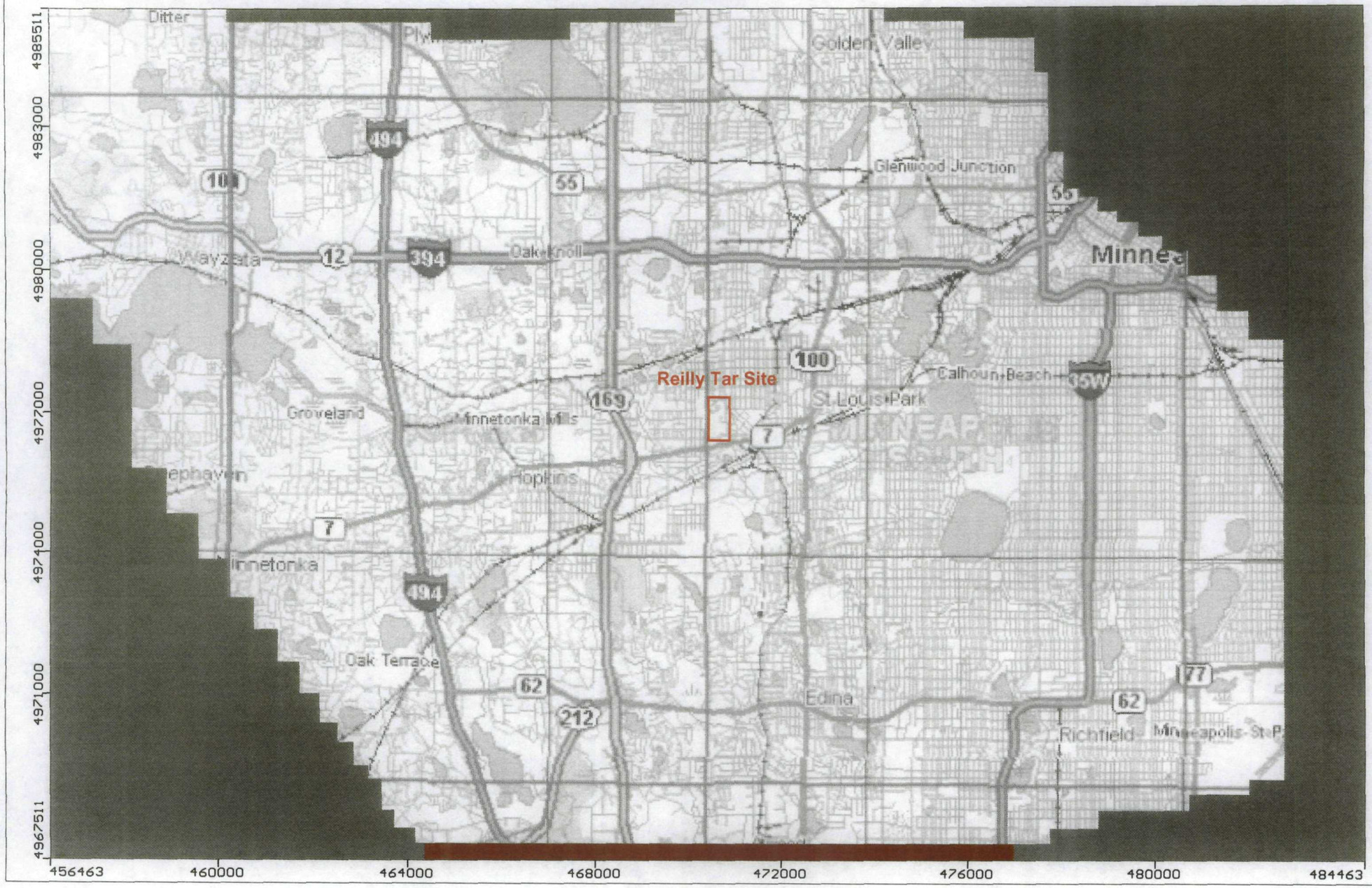

Figure 3-5. Model Domain Area and Prescribed Head Boundaries for the Model Layer 4 Representing the Glenwood Formation around the Reilly Tar Site.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

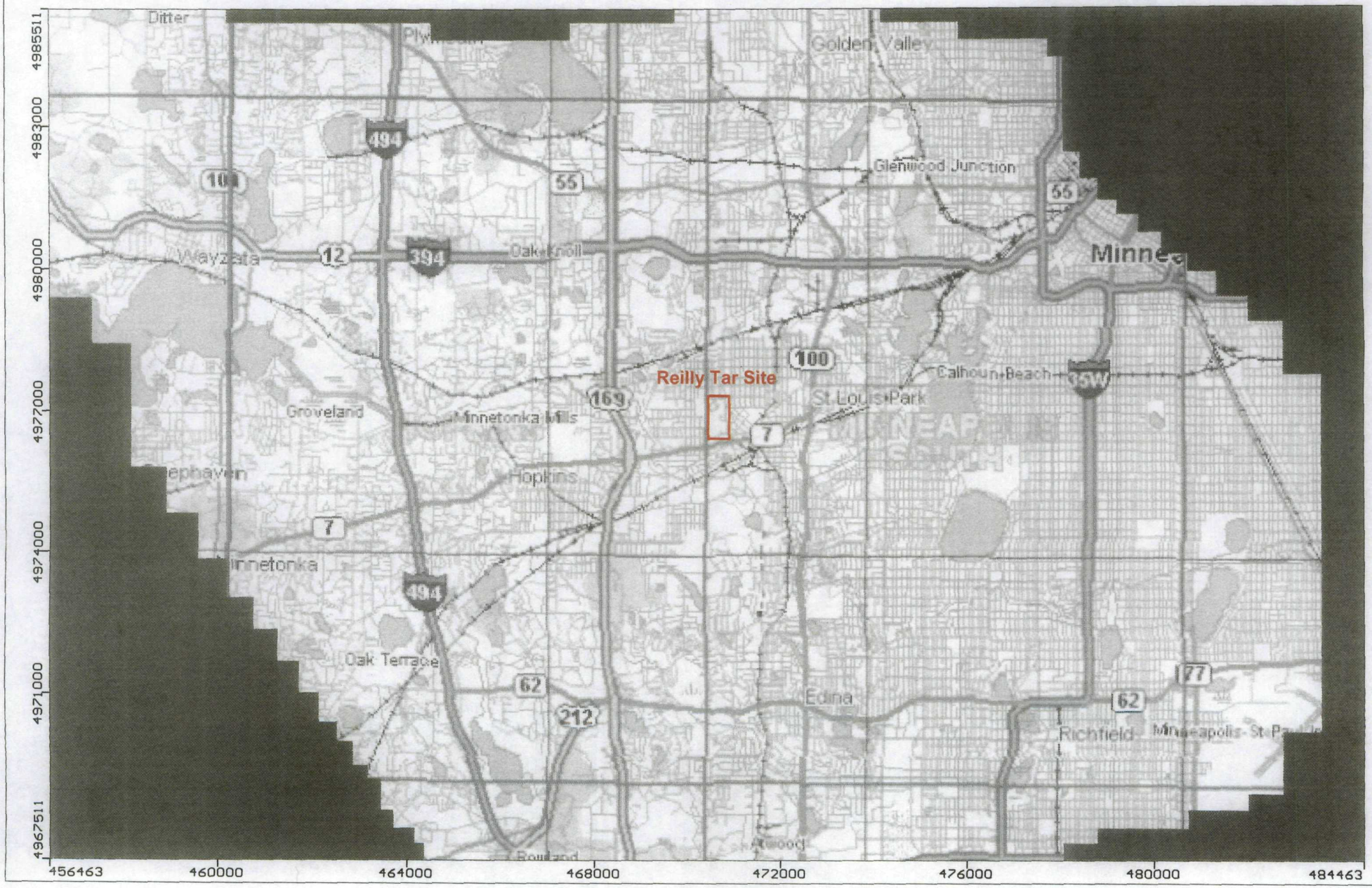

Figure 3-6. Model Domain Area and Prescribed Head Boundaries for the Model Layer 5 Representing the St. Peter Aquifer.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

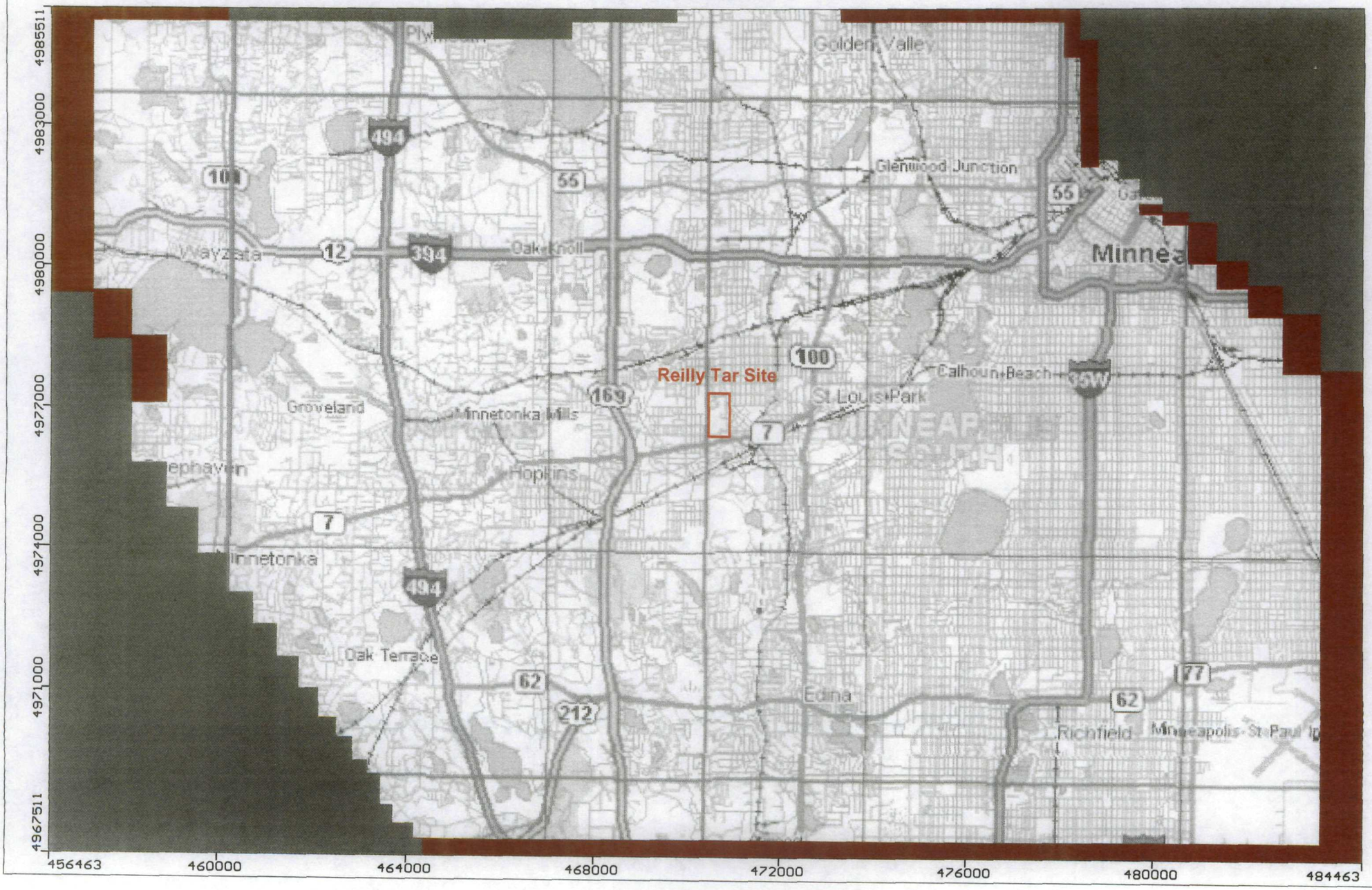

Figure 3-7. Model Domain Area and Prescribed Head Boundaries for the Model Layer 6 Representing the Basal St. Peter Formation.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

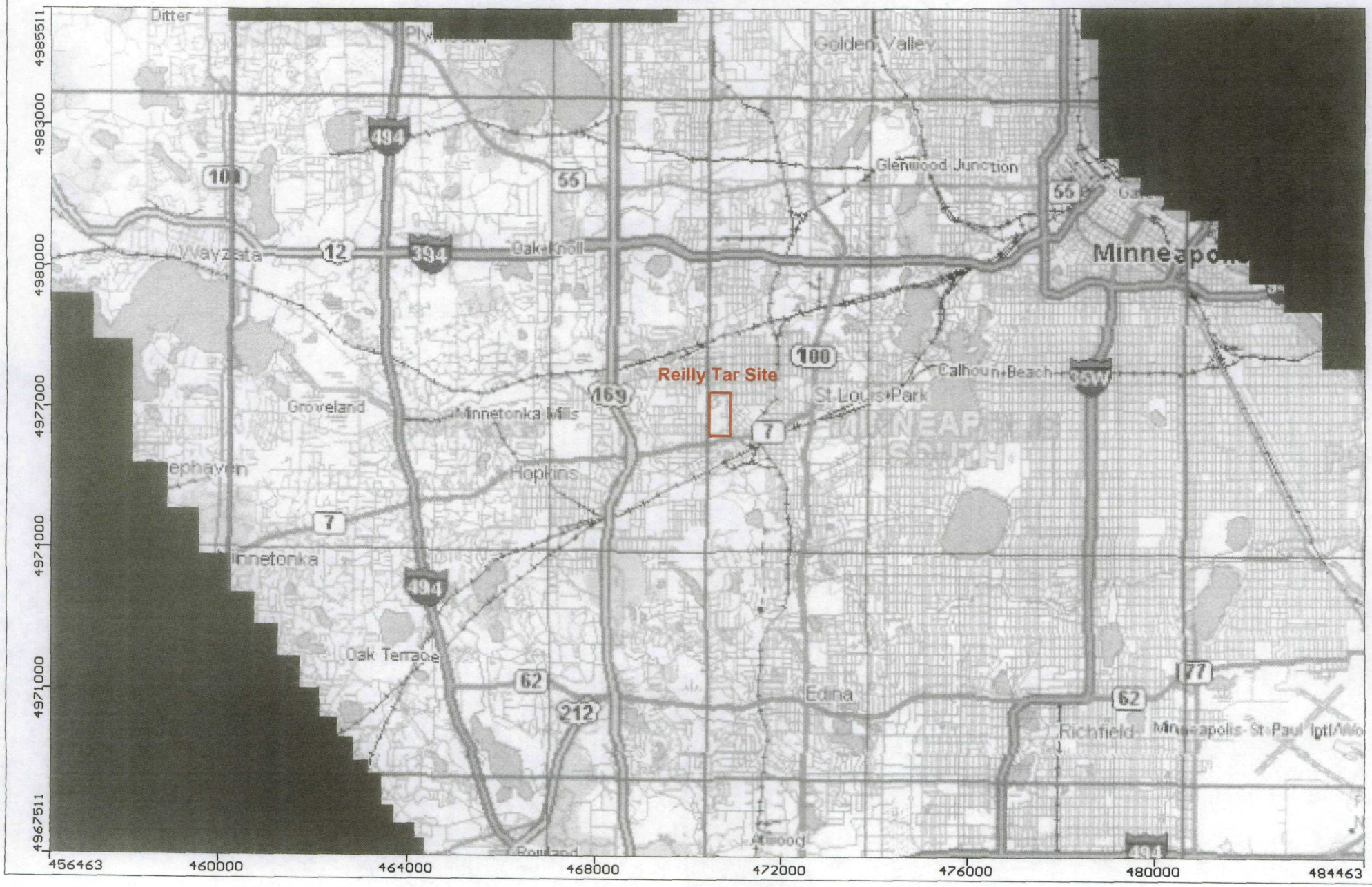

Figure 3-8. Model Domain Area and Prescribed Head Boundaries for the Model Layer 7
Representing the Prairie du Chien - Jordan Aquifer System.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

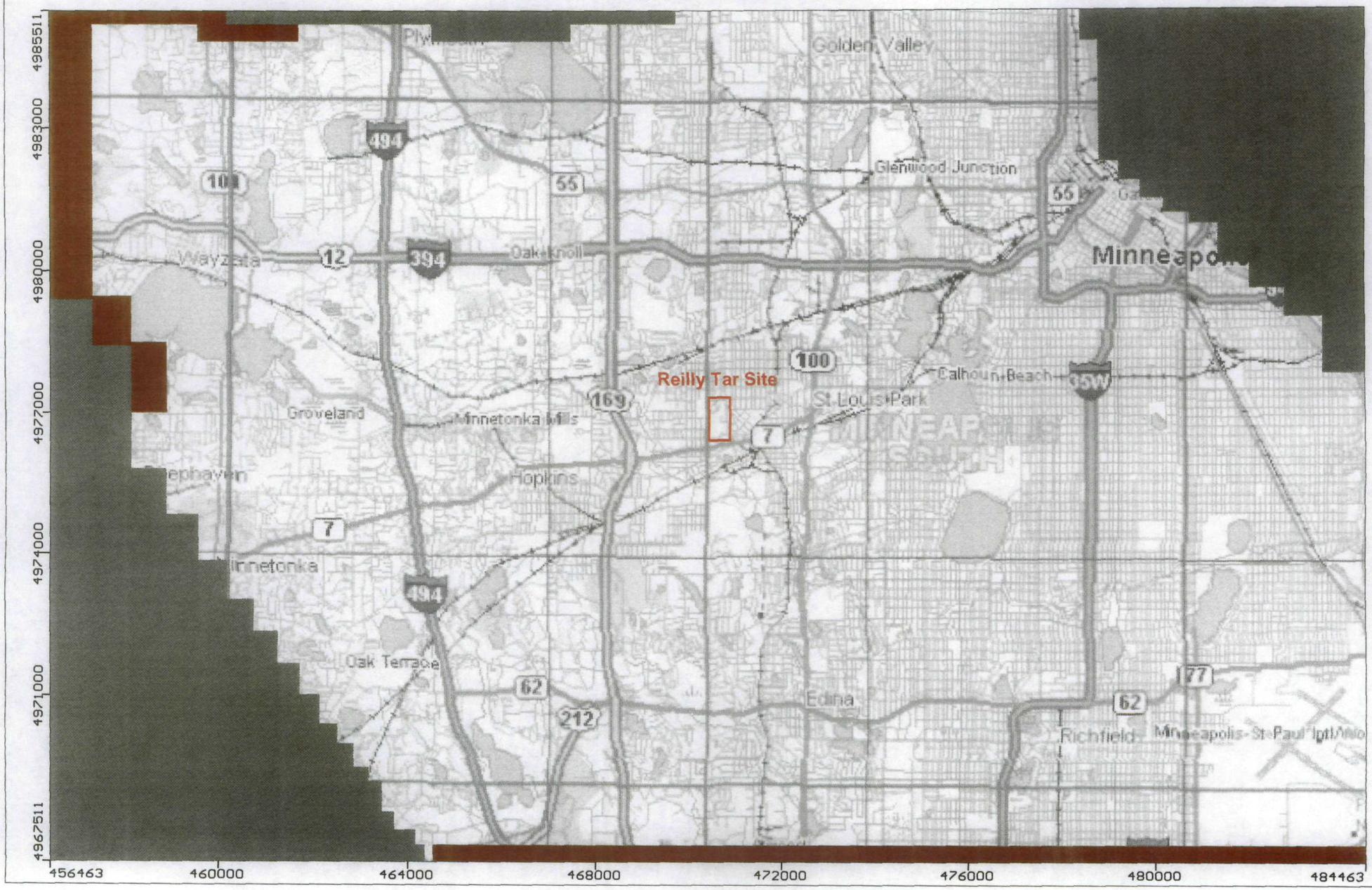

Figure 3-9. MODFLOW Model Grid - Lateral View.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

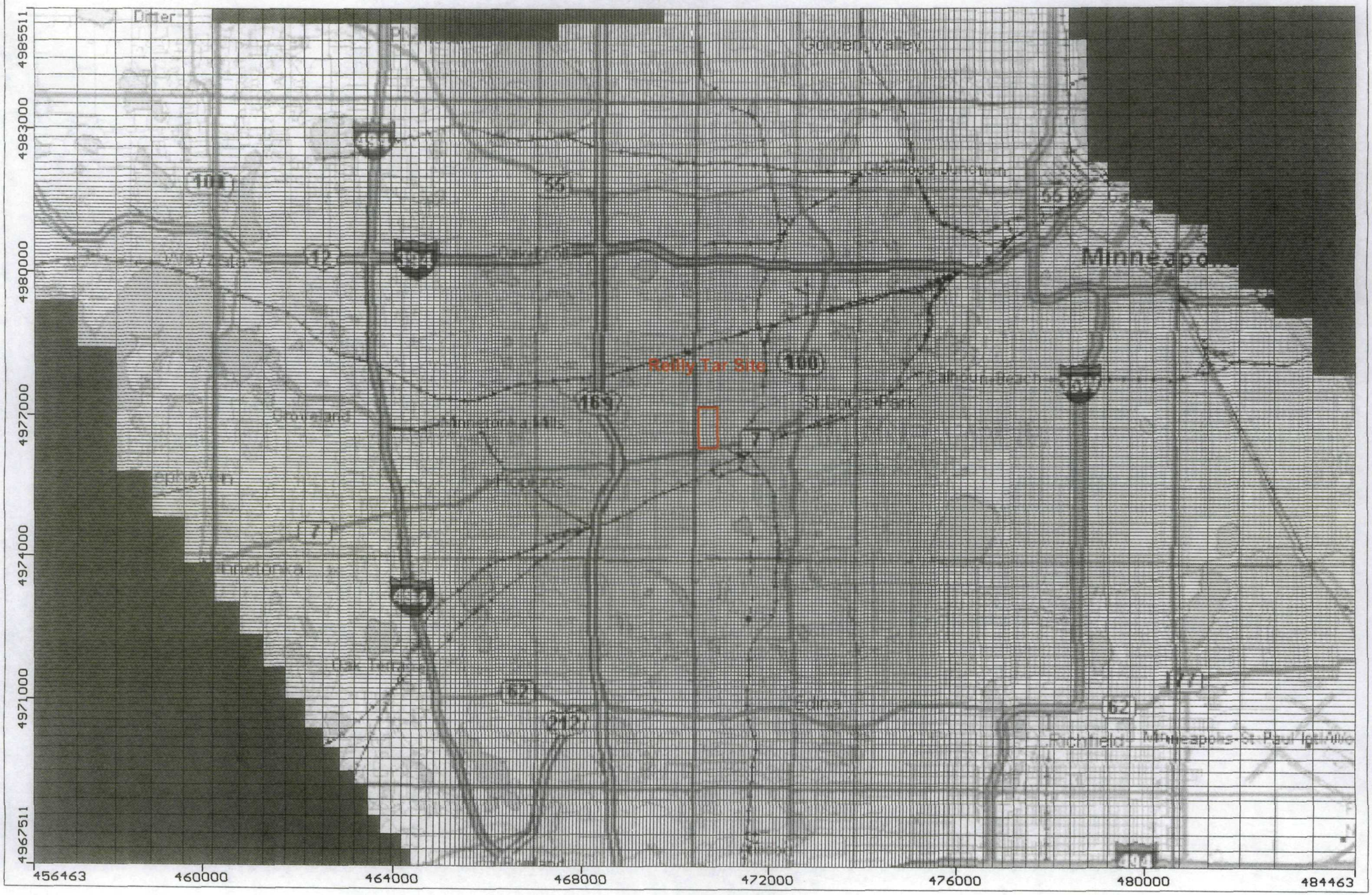

Figure 3-10. MODFLOW Model Grid - Vertical Cross-Section View along Grid Row No 84.

Reilly Tar Site / Meadowbrook Ground Water Model.
STS Project No. 99330-XF

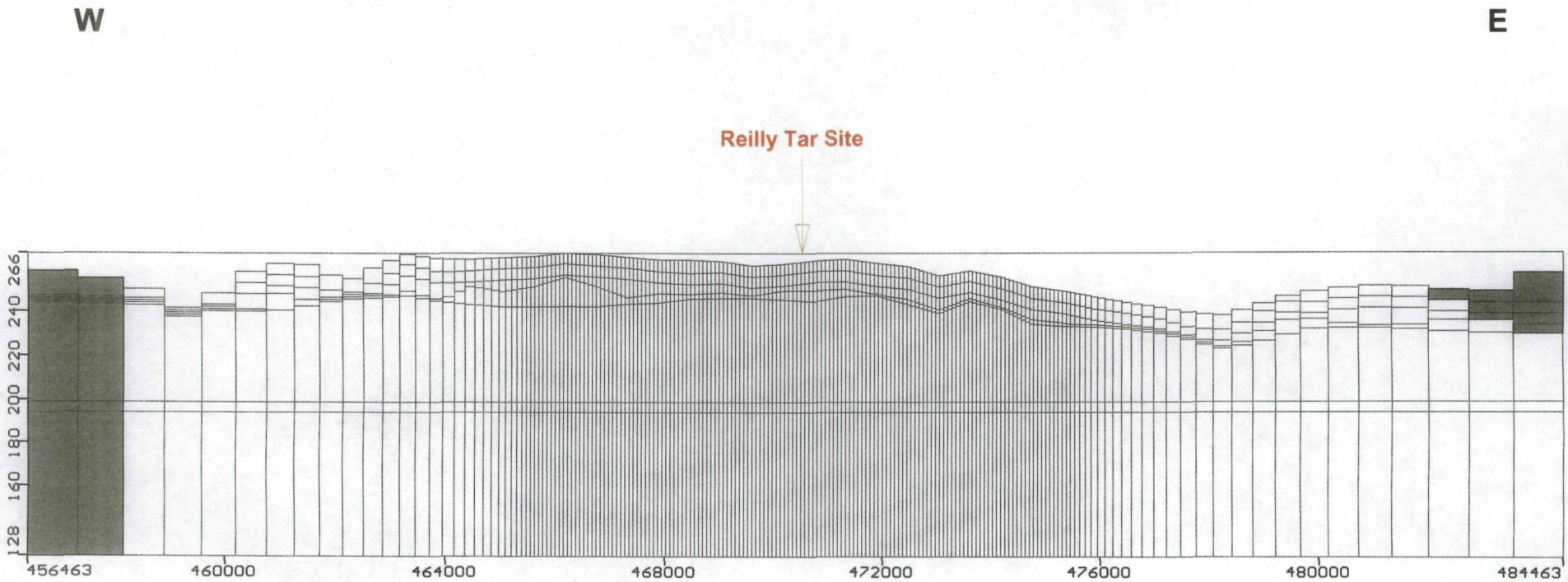

Figure 3-11. MODFLOW Model Grid - Vertical Cross-Section View along Grid Column No 97.

Reilly Tar Site / Meadowbrook Ground Water Model.
STS Project No. 99330-XF

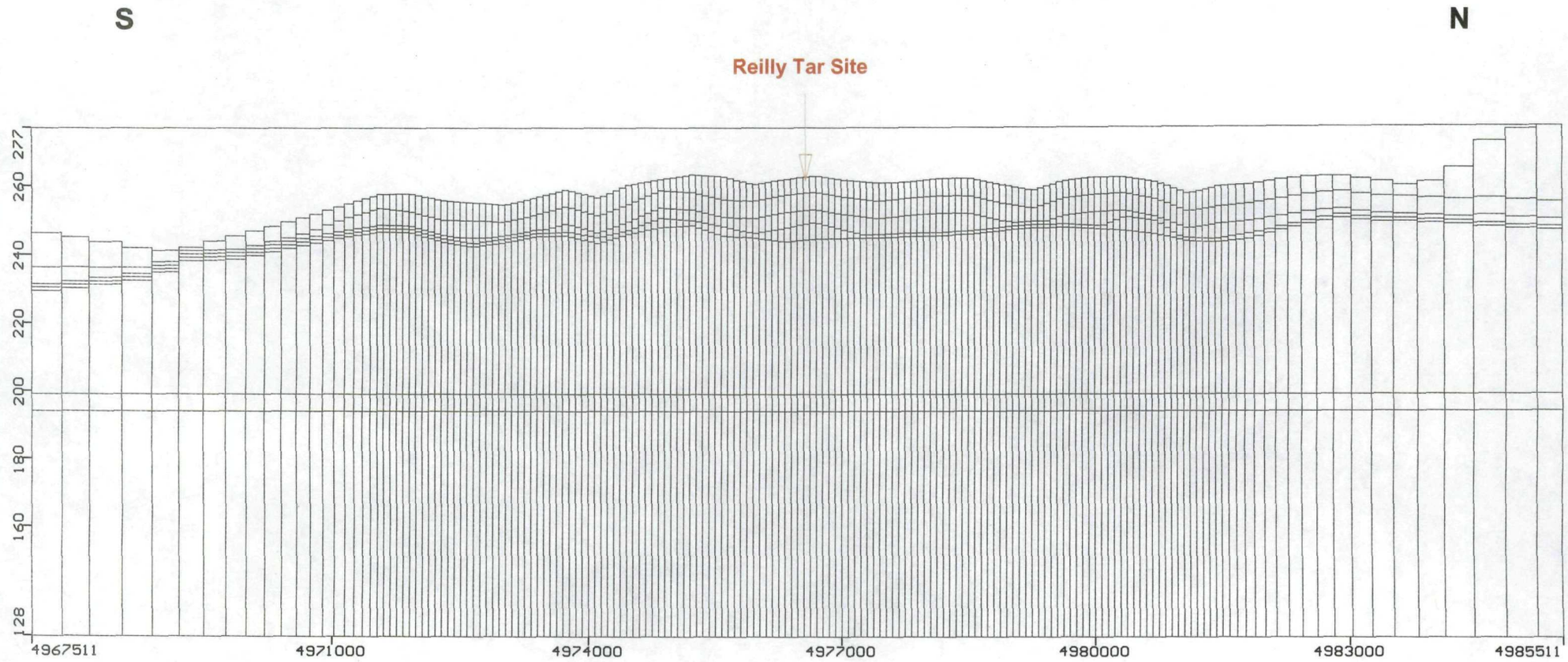

Figure 3-12. Pumping Wells Represented in the Model.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Figure 3-13. Observation Wells Included in the Model.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

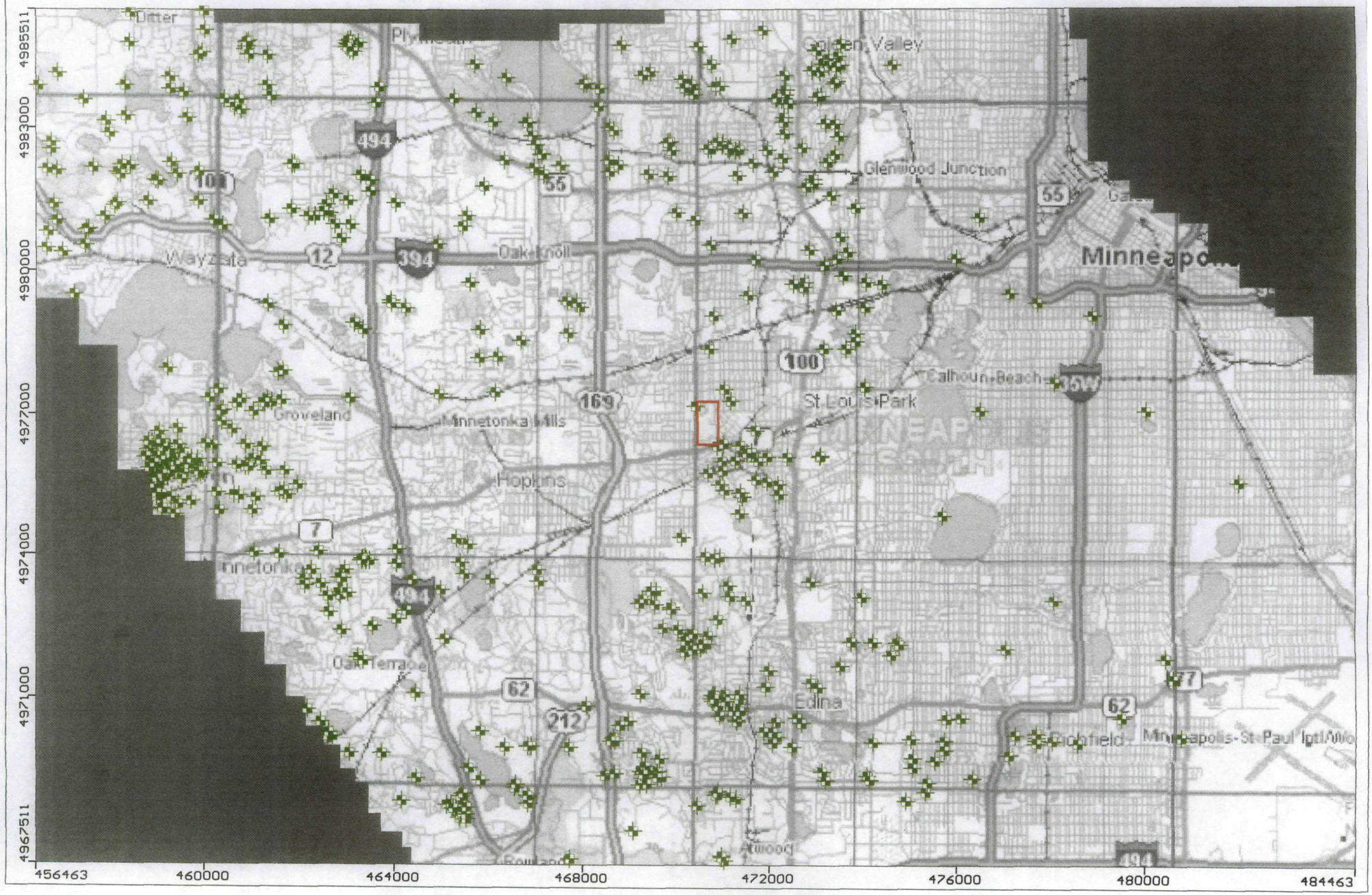

Figure 3-14. Recharge Zones used in the Model.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

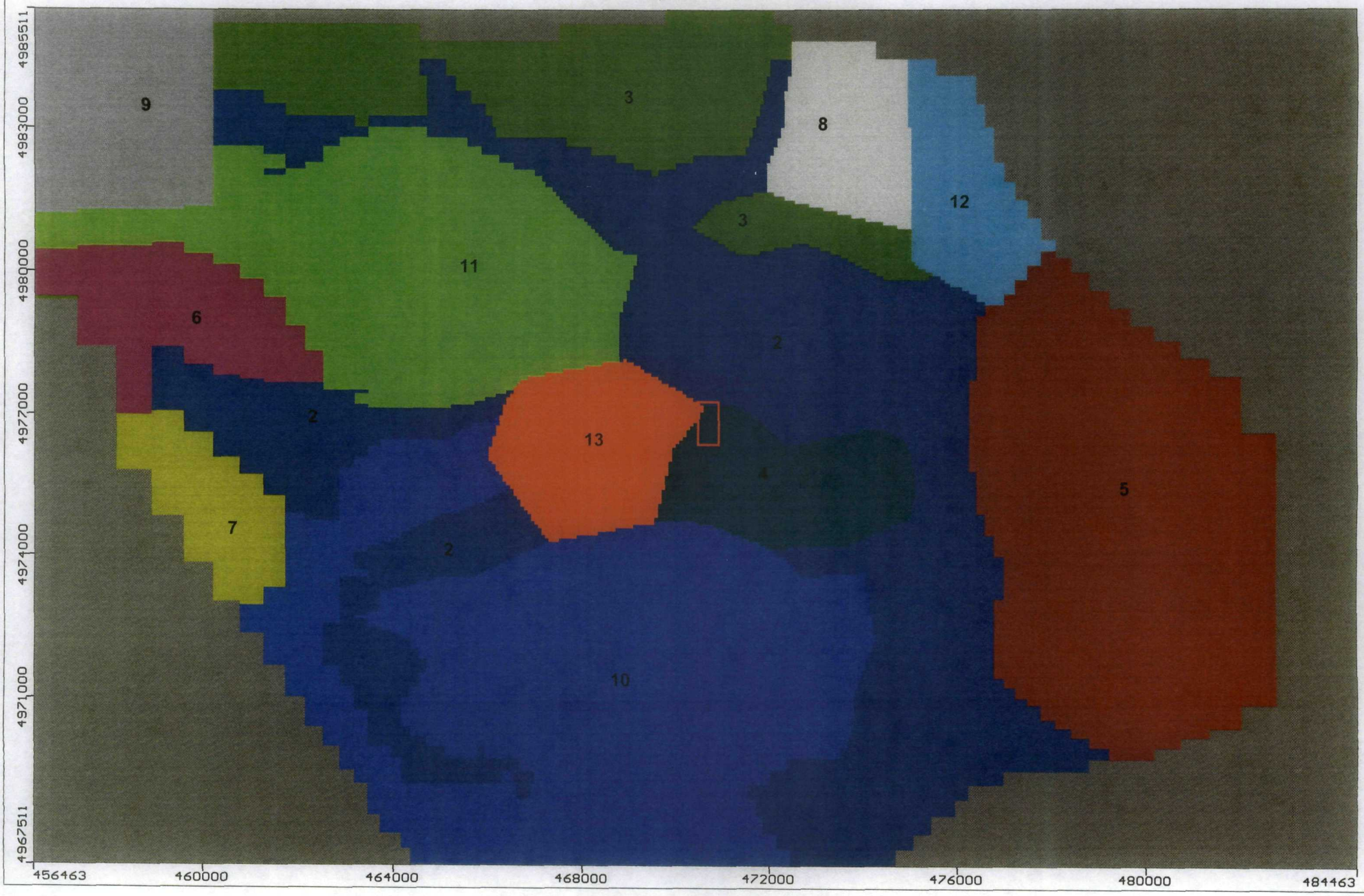

Figure 3-15a. Hydraulic Conductivity used in the Model Layer 1.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

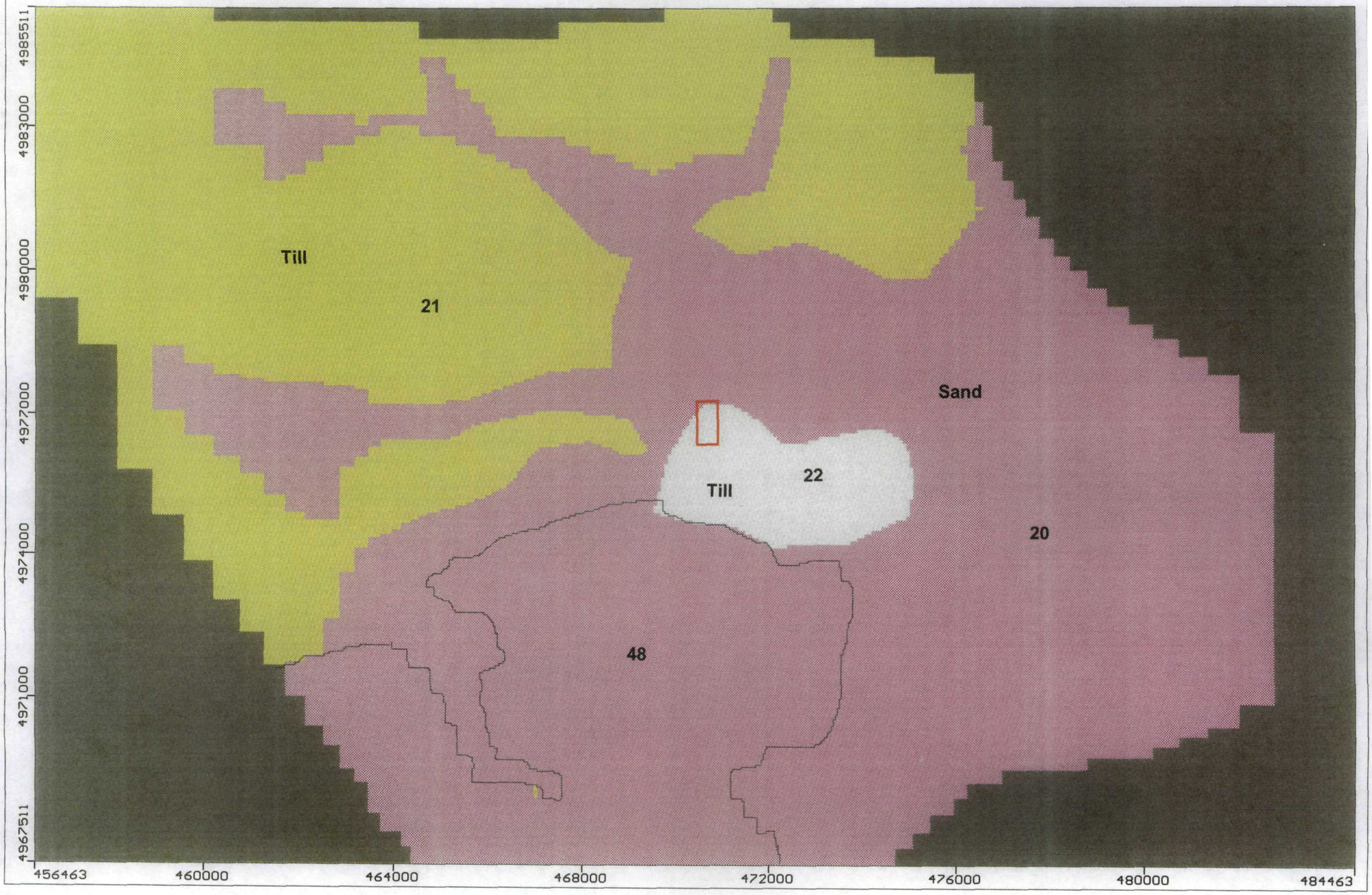

Figure 3-15b. Storage Zones used in the Model Layer 1.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

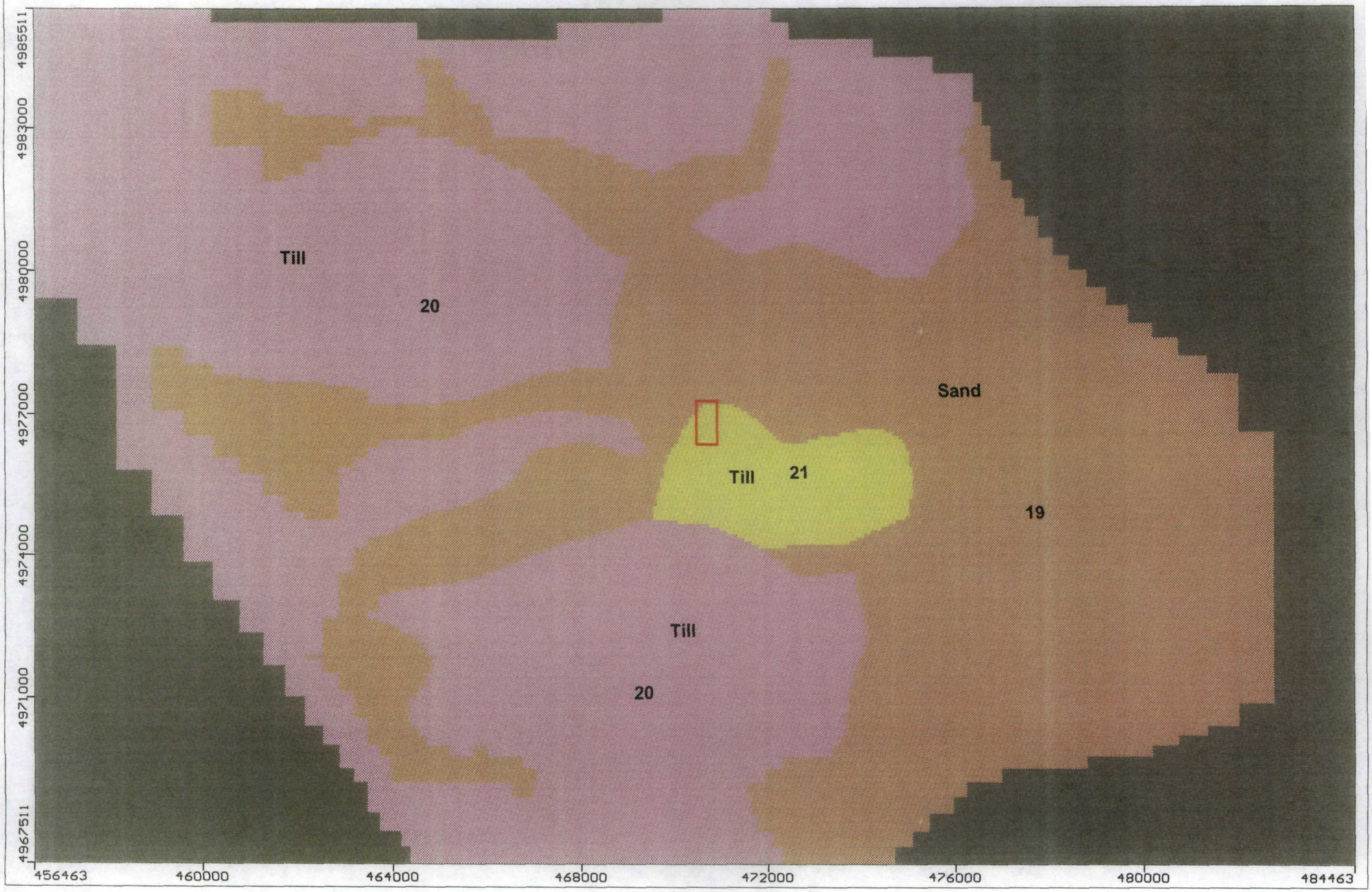

Figure 3-16a. Hydraulic Conductivity used in the Model Layer 2.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

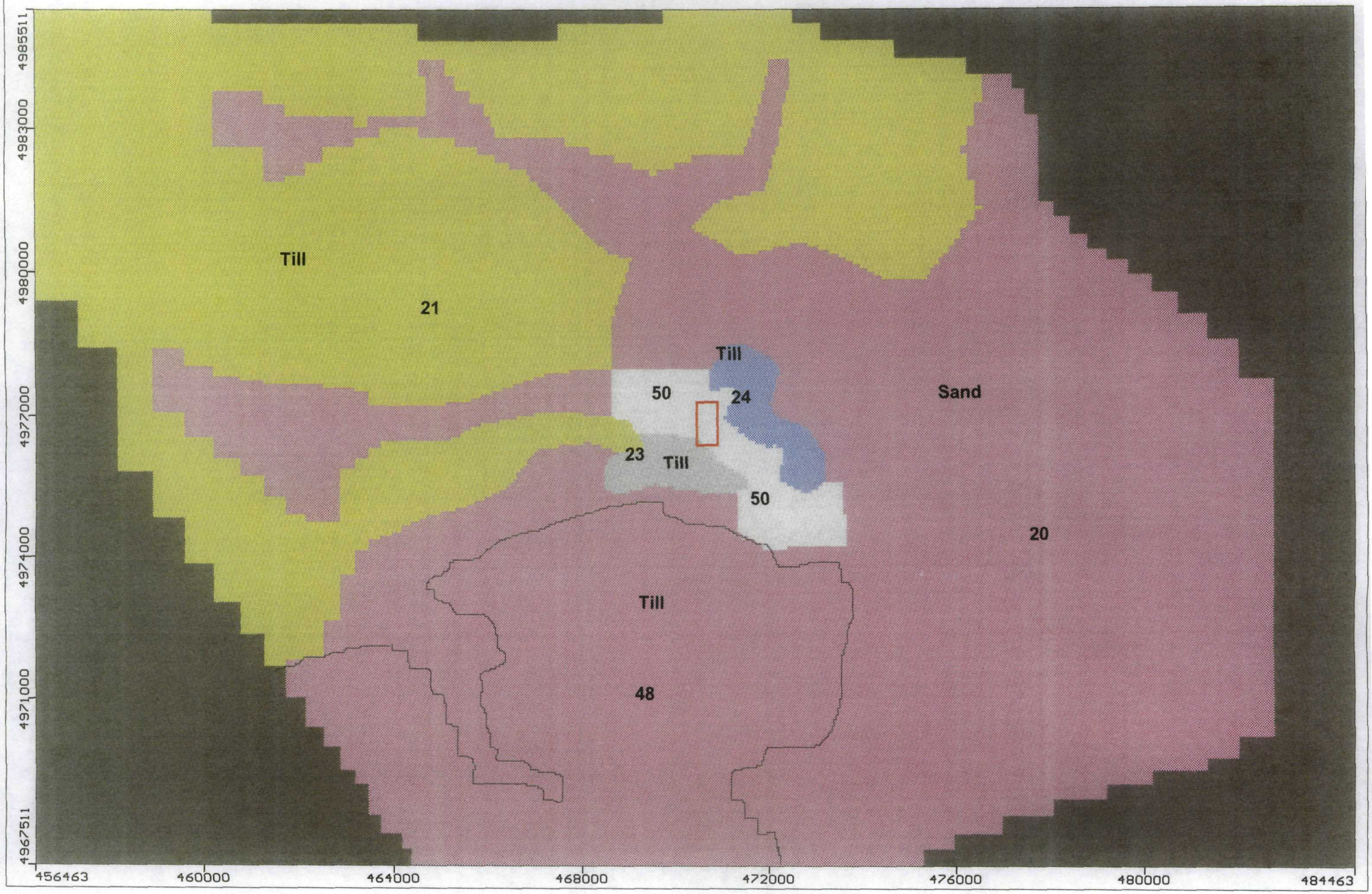

Figure 3-16b. Storage Zones used in the Model Layer 2.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

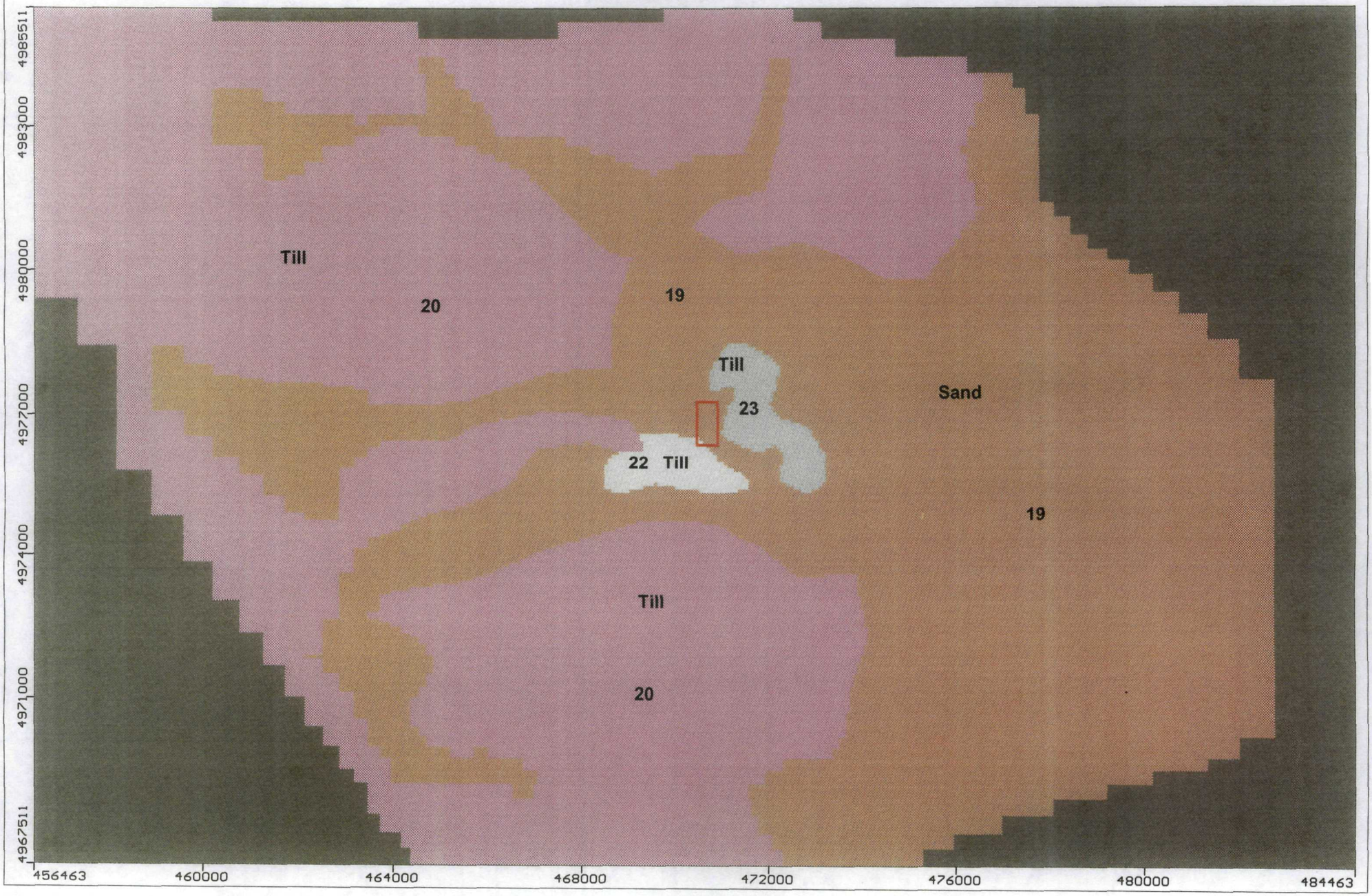

Figure 3-17a. Hydraulic Conductivity used in the Model Layer 3.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

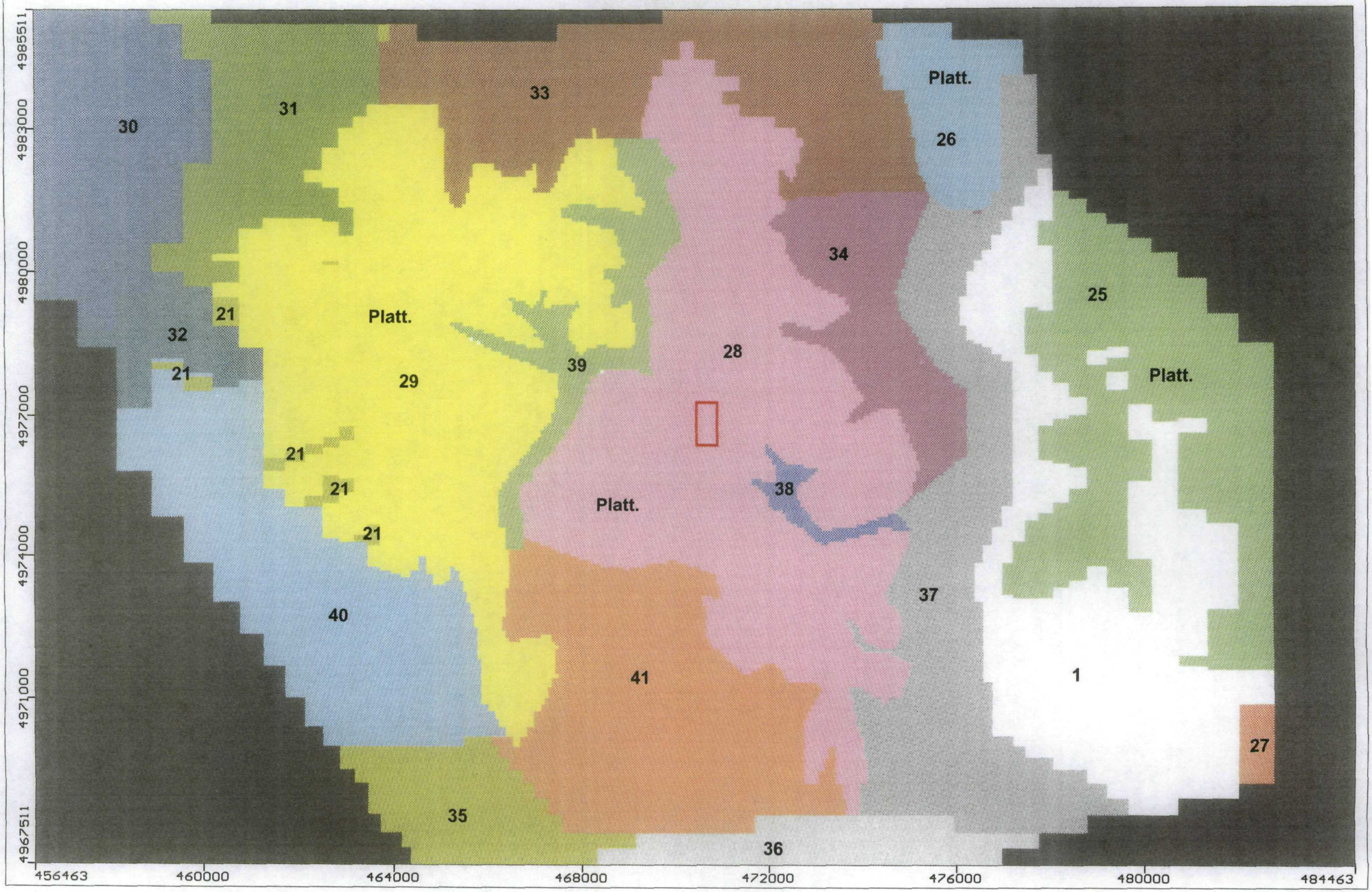

Figure 3-17b. Storage Zones used in the Model Layer 3.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

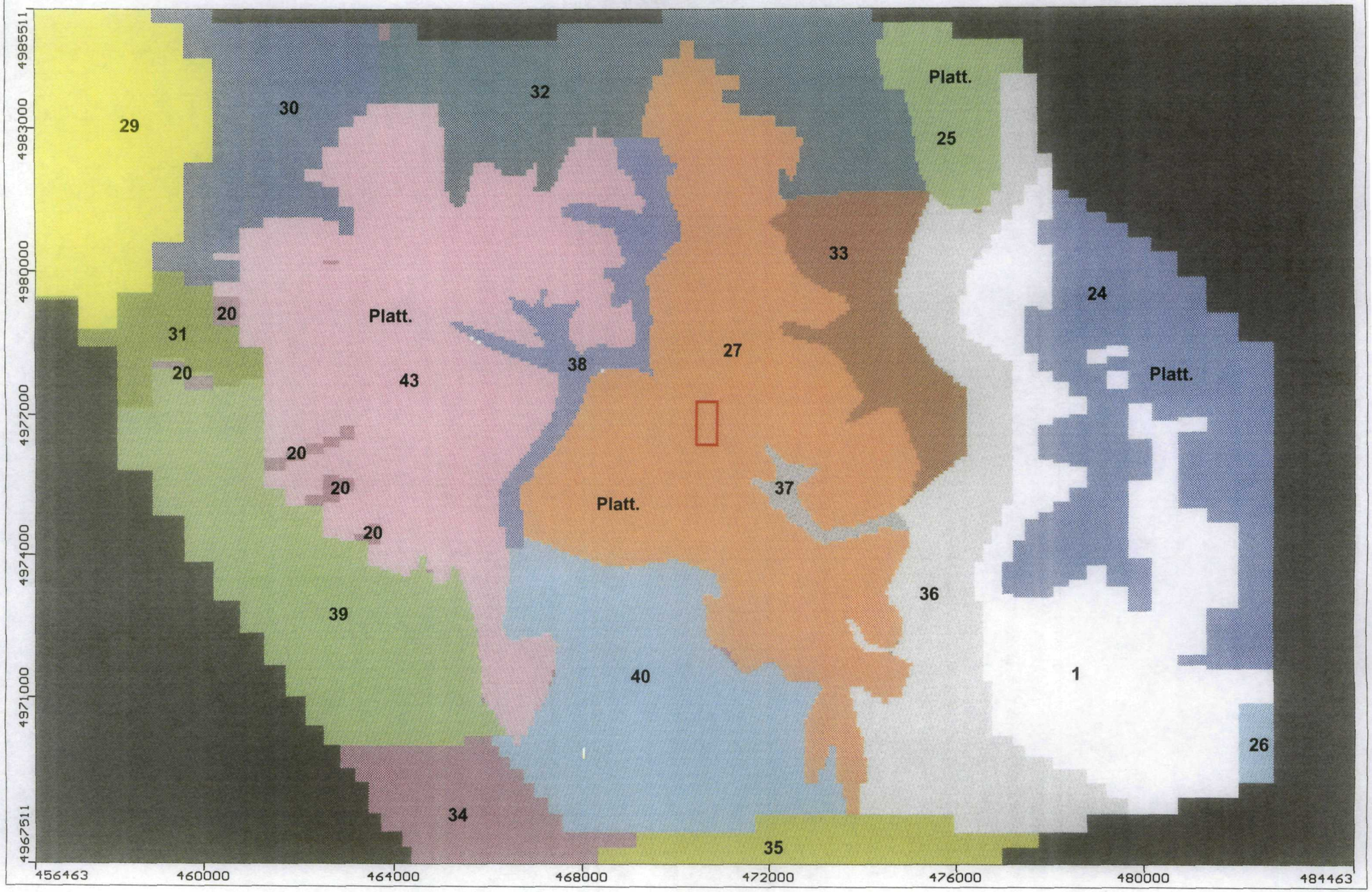

Figure 3-18a. Hydraulic Conductivity used in the Model Layer 4.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

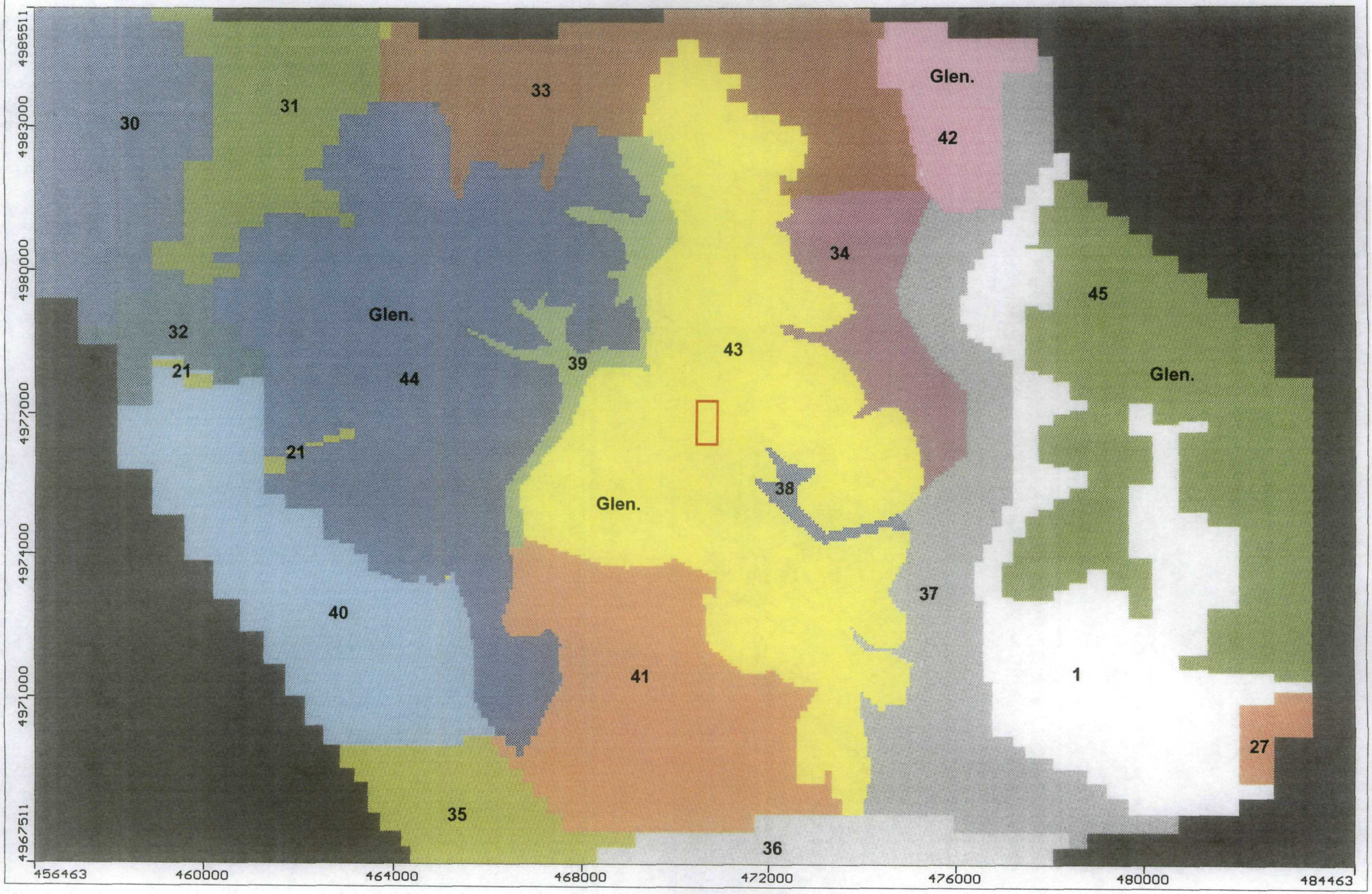

Figure 3-18b. Storage Zones used in the Model Layer 4.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

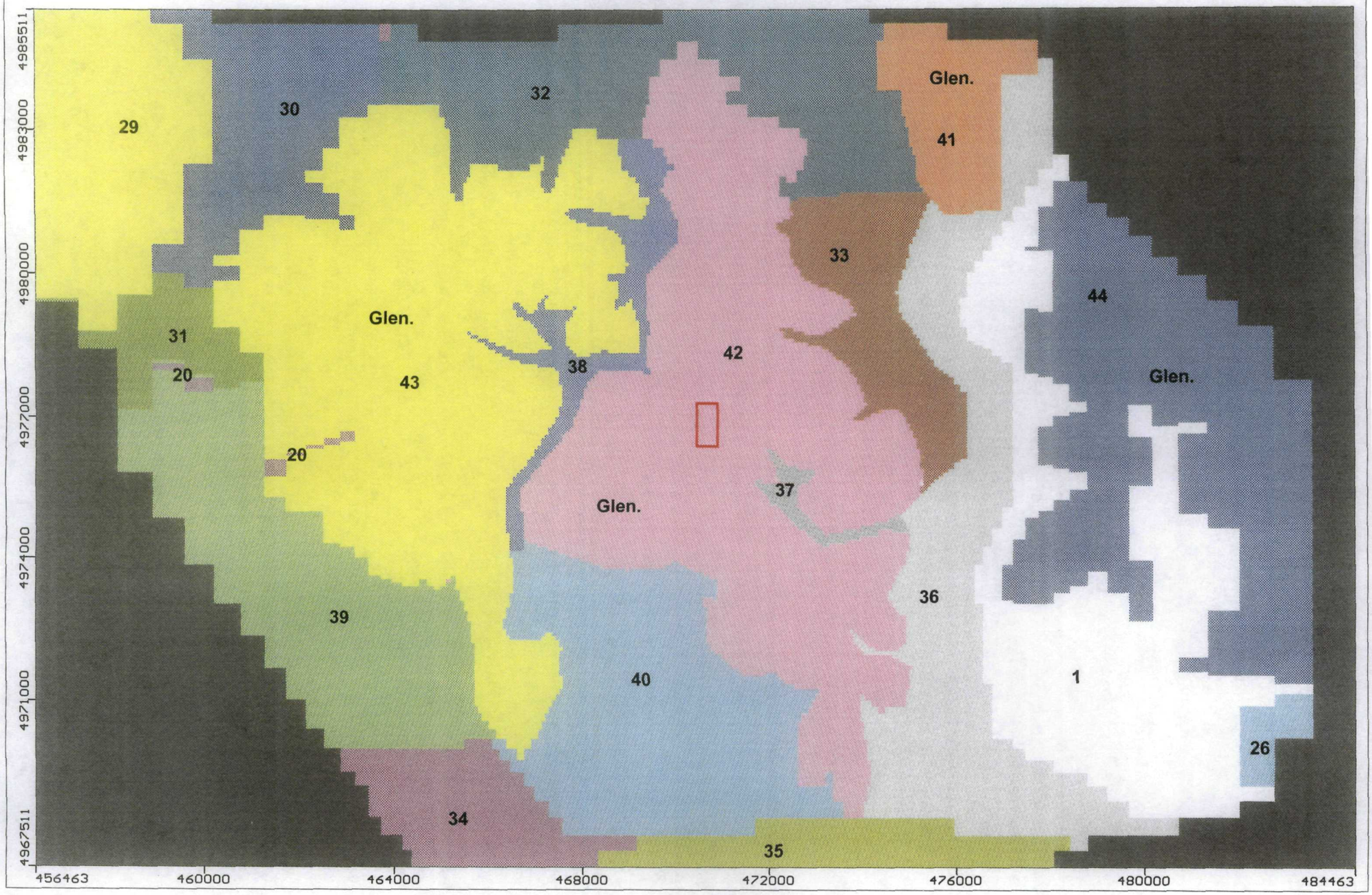

Figure 3-19a. Hydraulic Conductivity used in the Model Layer 5.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

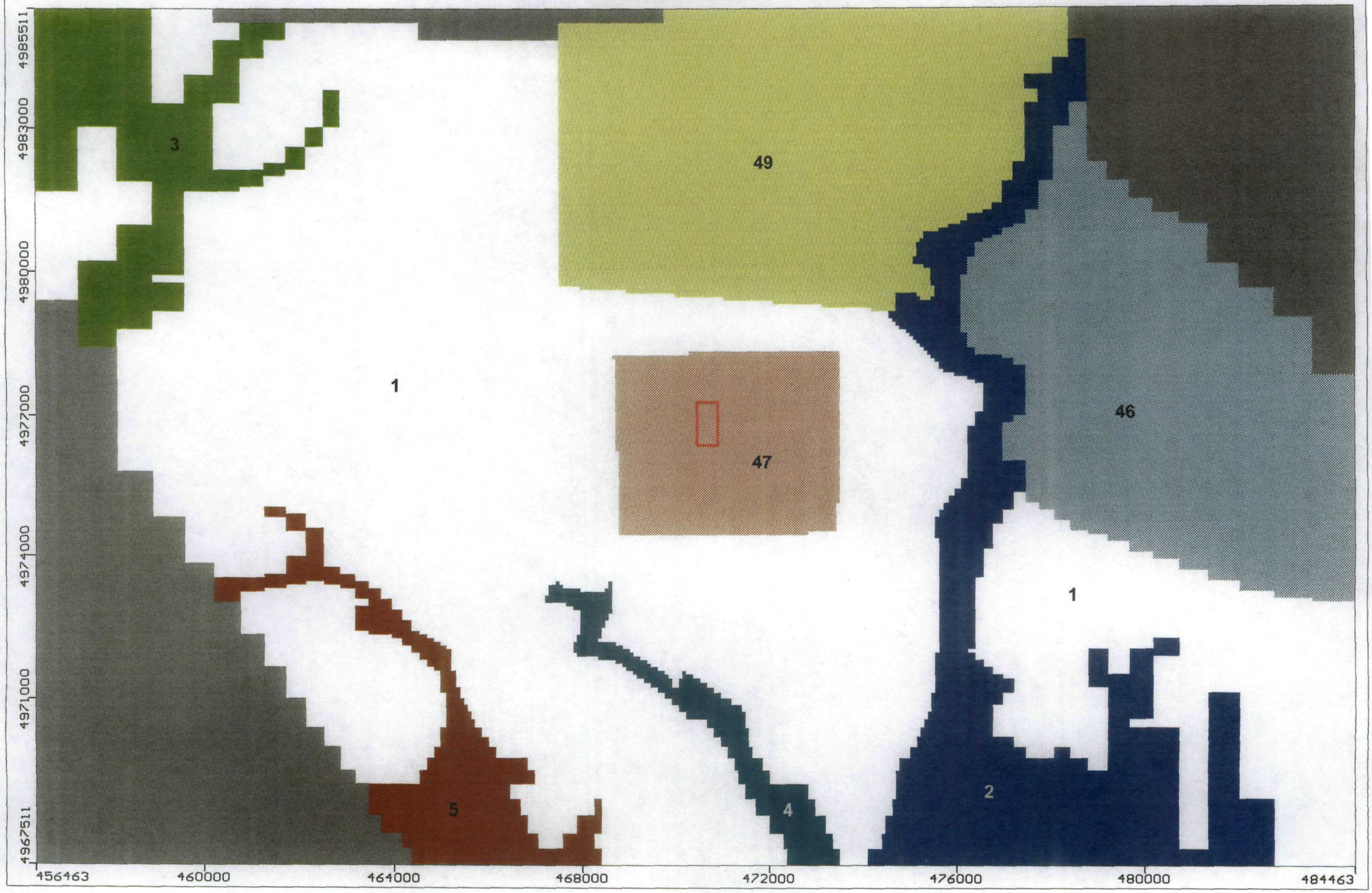

Figure 3-19b. Storage Zones used in the Model Layer 5.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

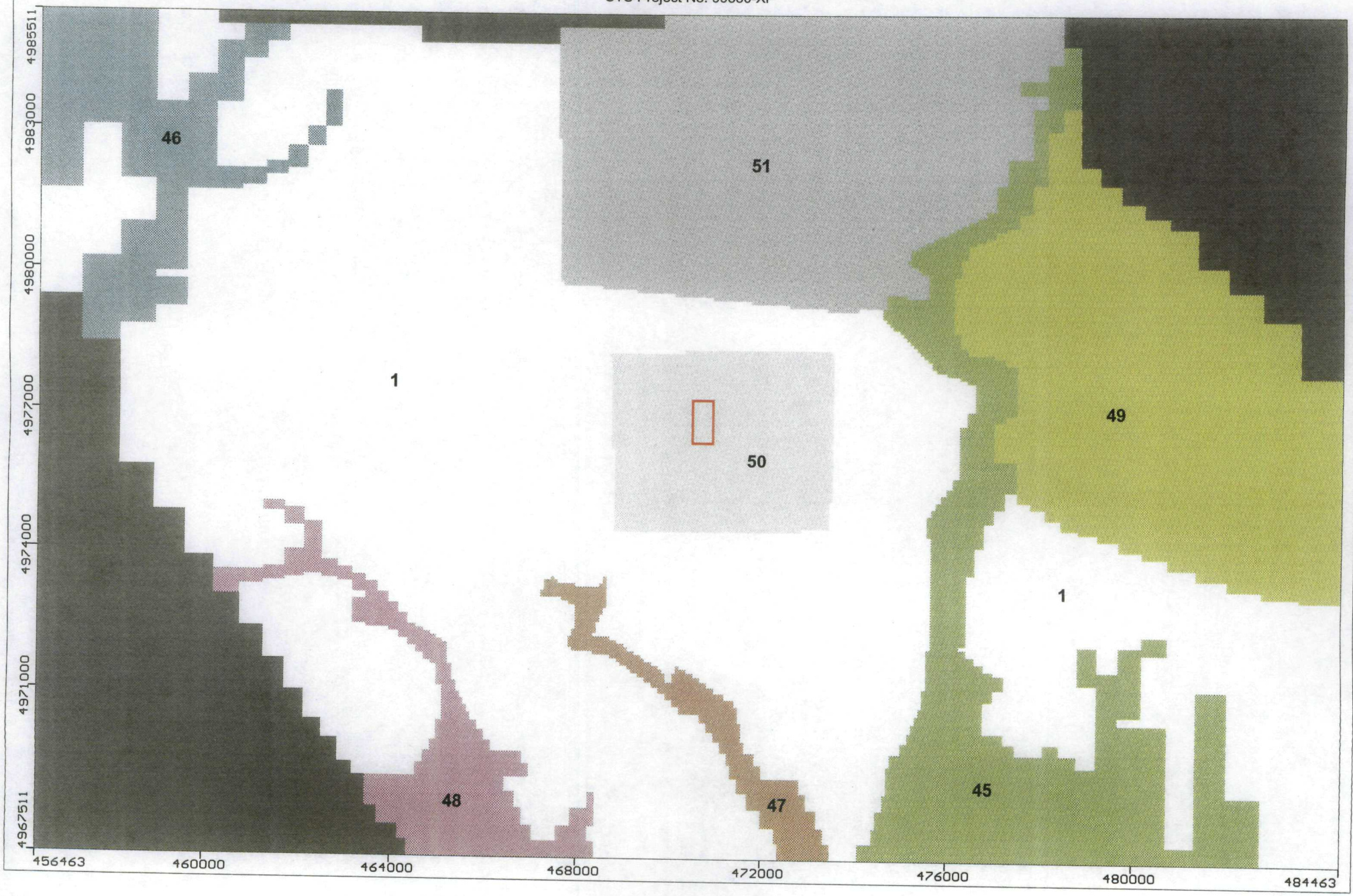

Figure 3-20a. Hydraulic Conductivity used in the Model Layer 6.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

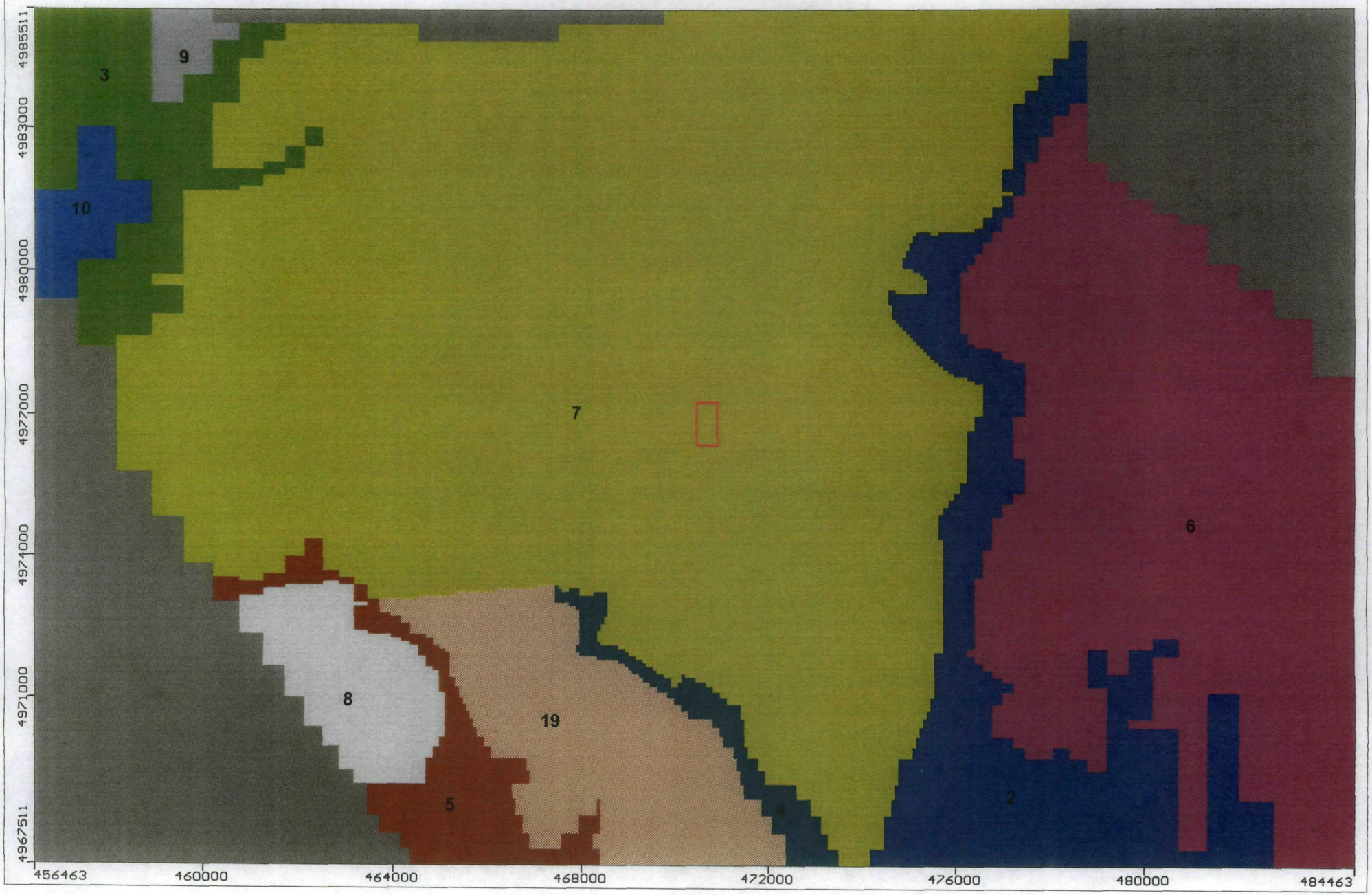

Figure 3-20b. Storage Zones used in the Model Layer 6.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

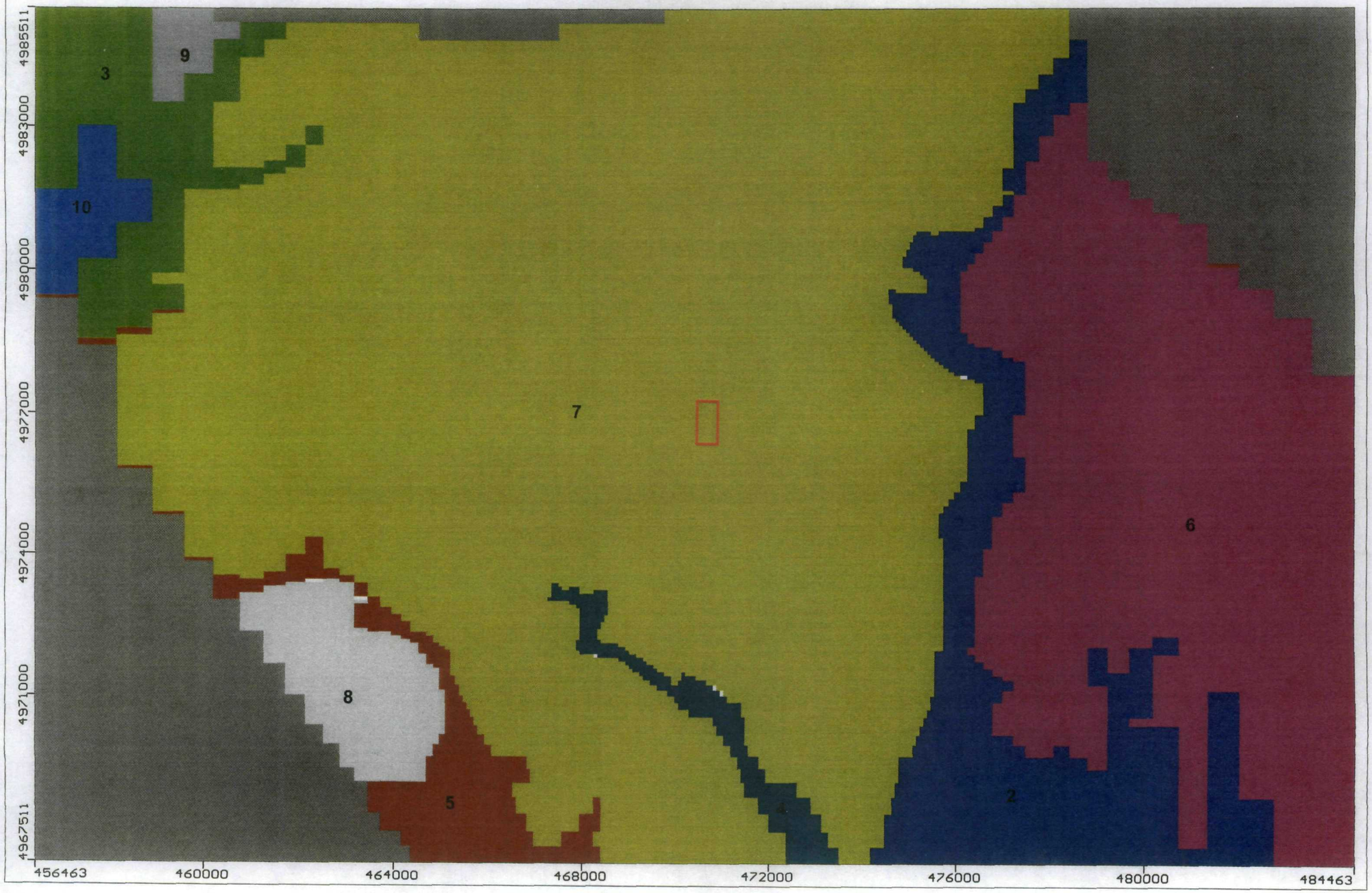

Figure 3-21a. Hydraulic Conductivity used in the Model Layer 7.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

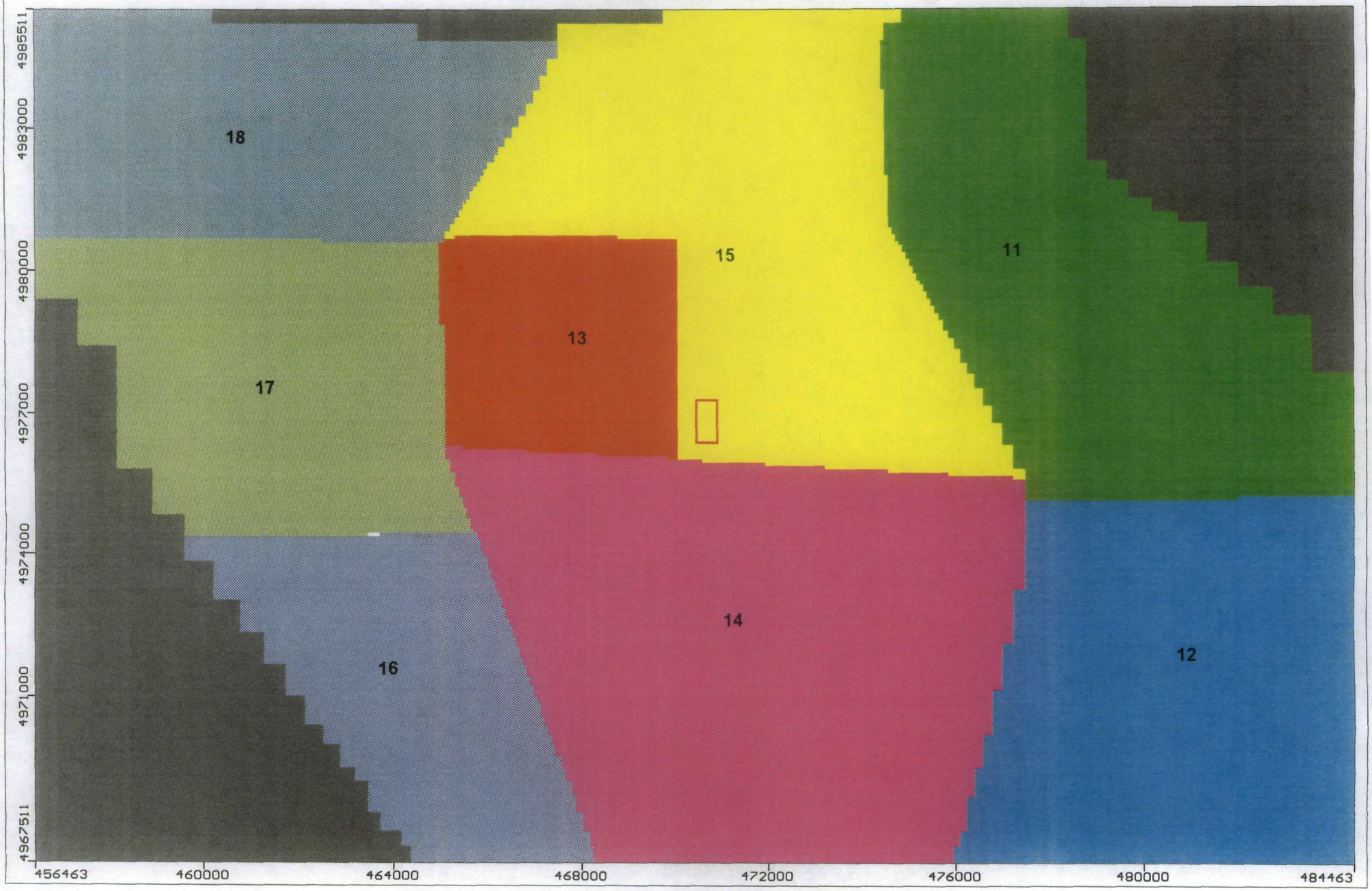

Figure 3-21b. Storage Zones used in the Model Layer 7.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

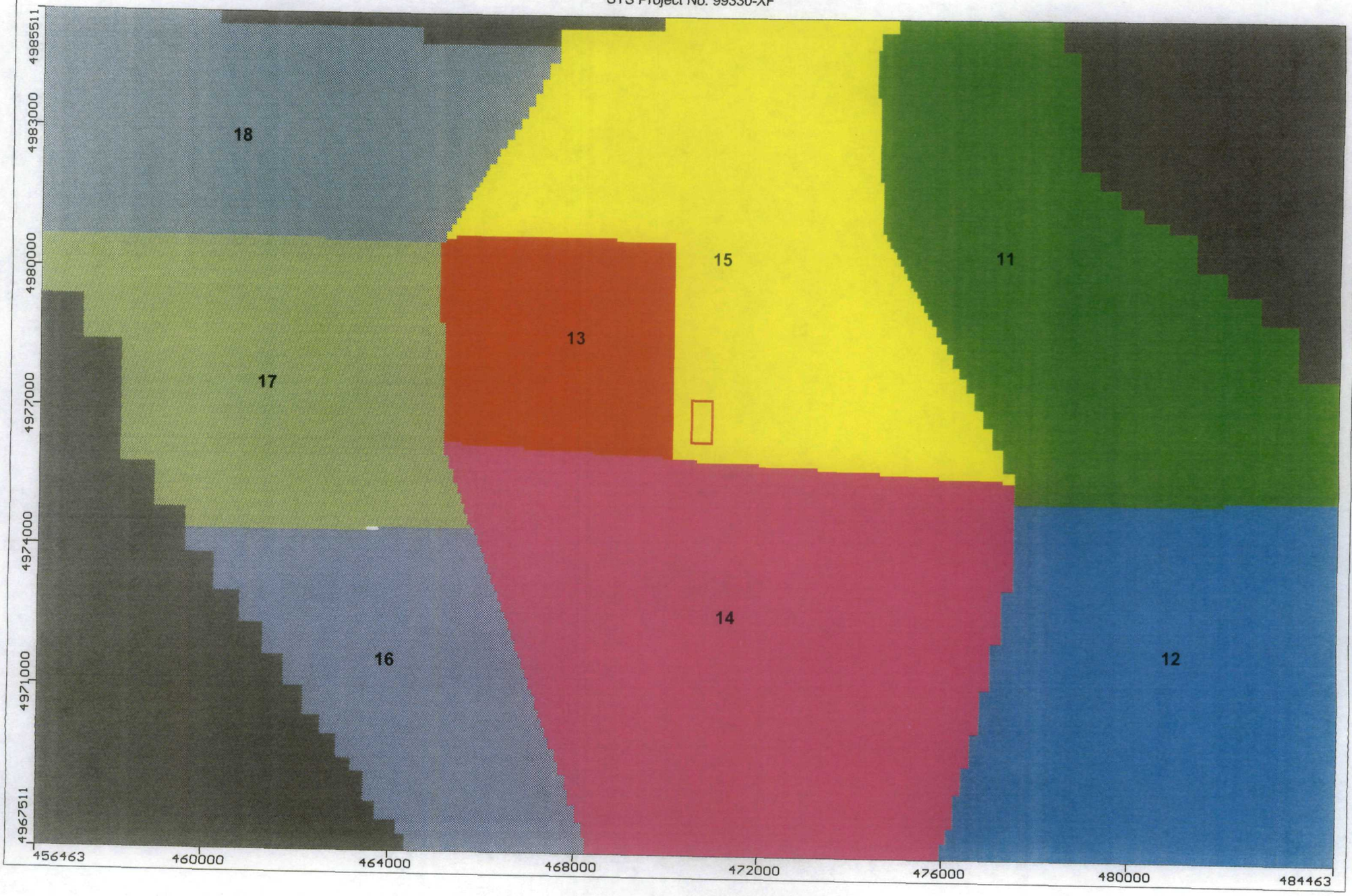

Figure 4-1. Distribution of Residuals - Drift and Platteville Wells (Model Layer 2) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

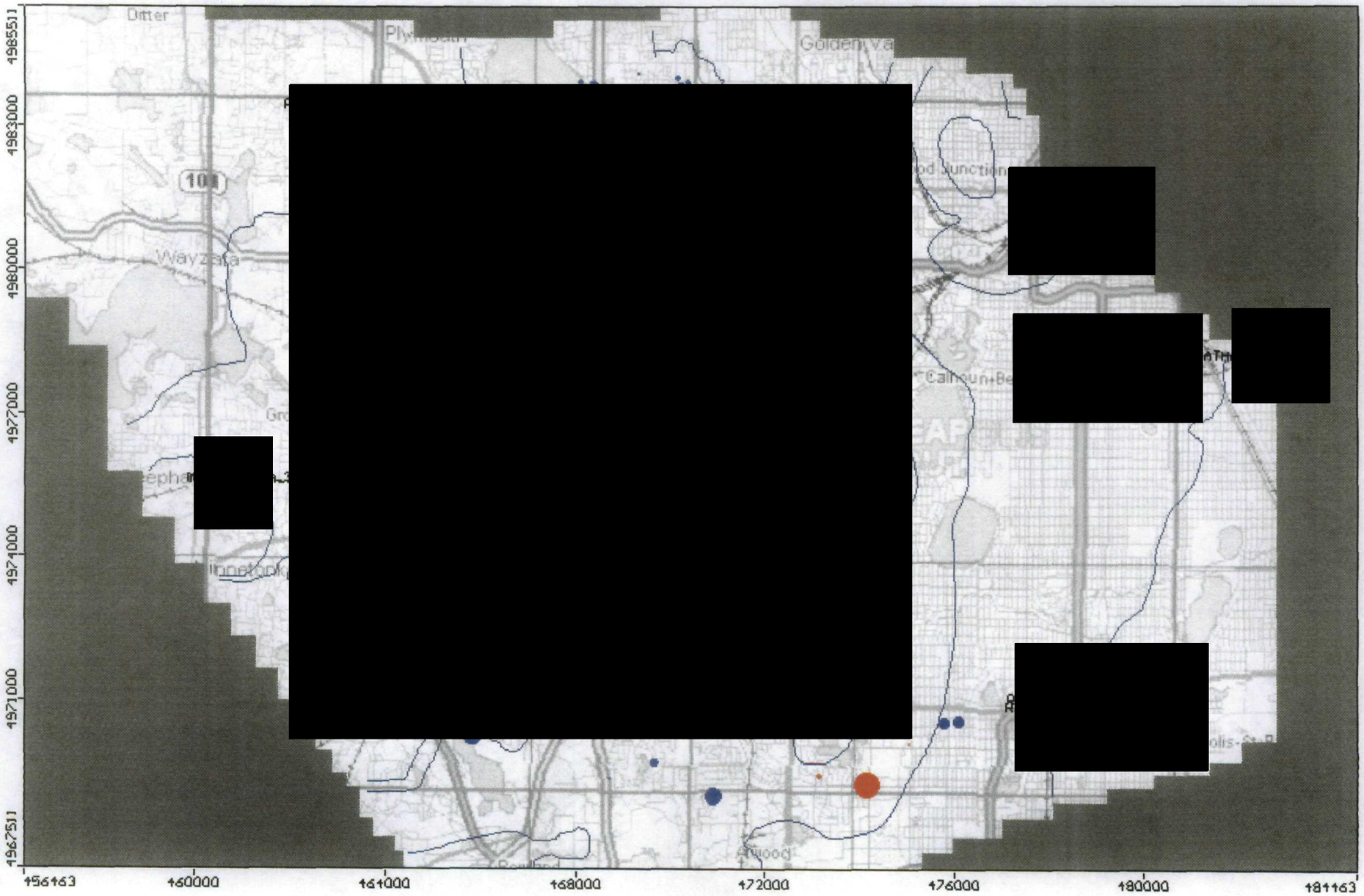

Figure 4-2. Distribution of Residuals - St. Peter Wells (Model Layer 5) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Figure 4-3. Distribution of Residuals - Prairie du Chien - Jordan Wells (Model Layer 7) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

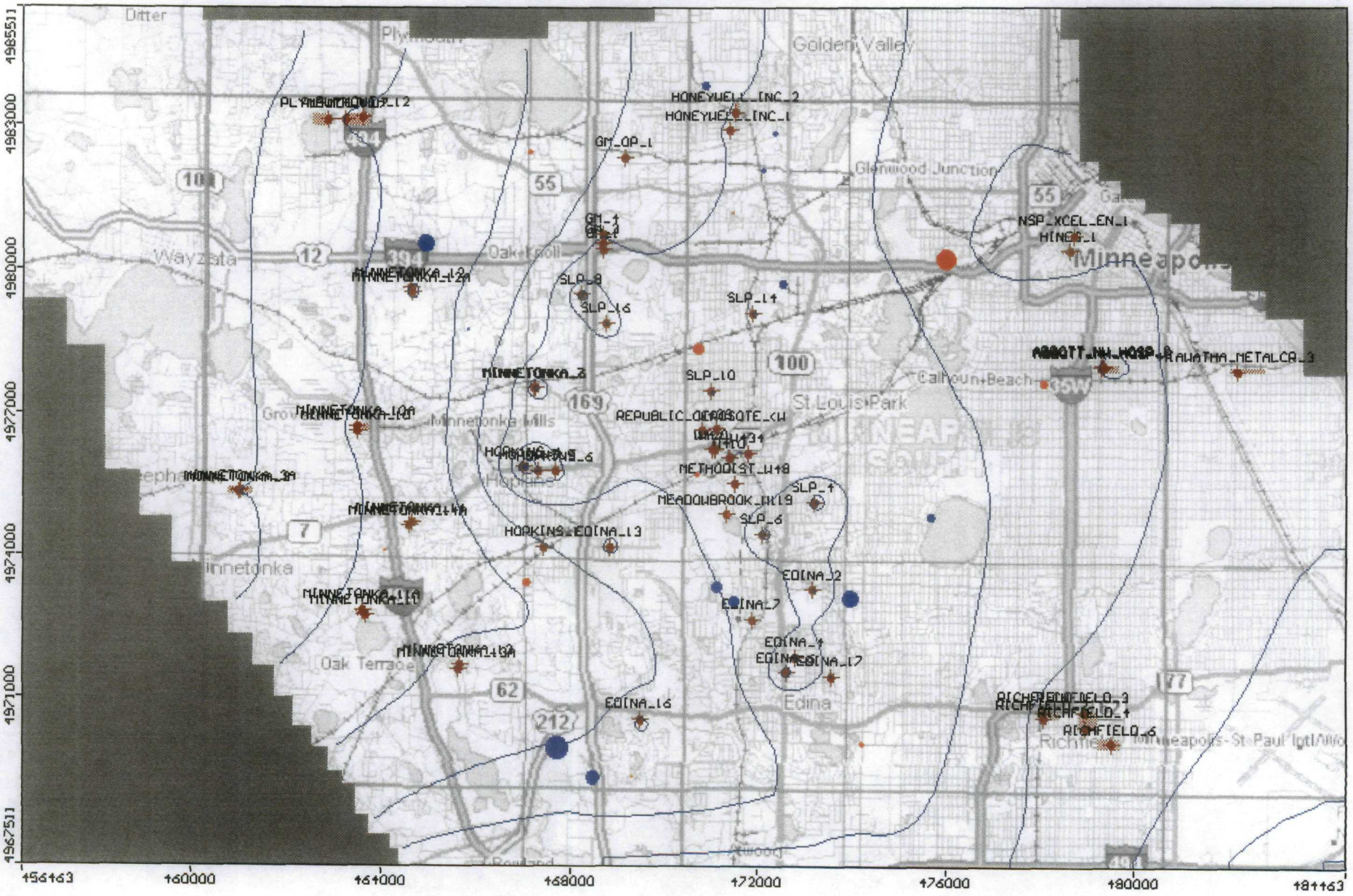

Figure 4-4. Distribution of Residuals - Drift and Platteville Wells (Model Layer 2) - High Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

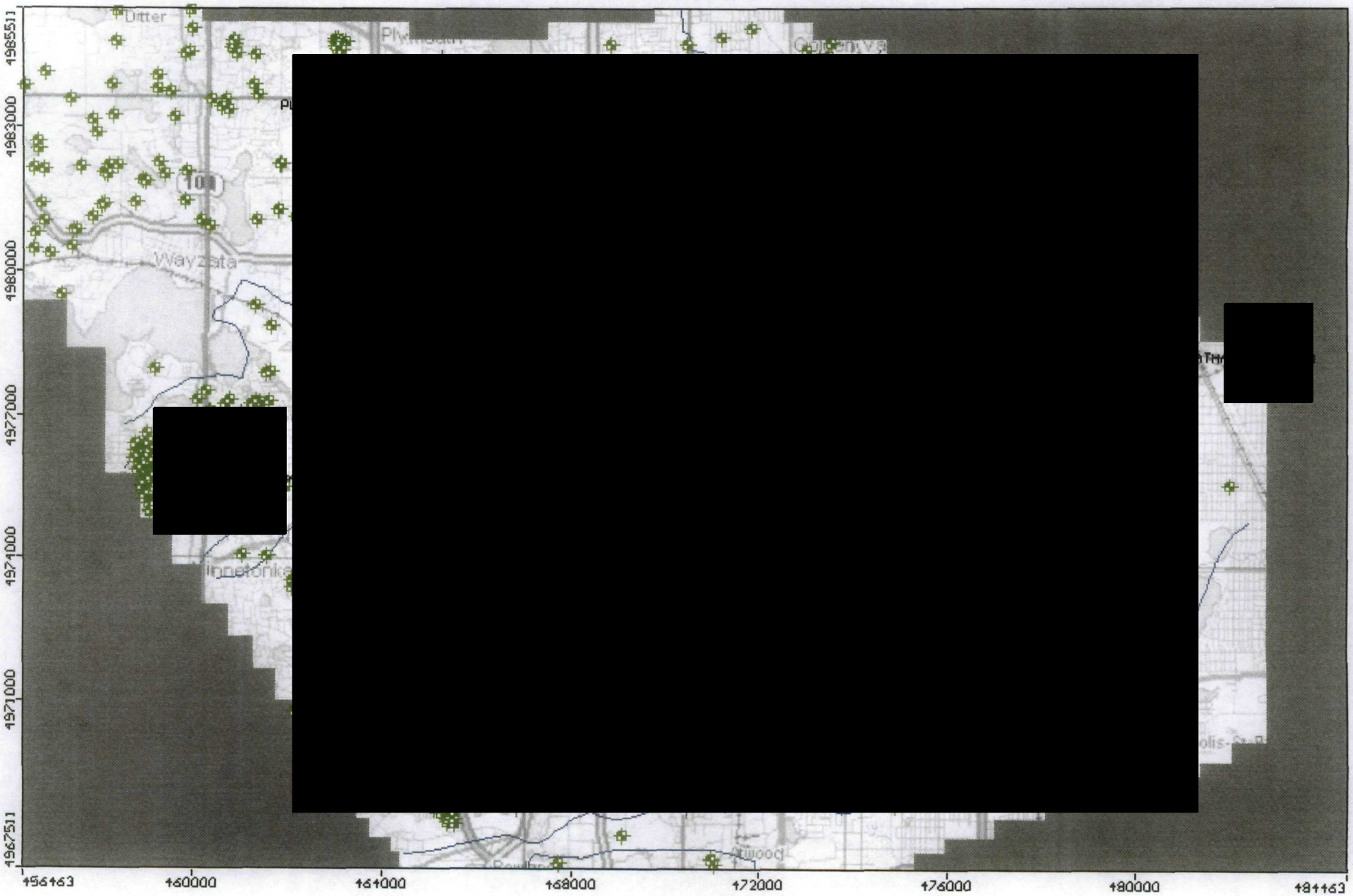

Figure 4-5. Distribution of Residuals - St. Peter Wells (Model Layer 5) - High Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

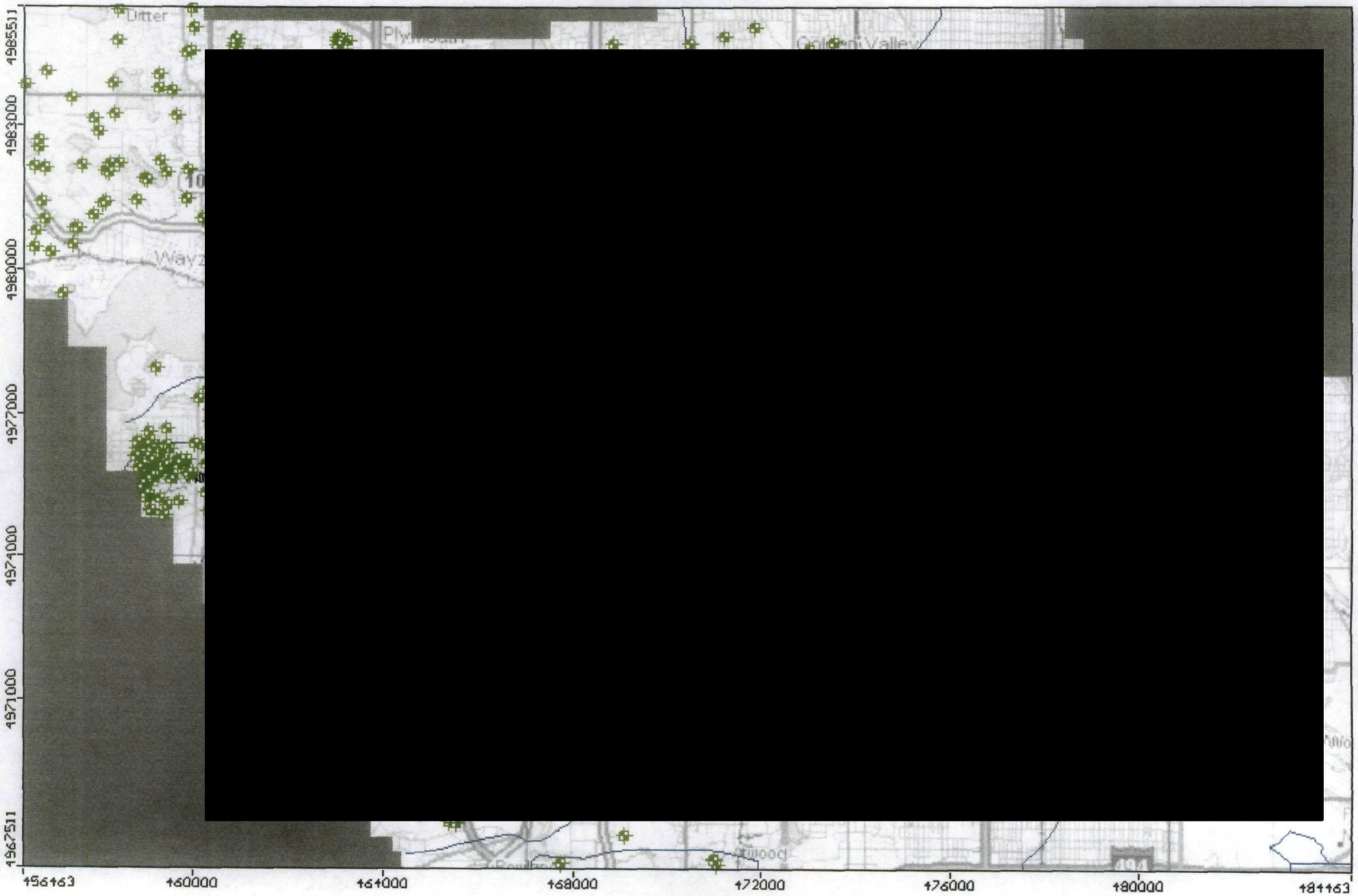

Figure 4-6. Distribution of Residuals - Prairie du Chien - Jordan Wells (Model Layer 7) - High Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Figure 4-7. Budget Zones within the Model Layer 1.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

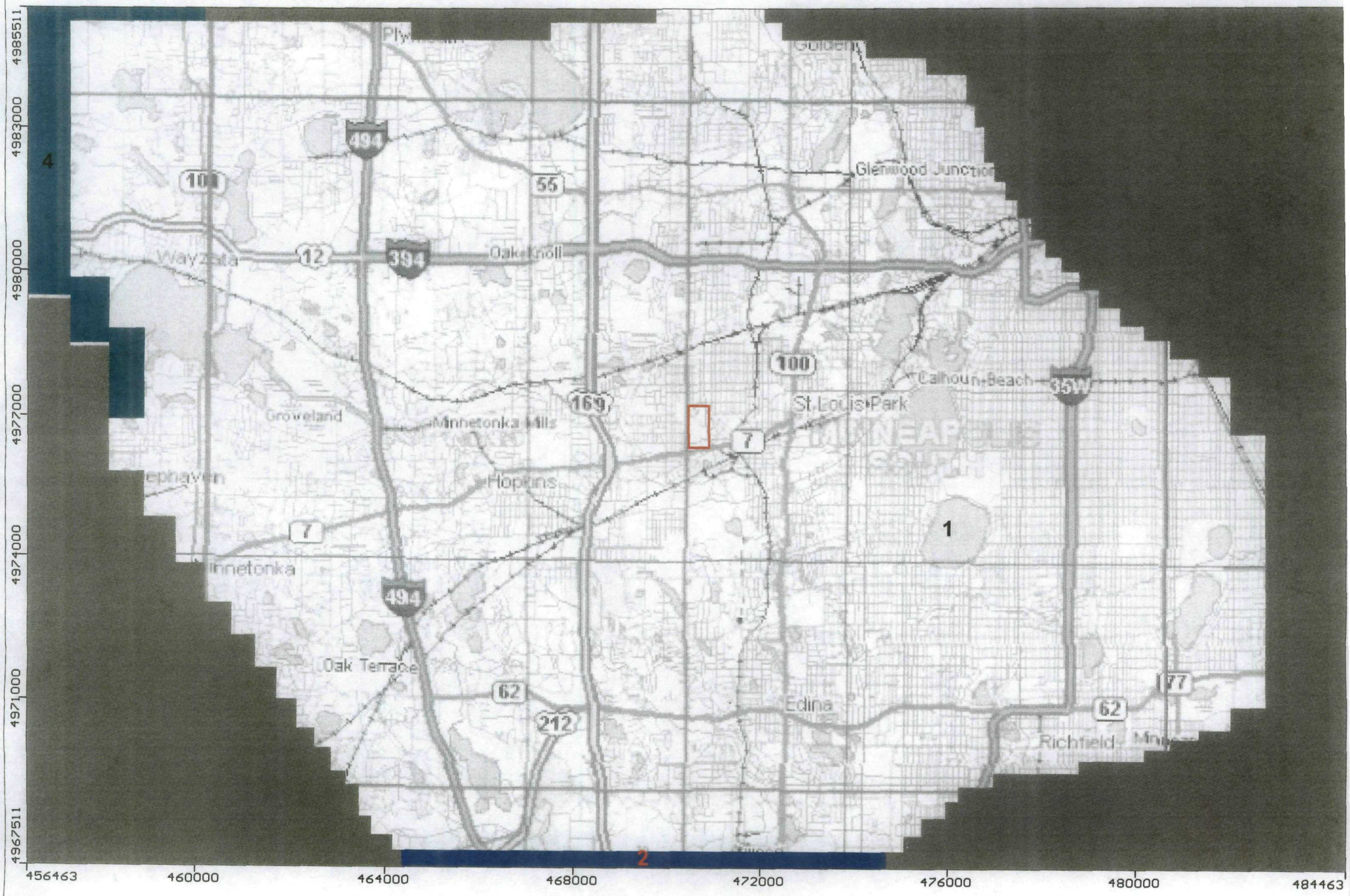

Figure 4-8. Budget Zones within the Model Layer 2.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

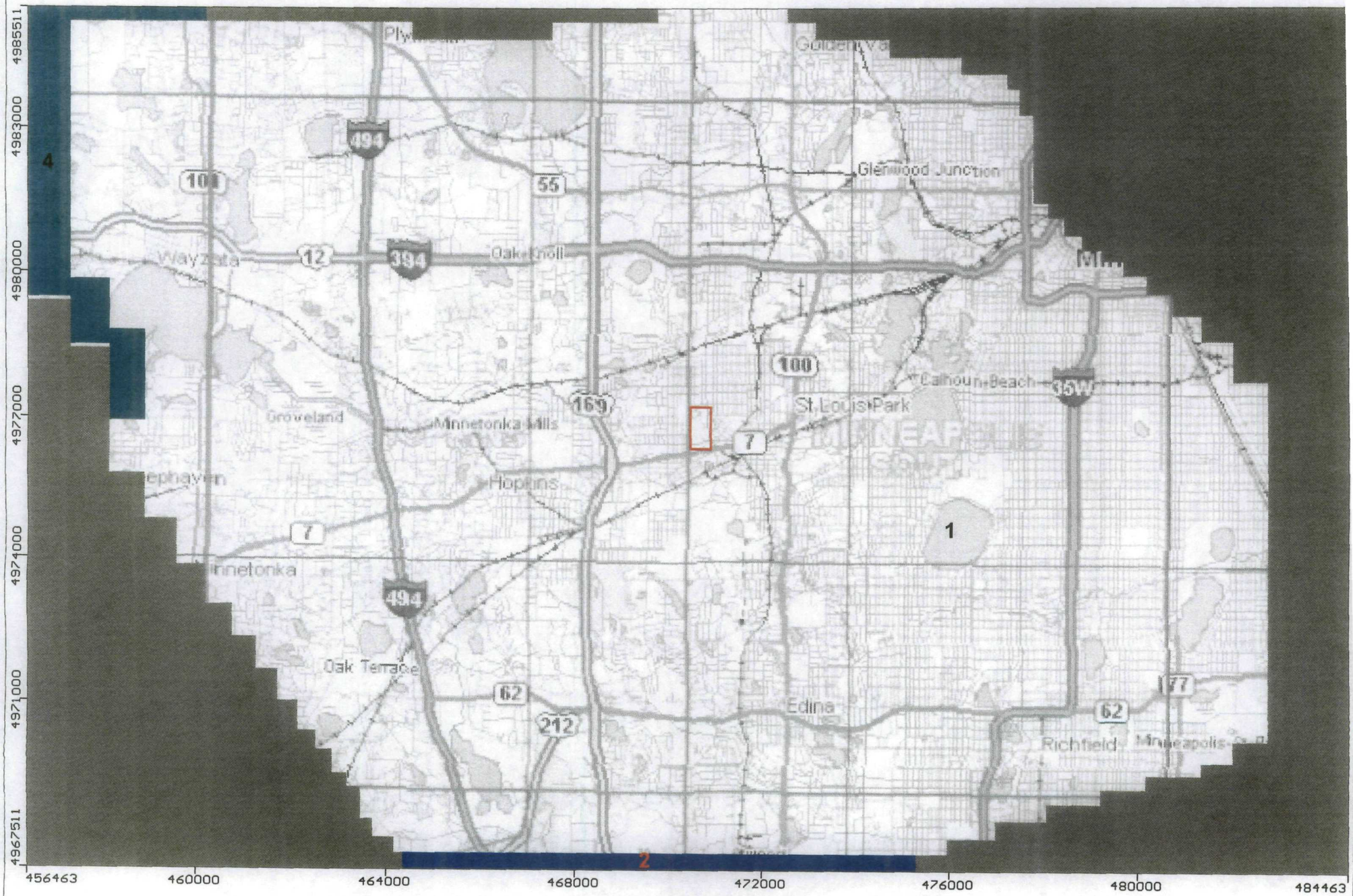

Figure 4-9. Budget Zones within the Model Layer 3.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

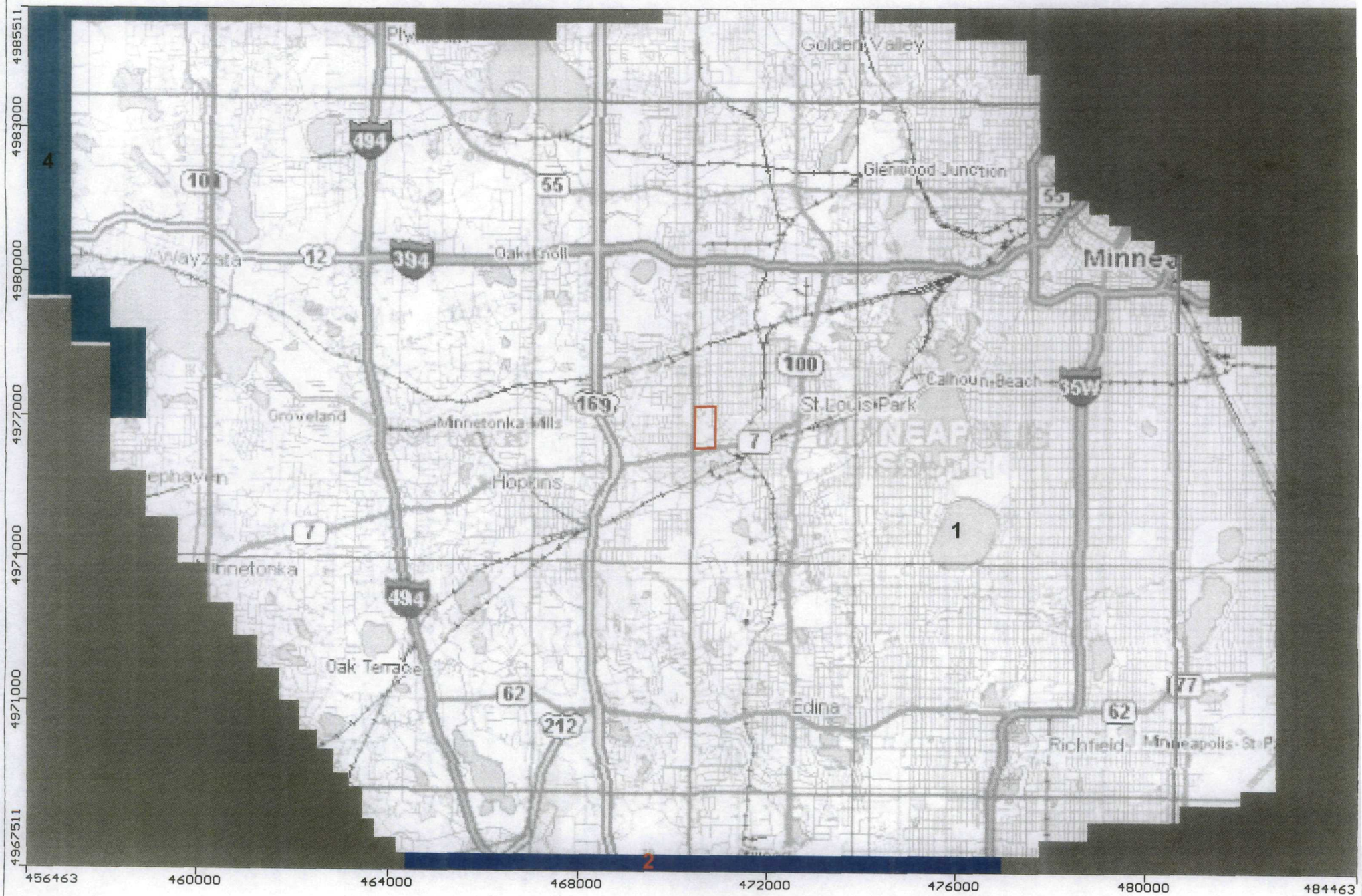

Figure 4-10. Budget Zones within the Model Layer 4.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

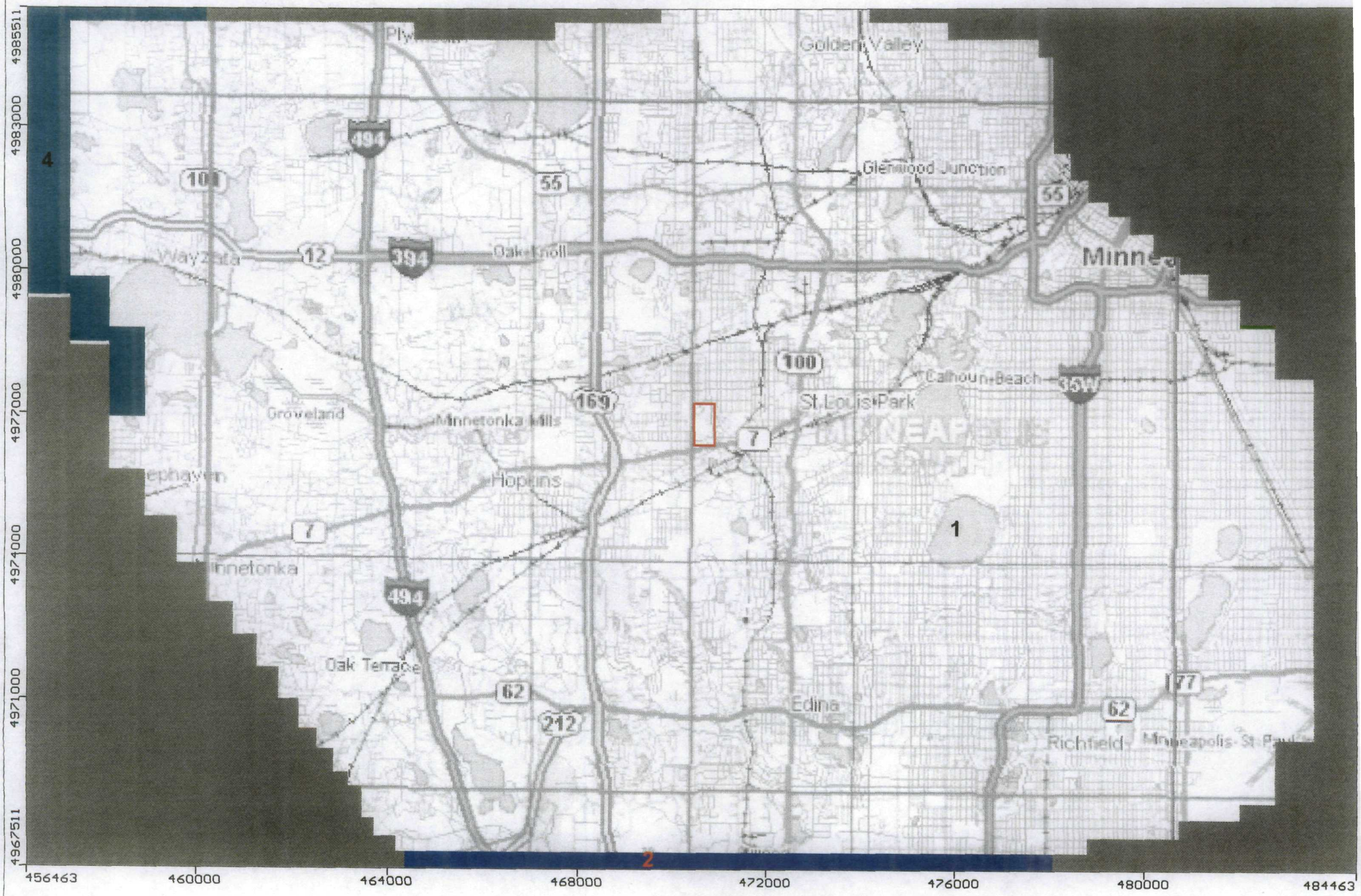

Figure 4-11. Budget Zones within the Model Layer 5.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

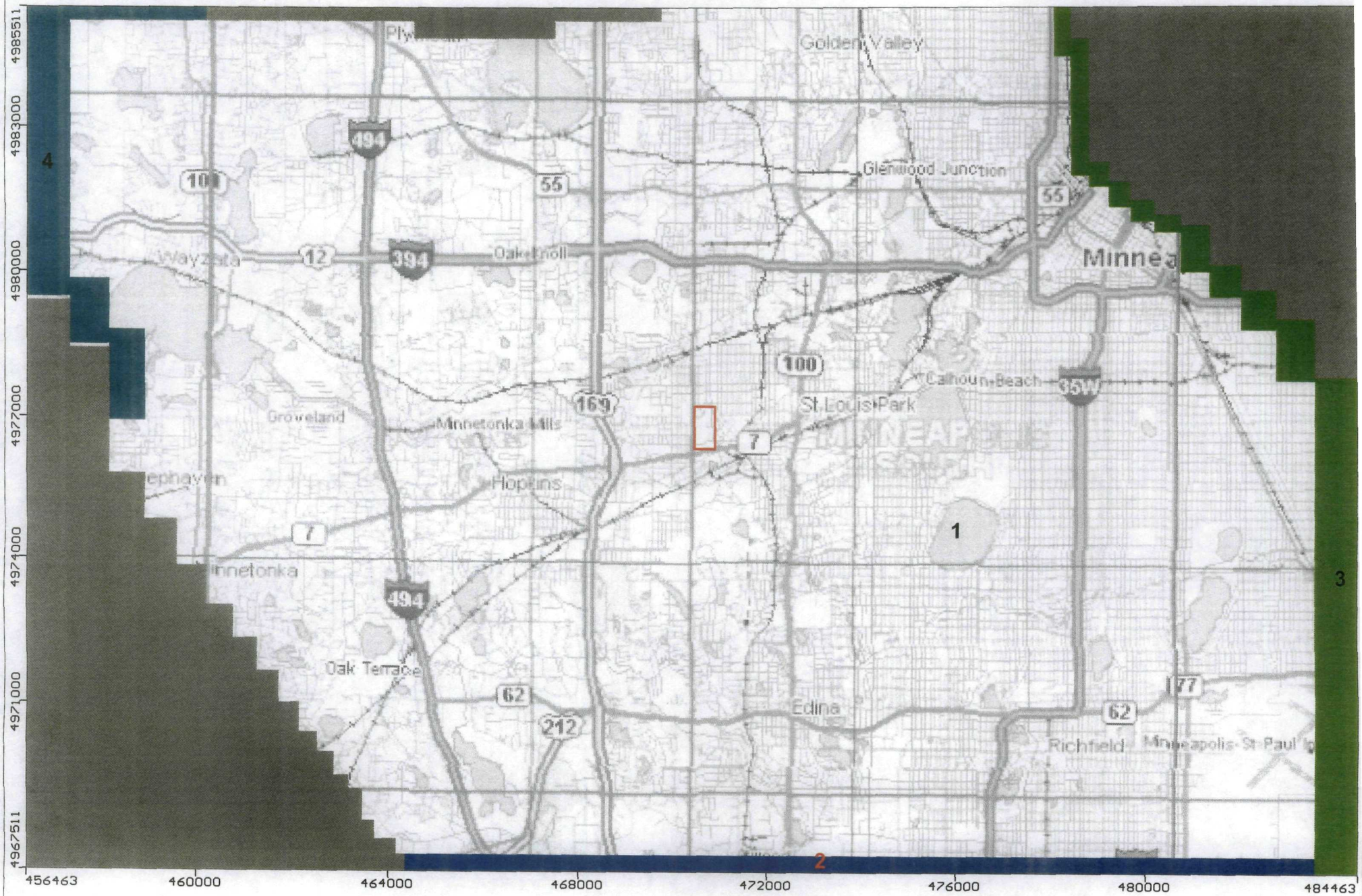

Figure 4-12. Budget Zones within the Model Layer 7.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

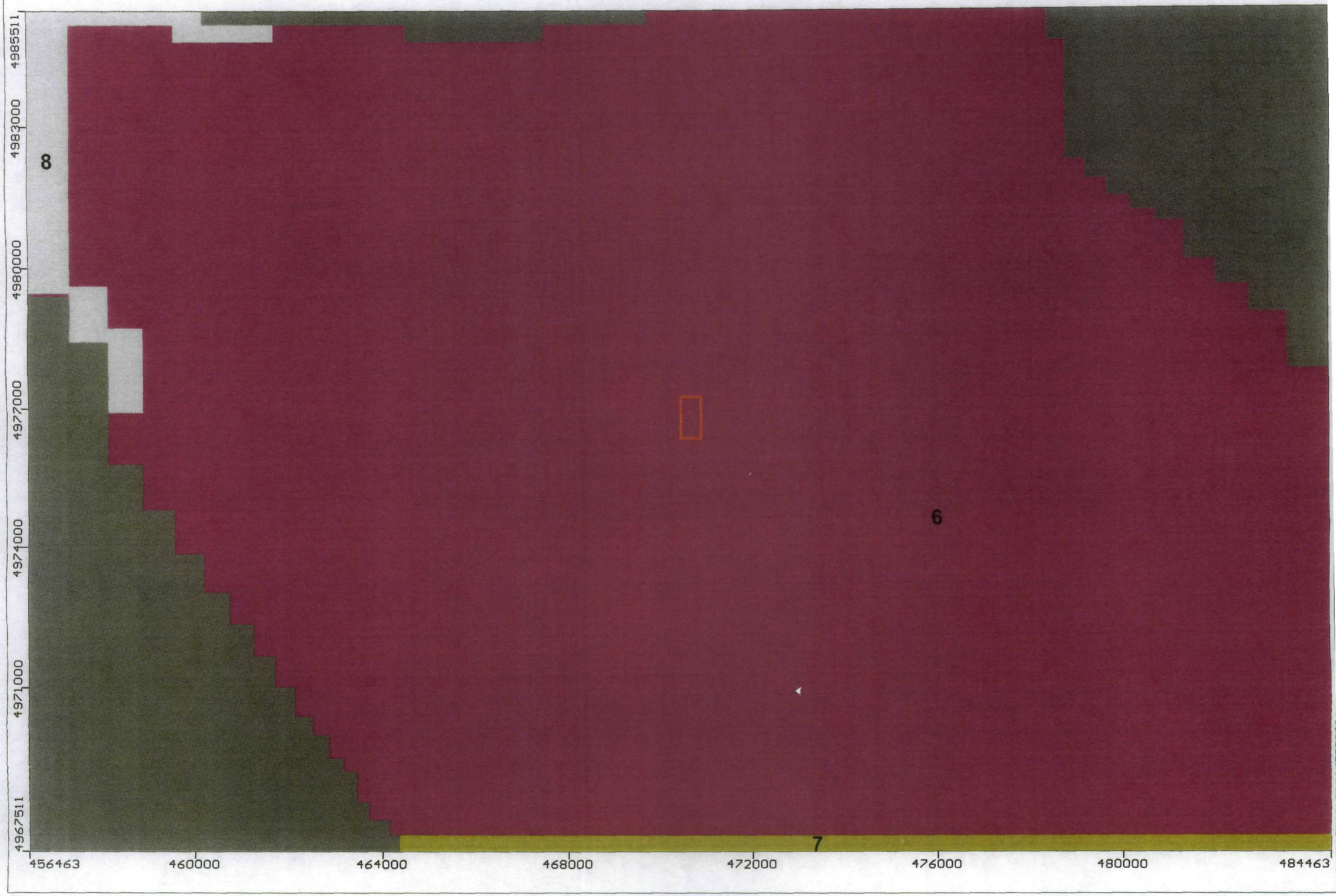

Figure 4-13. The Model Calculated Head Difference between Model Layer 3 (Platteville) and Model Layer 7 (Prairie du Chien - Jordan).

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

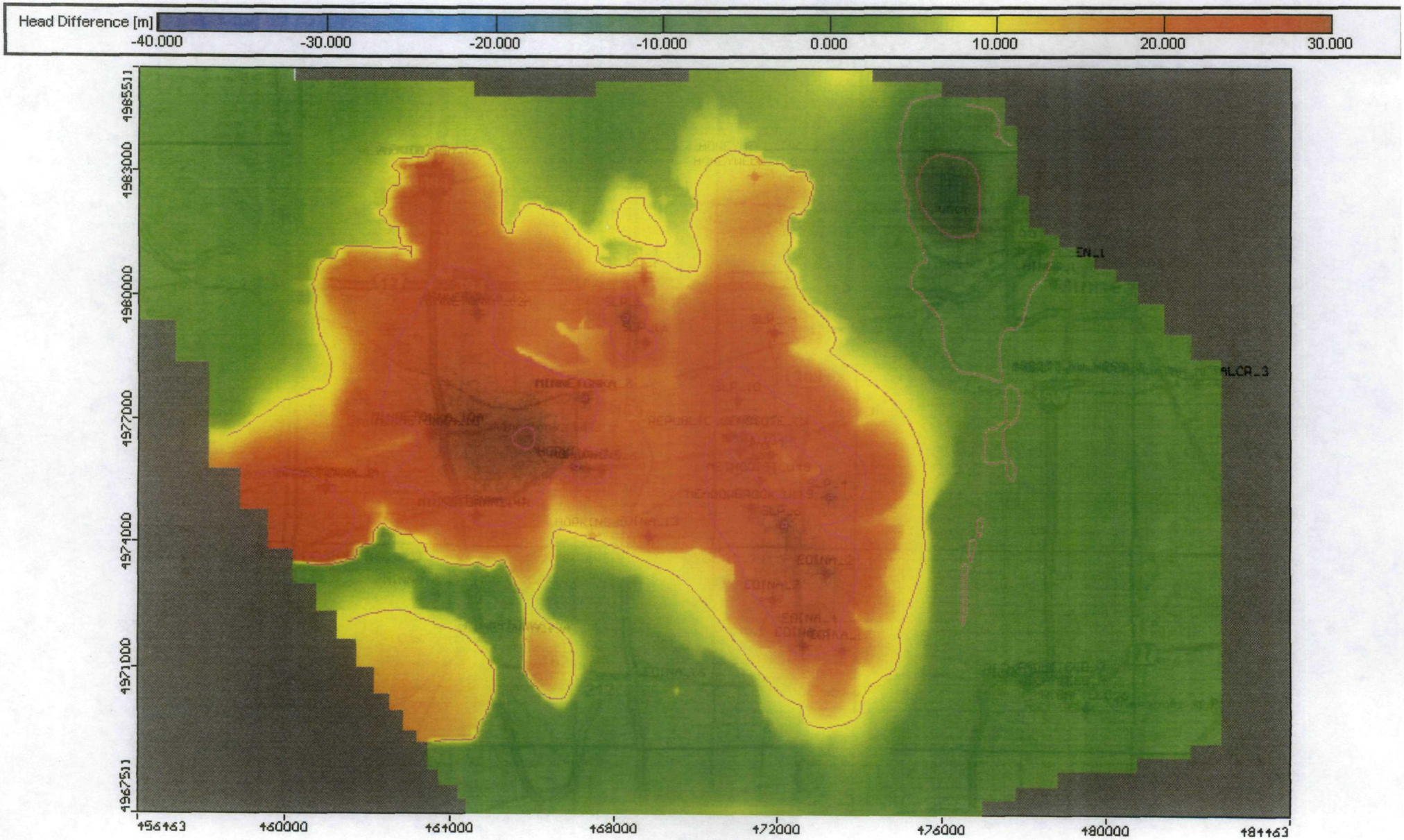

Figure 5-1. Model Calculated vs. Measured Head in Meadowbrook Golf Course Well
May 2005 - April 2006

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

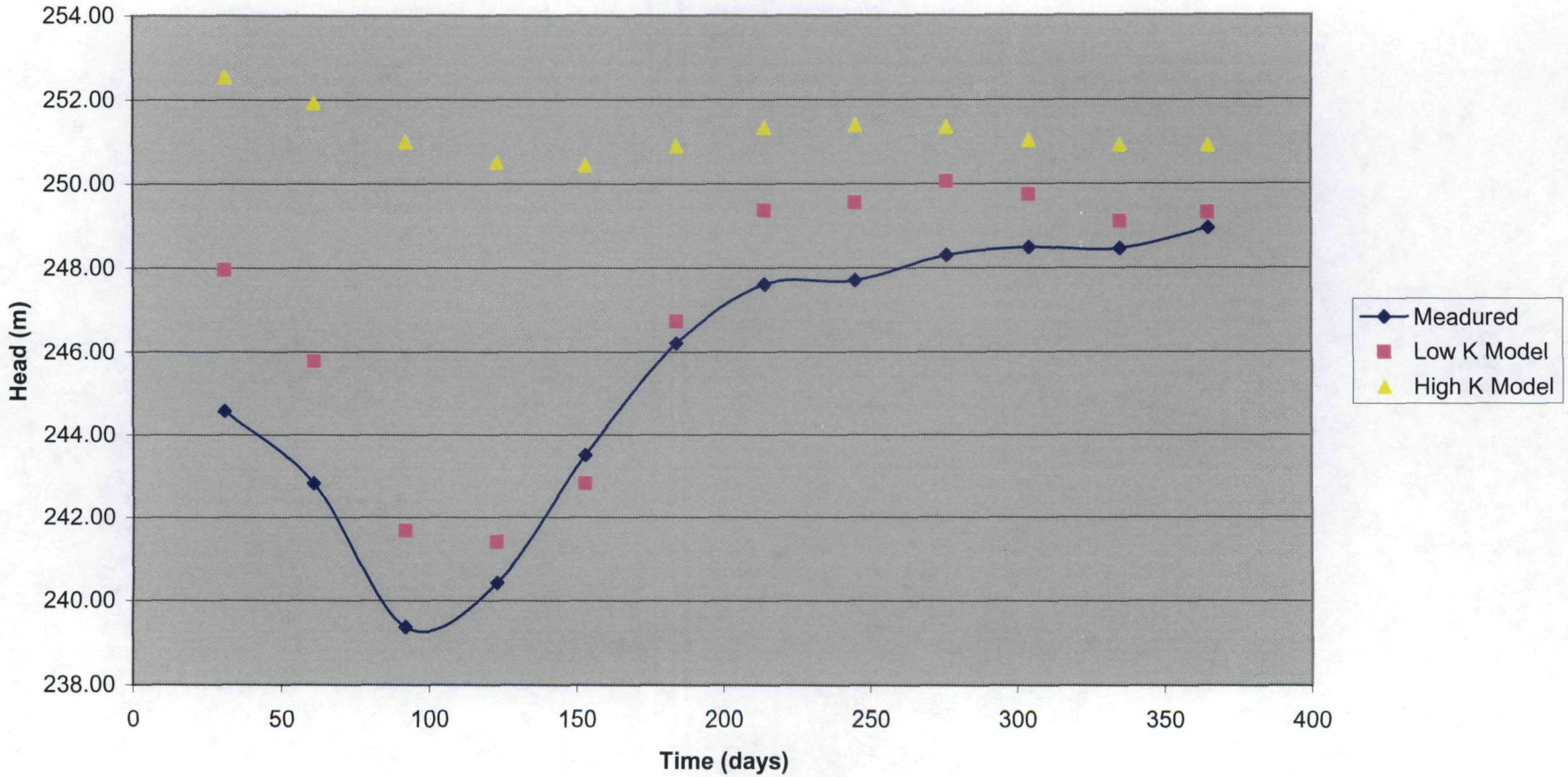

Figure 6-1a. MODPATH Calculated Particles' Pathlines - Particles Originating within the Drift PAH and Phenolics' Plume.
Current Gradient Control System plus W434 Scenario (Scenario No. 1) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

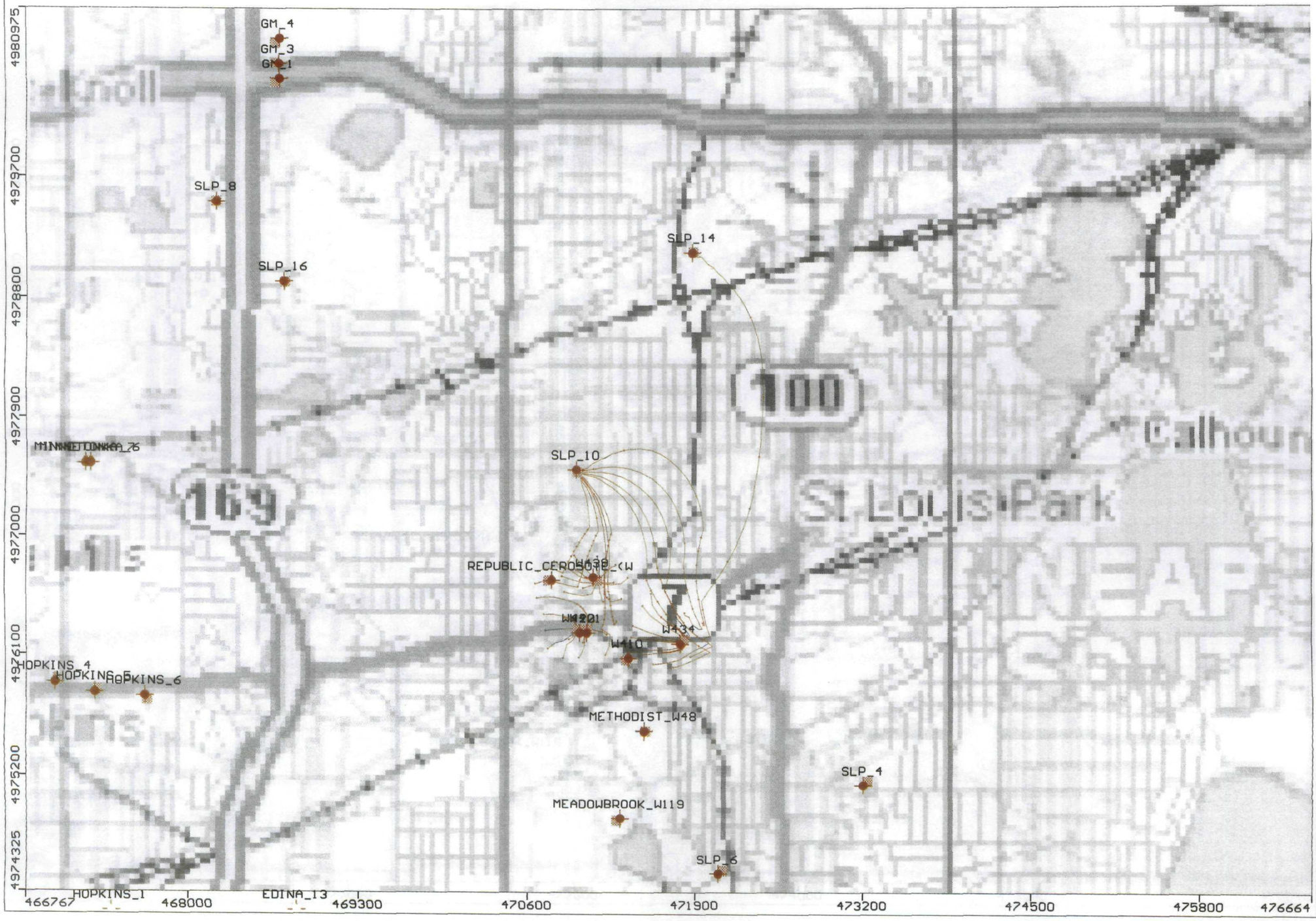

Figure 6-1b. MODPATH Calculated Particles' Pathlines - Particles Originating within the Drift PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off Scenario (Scenario No. 2) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

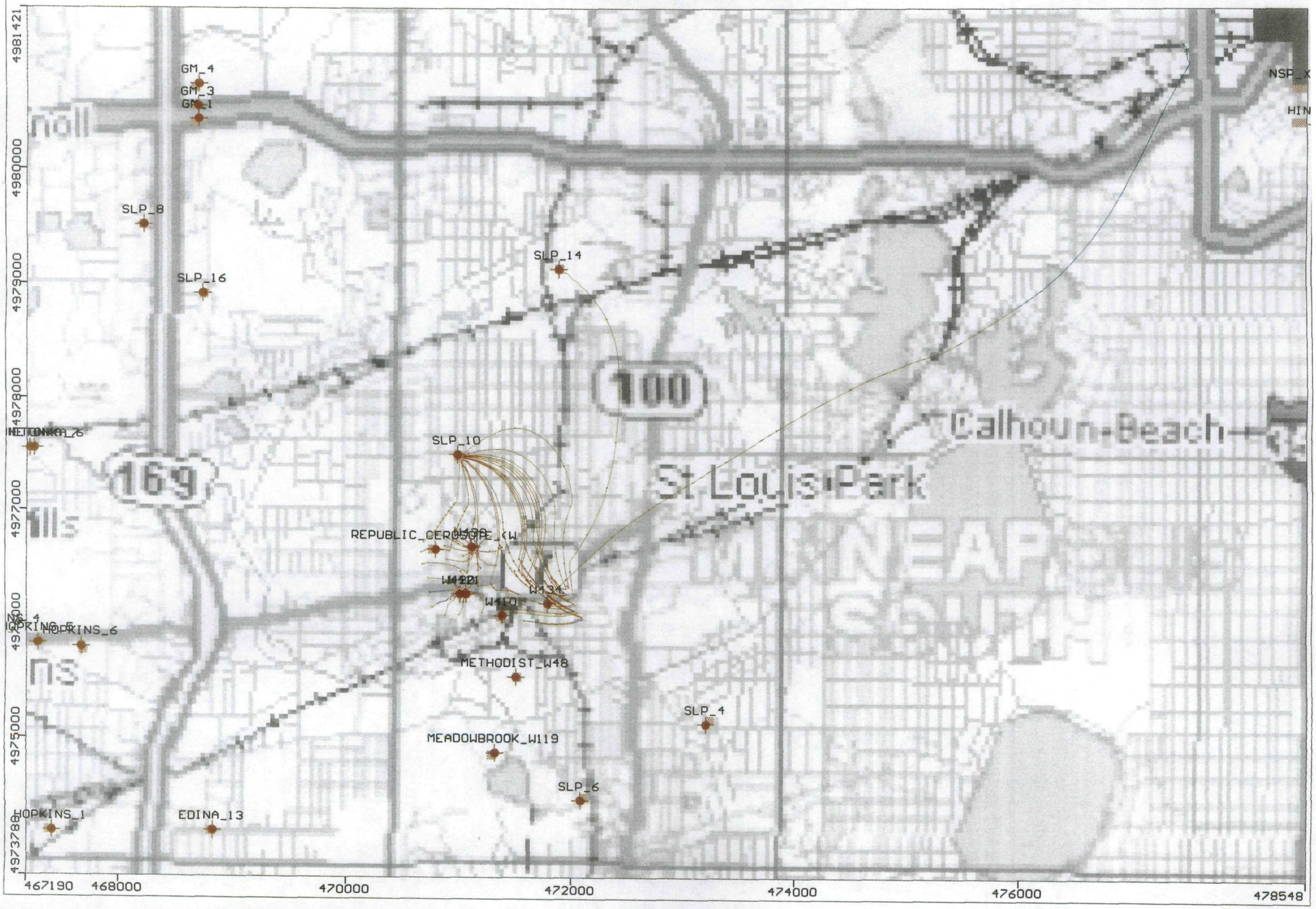

Figure 6-1c. MODPATH Calculated Particles' Pathlines - Particles Originating within the Drift PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off, Methodist Hospital Well (W48) Turned-On (300gpm - 1,635 m3/day) Scenario
(Scenario No. 3) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

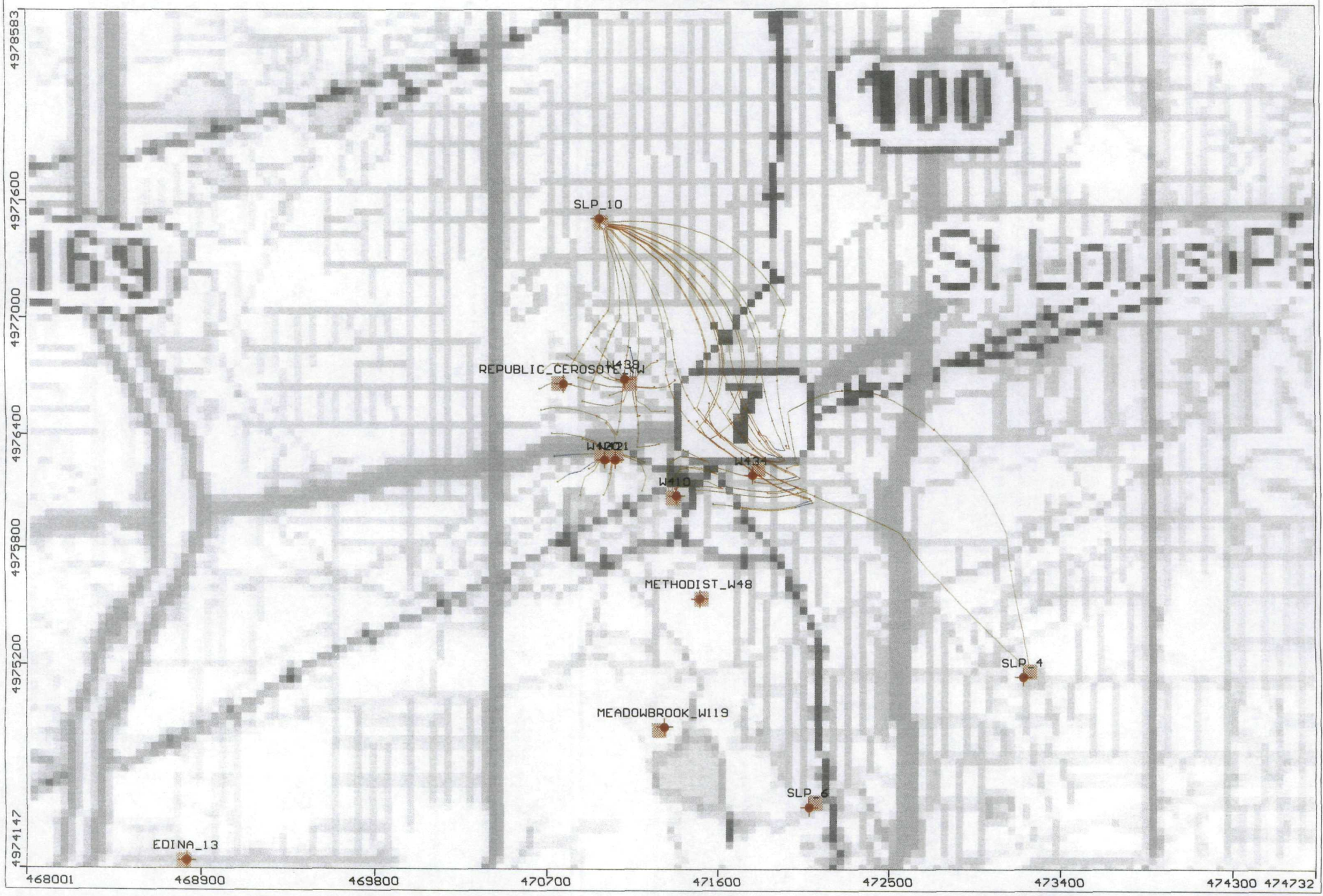

Figure 6-1d. MODPATH Calculated Particles' Pathlines - Particles Originating within the Drift PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off, Meadowbrook Golf Course Well (W119) Turned-On (300gpm - 1,635 m3/day) Scenario
(Scenario No. 4) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
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Figure 6-1e. MODPATH Calculated Particles' Pathlines - Particles Originating within the Drift PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off, St. Louis Park Municipal Well No. 6 (SLP6) Turned-On (762gpm - 4,157 m3/day) Scenario
(Scenario No. 5) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

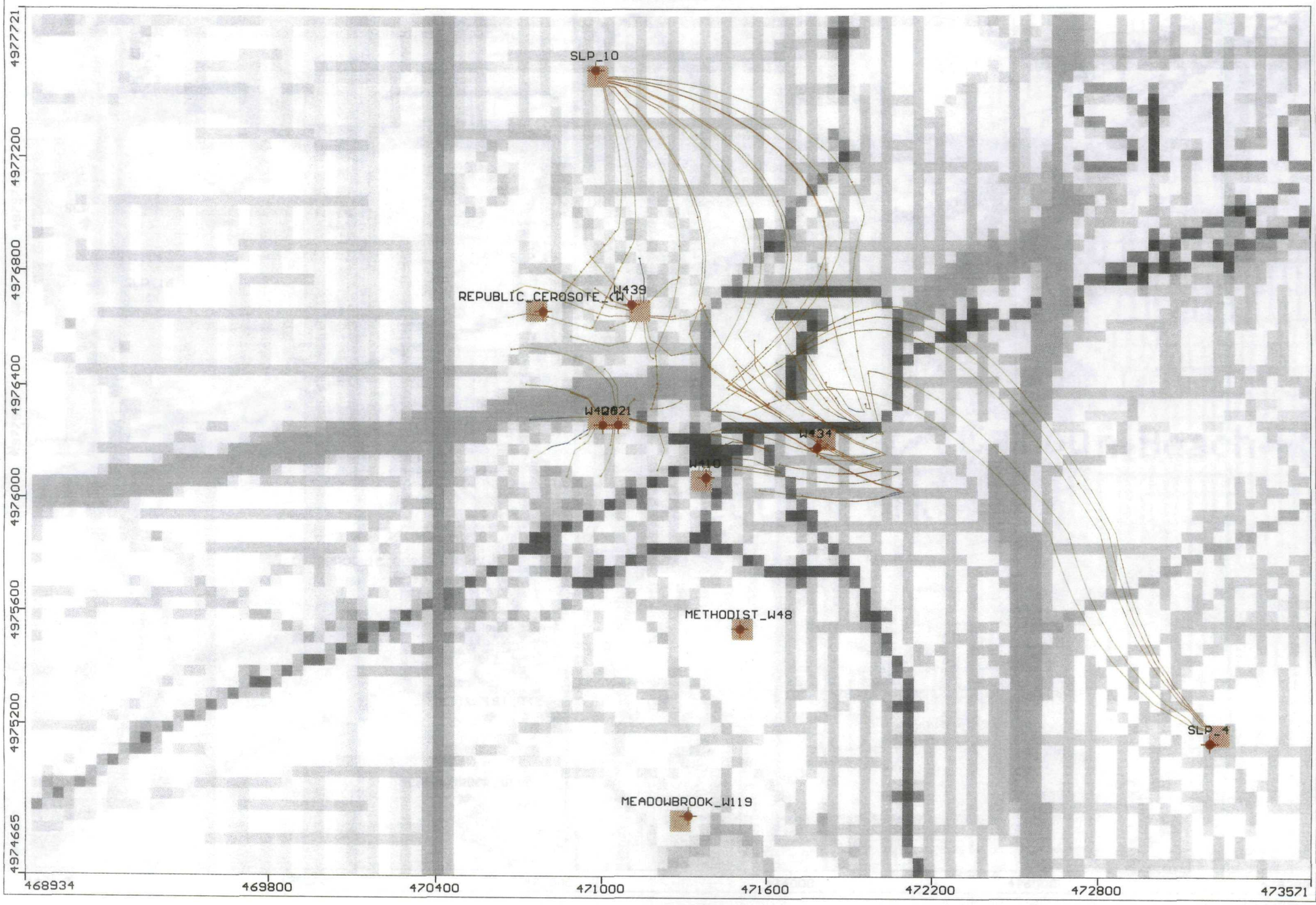

Figure 6-2a. MODPATH Calculated Particles' Pathlines - Particles Originating within the Platteville PAH and Phenolics' Plume.
Current Gradient Control System plus W434 Scenario (Scenario No. 1) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

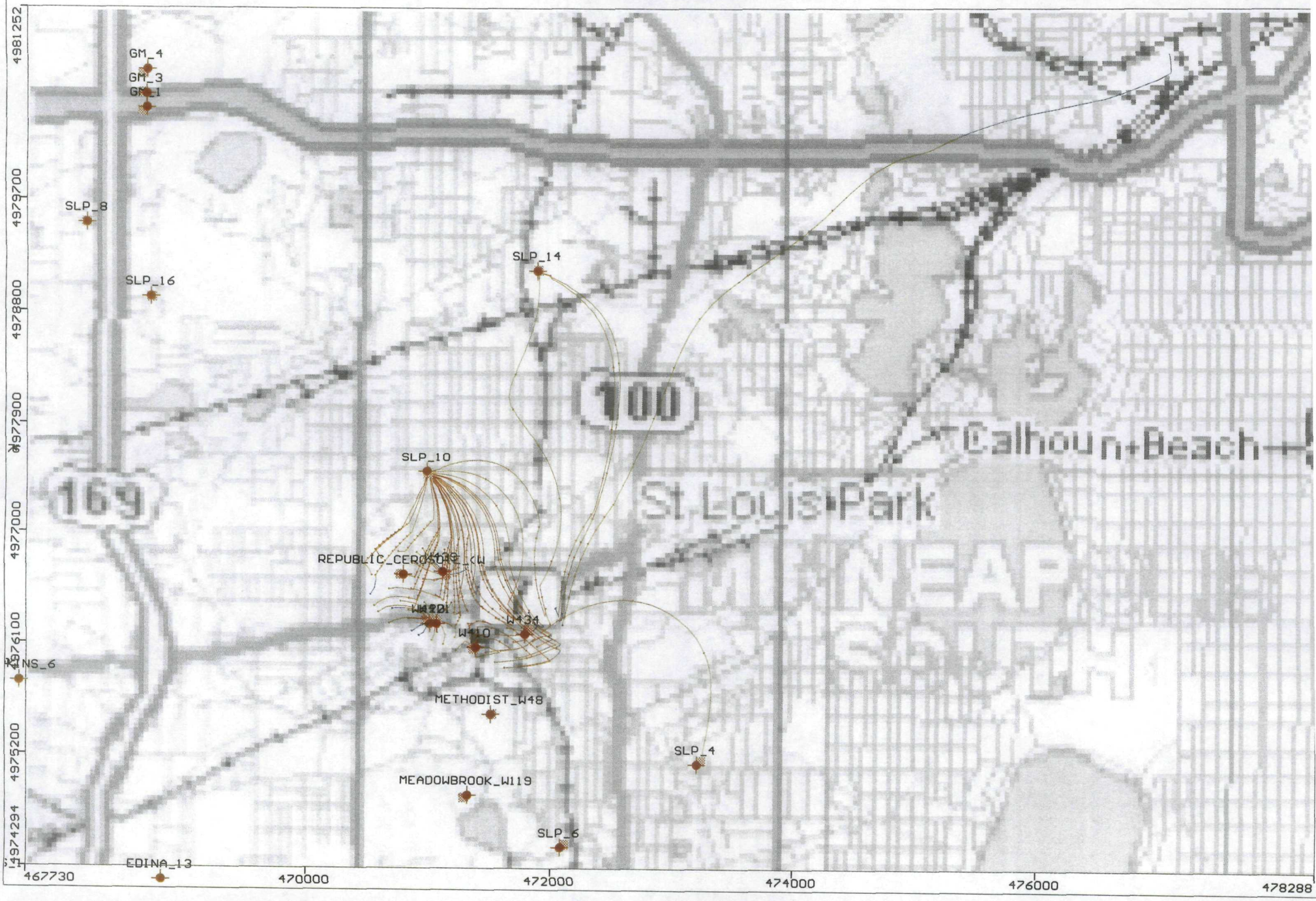

Figure 6-2b. MODPATH Calculated Particles' Pathlines - Particles Originating within the Platteville PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off Scenario (Scenario No. 2) - Low Transmissivity Model Version.

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Figure 6-2c. MODPATH Calculated Particles' Pathlines - Particles Originating within the Platteville PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off, Methodist Hospital Well (W48) Turned-On (300gpm - 1,635 m3/day) Scenario
(Scenario No. 3) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

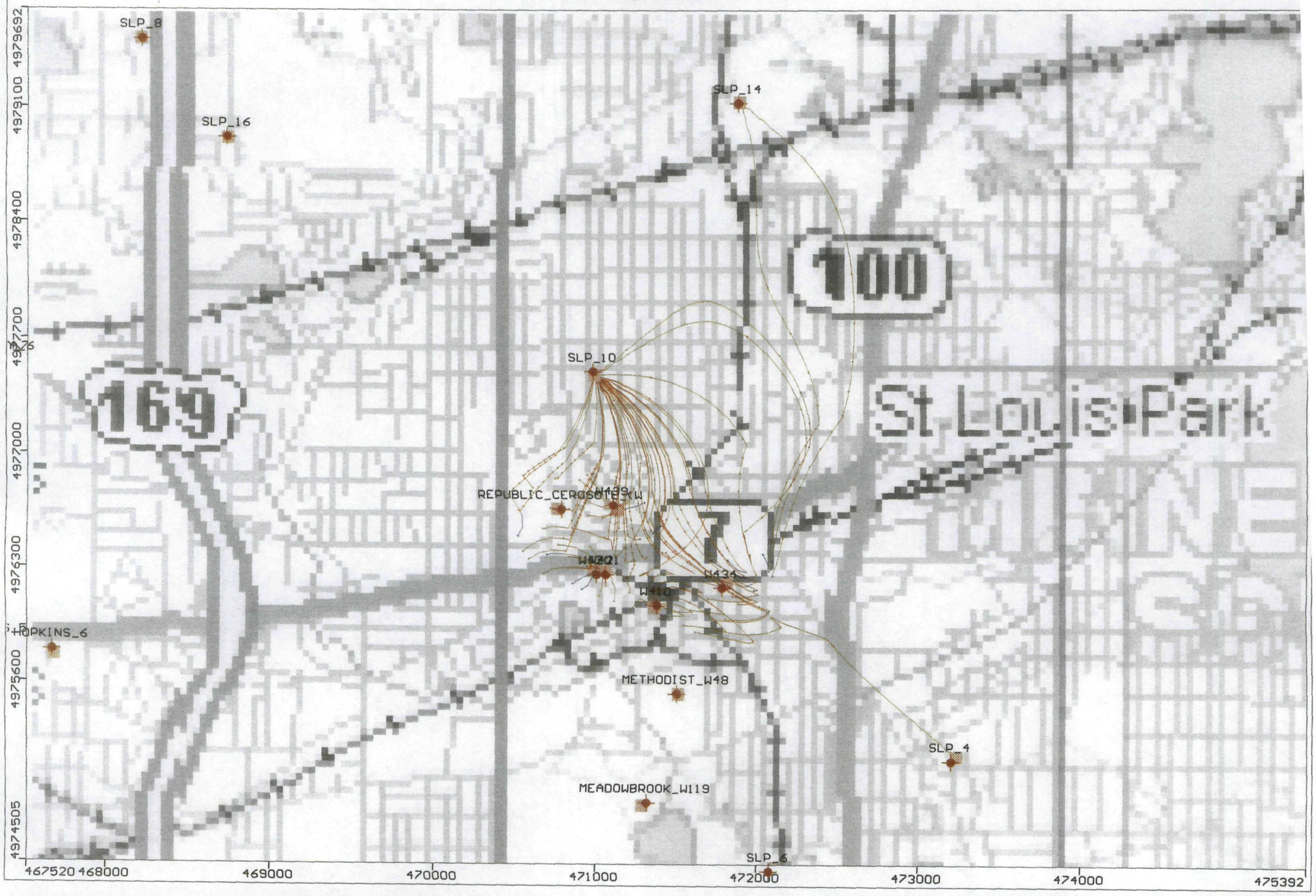

Figure 6-2d. MODPATH Calculated Particles' Pathlines - Particles Originating within the Platteville PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off, Meadowbrook Golf Course Well (W119) Turned-On (300gpm - 1,635 m3/day) Scenario
(Scenario No. 4) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

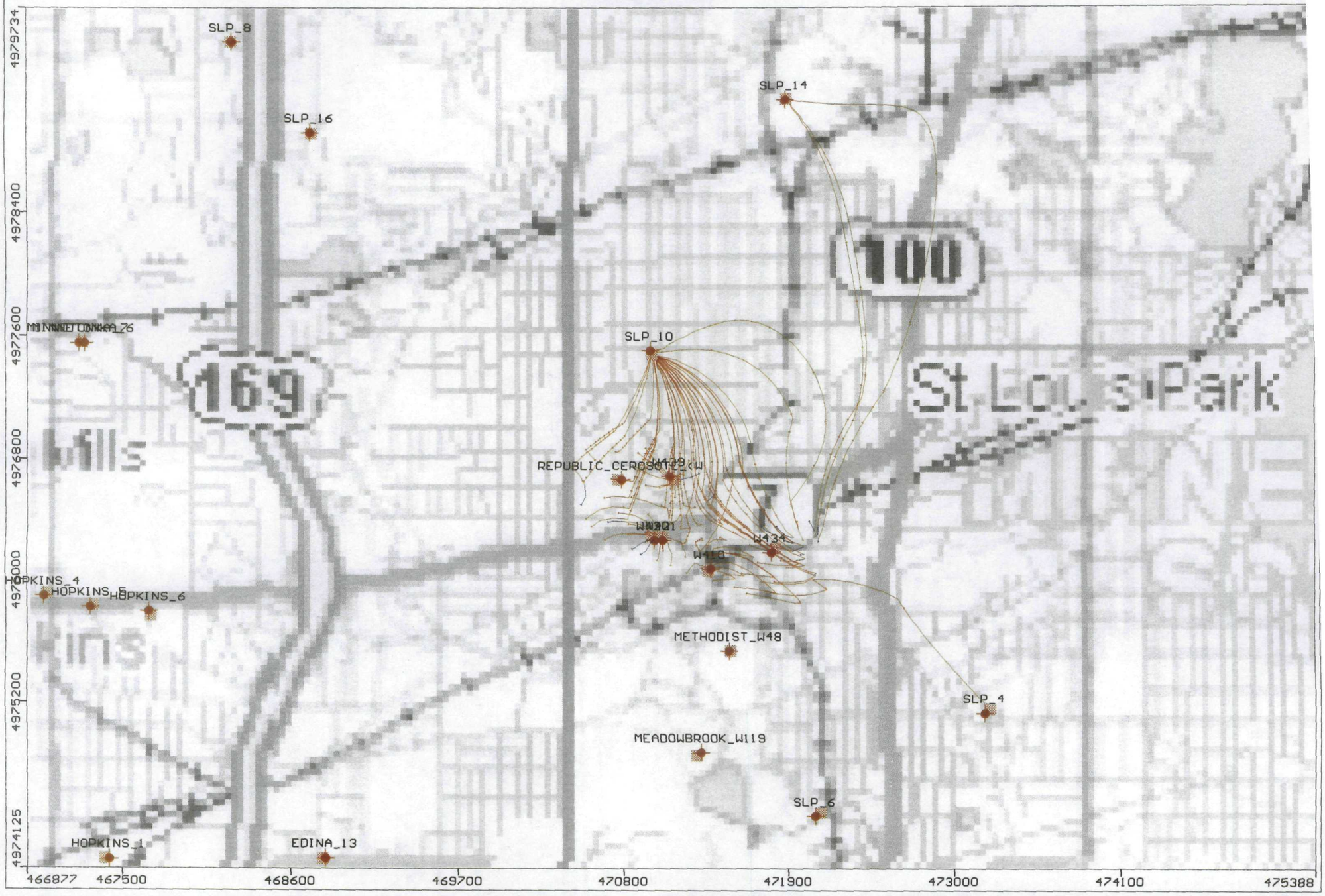

Figure 6-2e. MODPATH Calculated Particles' Pathlines - Particles Originating within the Platteville PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off, St. Louis Park Municipal Well No. 6 (SLP6) Turned-On (762gpm - 4,157 m3/day) Scenario
(Scenario No. 5) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

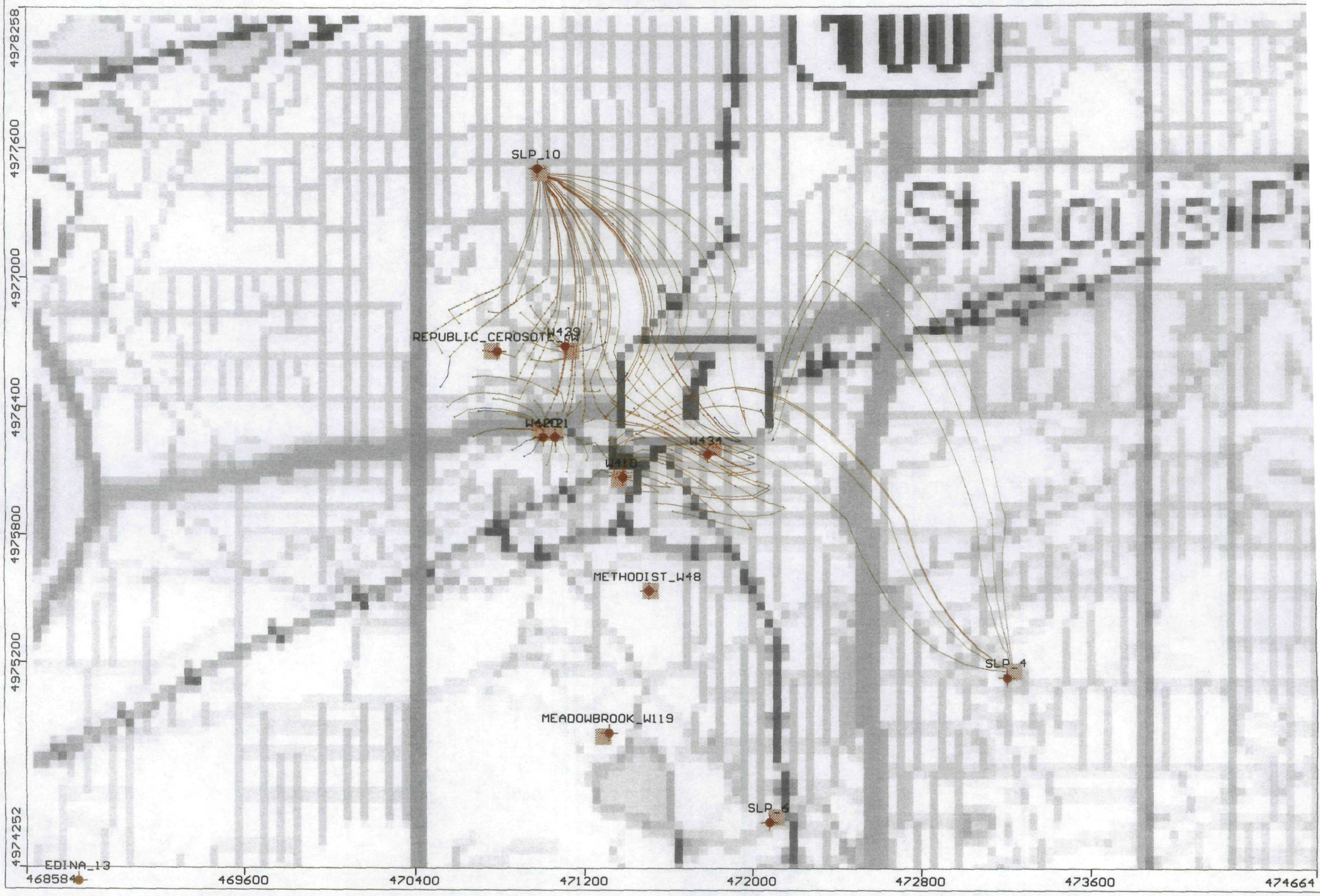

Figure 6-3a. MODPATH Calculated Particles' Pathlines - Particles Originating within the St. Peter PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off Scenario (Scenario No. 2) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

Figure 6-3b. MODPATH Calculated Particles' Pathlines - Particles Originating within the St. Peter PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off, Methodist Hospital Well (W48) Turned-On (300gpm - 1,635 m3/day) Scenario
(Scenario No. 3) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

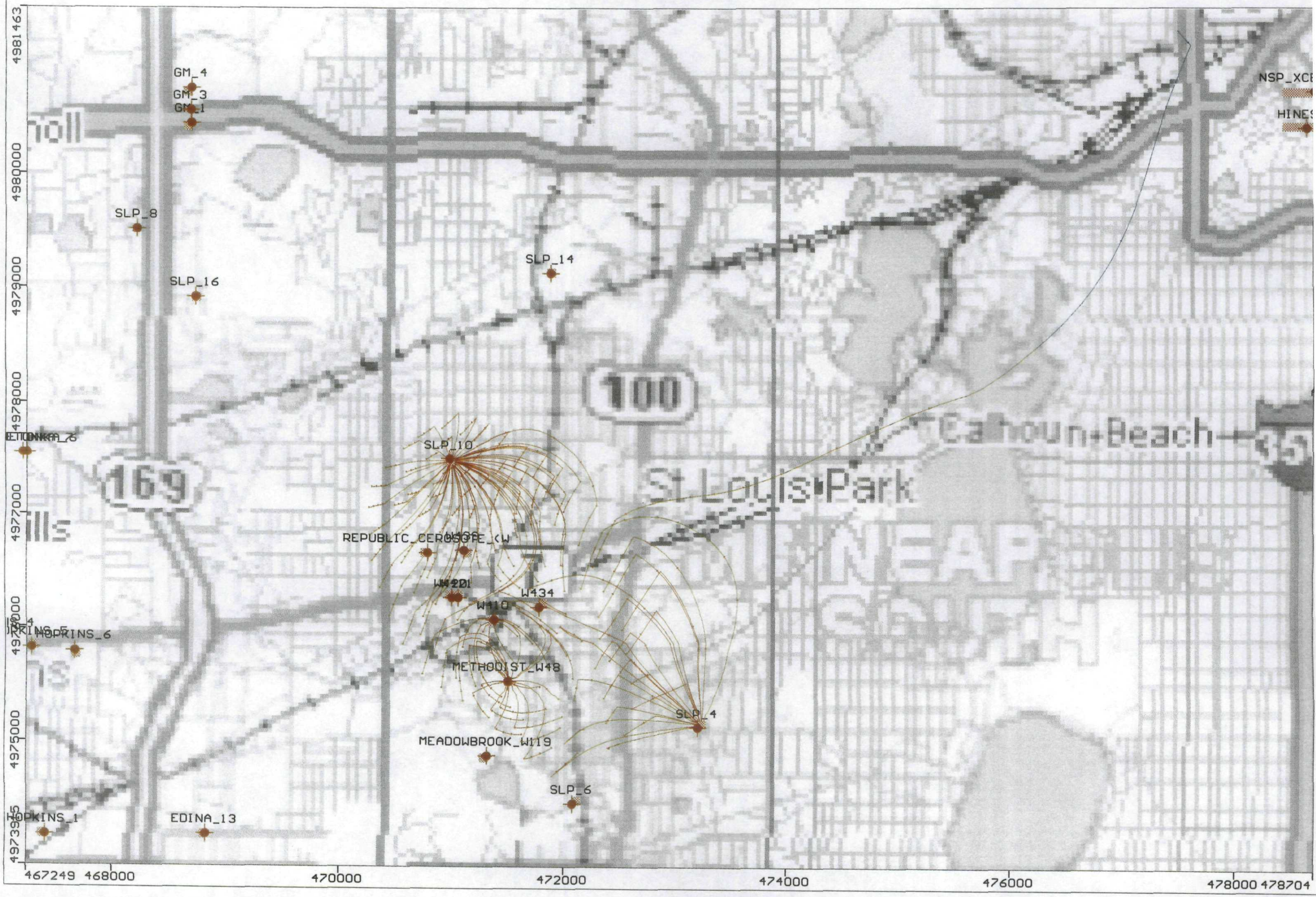

Figure 6-3c. MODPATH Calculated Particles' Pathlines - Particles Originating within the St. Peter PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off, Meadowbrook Golf Course Well (W119) Turned-On (300gpm - 1,635 m3/day) Scenario
(Scenario No. 4) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

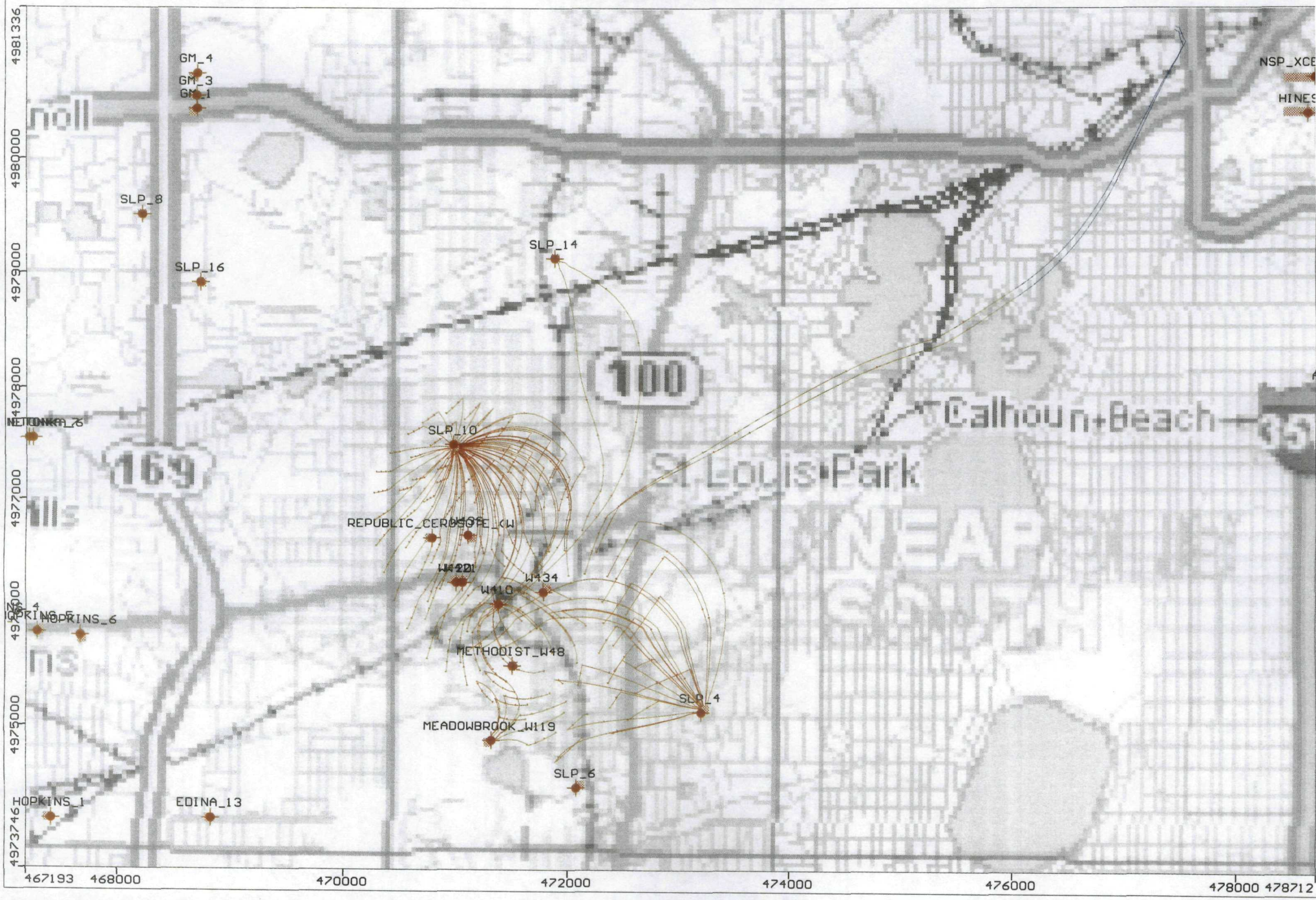

Figure 6-3d. MODPATH Calculated Particles' Pathlines - Particles Originating within the St. Peter PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off, St. Louis Park Municipal Well No. 6 (SLP6) Turned-On (762gpm - 4,157 m3/day) Scenario
(Scenario No. 5) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

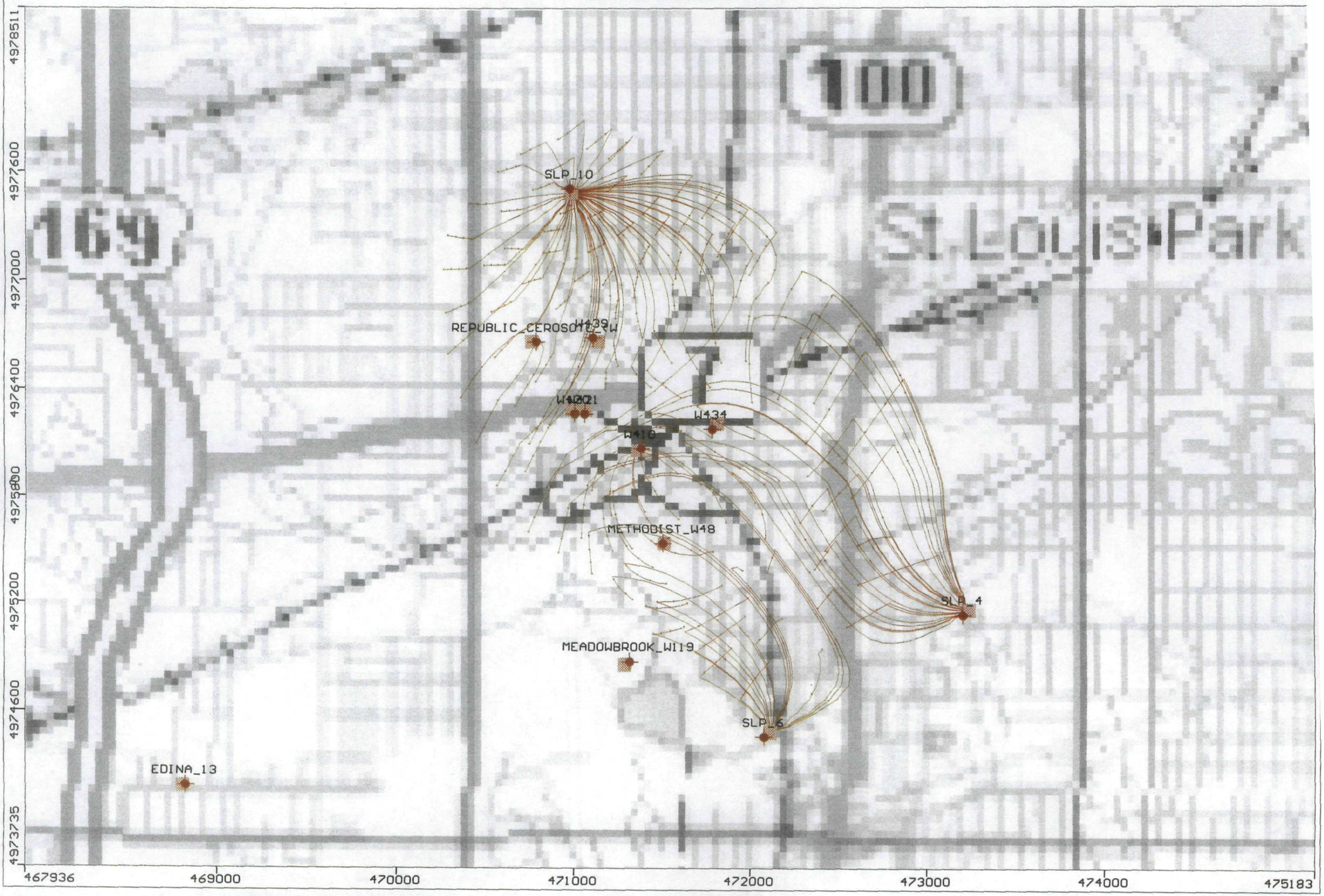

Figure 6-4a. MODPATH Calculated Particles' Pathlines - Particles Originating within the Prairie du Chien - Jordan PAH and Phenolics' Plume.
Current Gradient Control System, W434 Turned-Off Scenario (Scenario No. 2) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

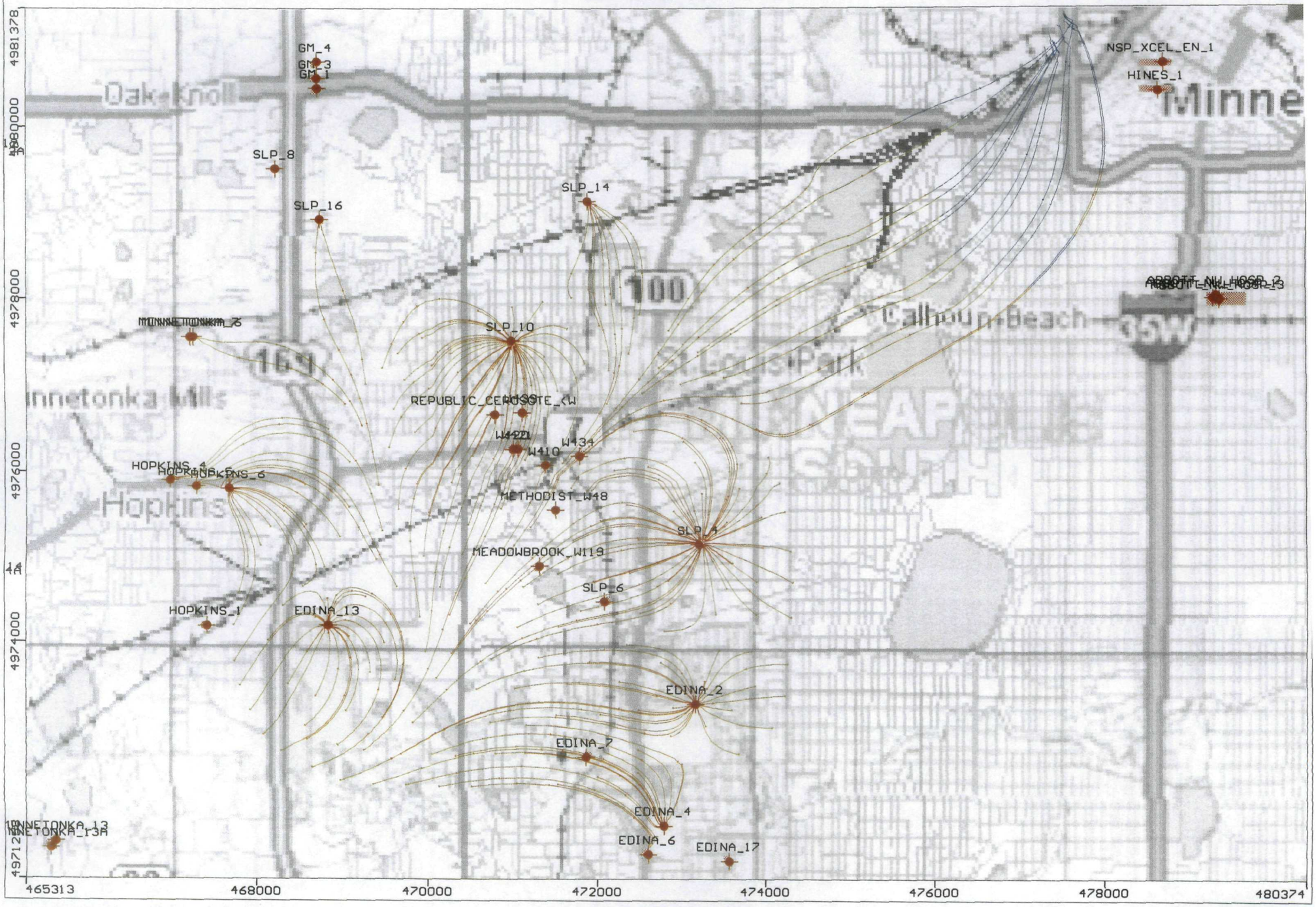

Figure 6-4b. MODPATH Calculated Particles' Pathlines - Particles Originating within the Prairie du Chien - Jordan PAH and Phenolics' Plume. Current Gradient Control System, W434 Turned-Off, Methodist Hospital Well (W48) Turned-On (300gpm - 1,635 m3/day) Scenario (Scenario No. 3) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

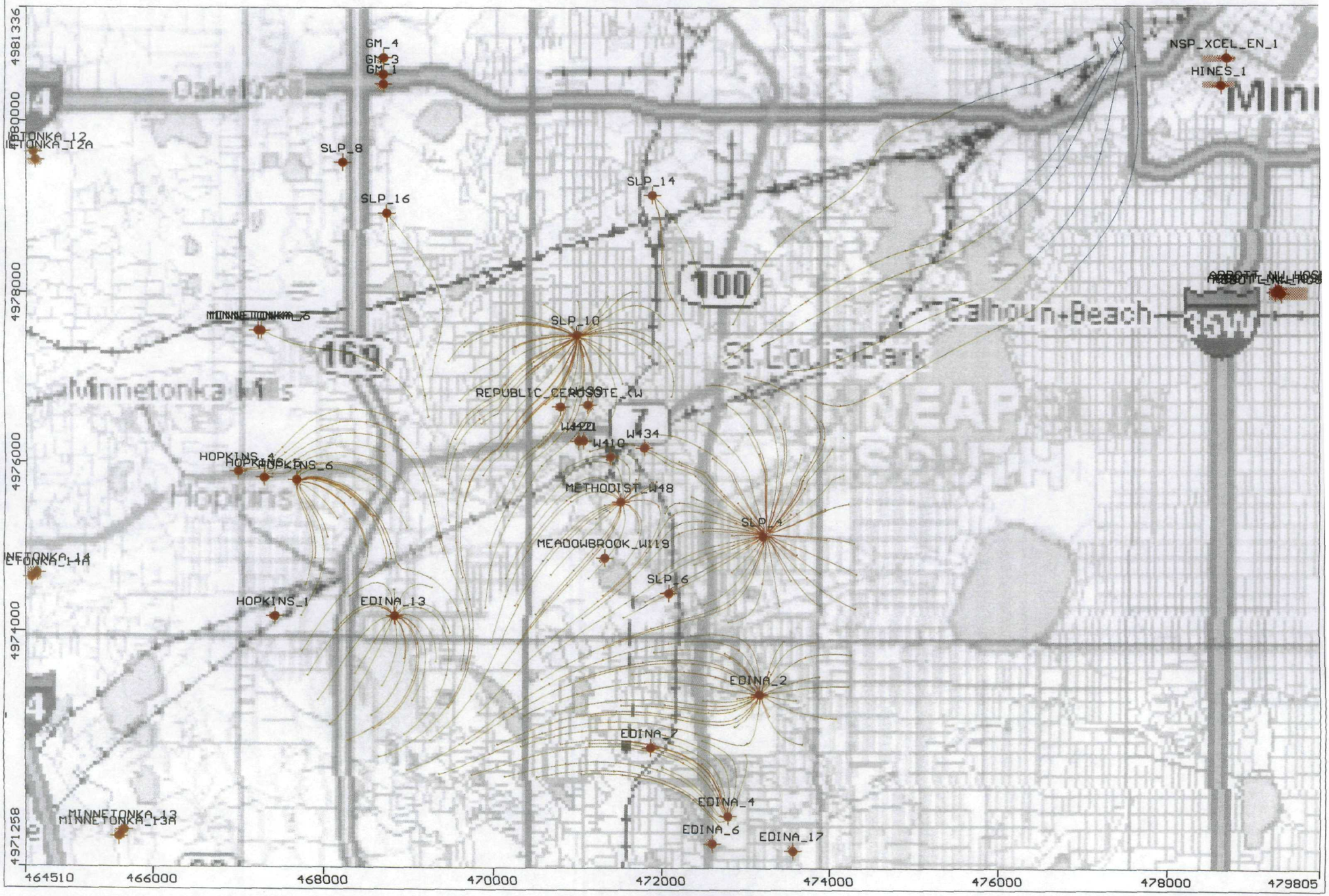

Figure 6-4c. MODPATH Calculated Particles' Pathlines - Particles Originating within the Prairie du Chien - Jordan PAH and Phenolics' Plume. Current Gradient Control System, W434 Turned-Off, Meadowbrook Golf Course Well (W119) Turned-On (300gpm - 1,635 m3/day) Scenario (Scenario No. 4) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

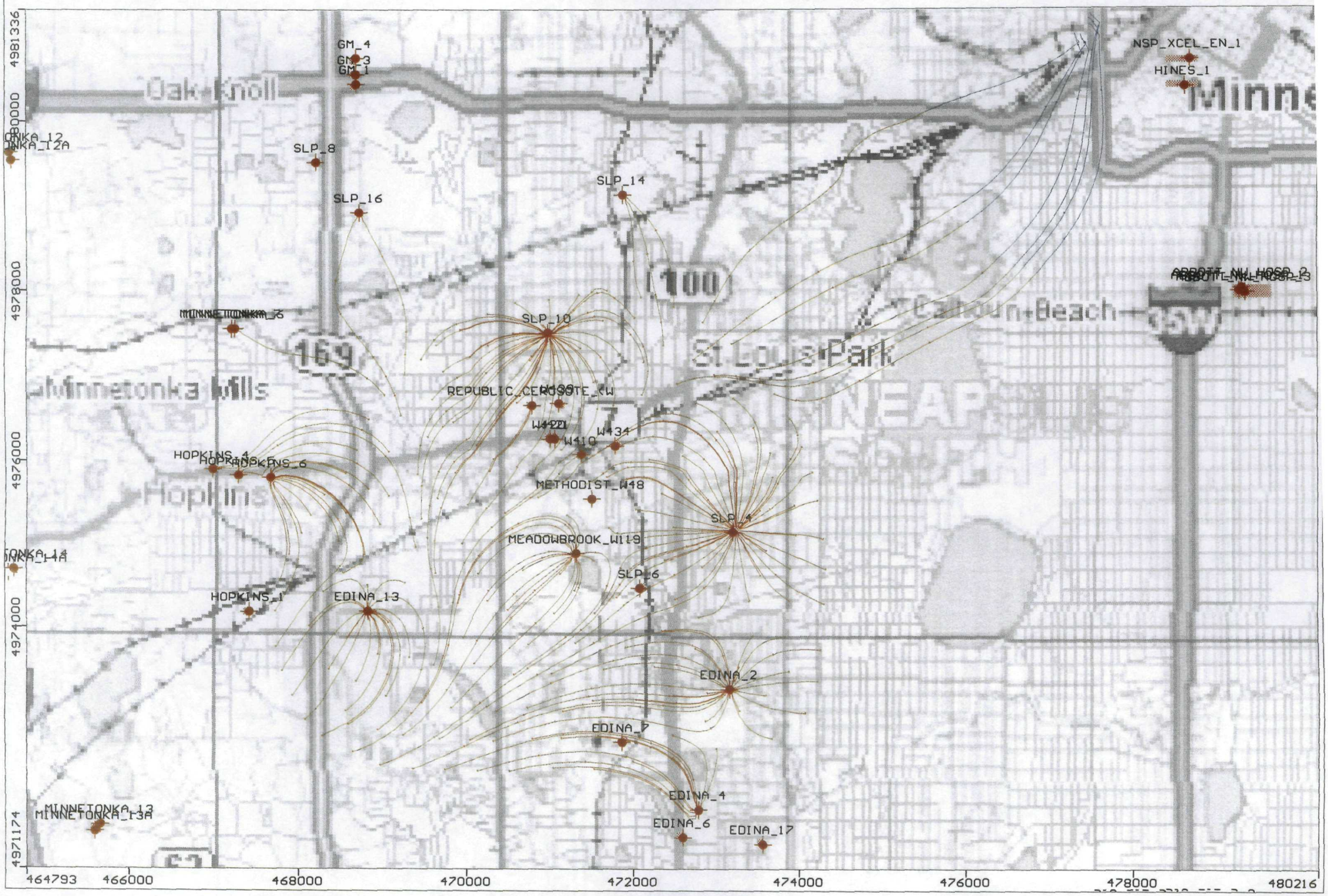

Figure 6-4d. MODPATH Calculated Particles' Pathlines - Particles Originating within the Prairie du Chien - Jordan PAH and Phenolics' Plume. Current Gradient Control System, W434 Turned-Off, St. Louis Park Municipal Well No. 6 (SLP6) Turned-On (762gpm - 4,157 m3/day) Scenario (Scenario No. 5) - Low Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
STS Project No. 99330-XF

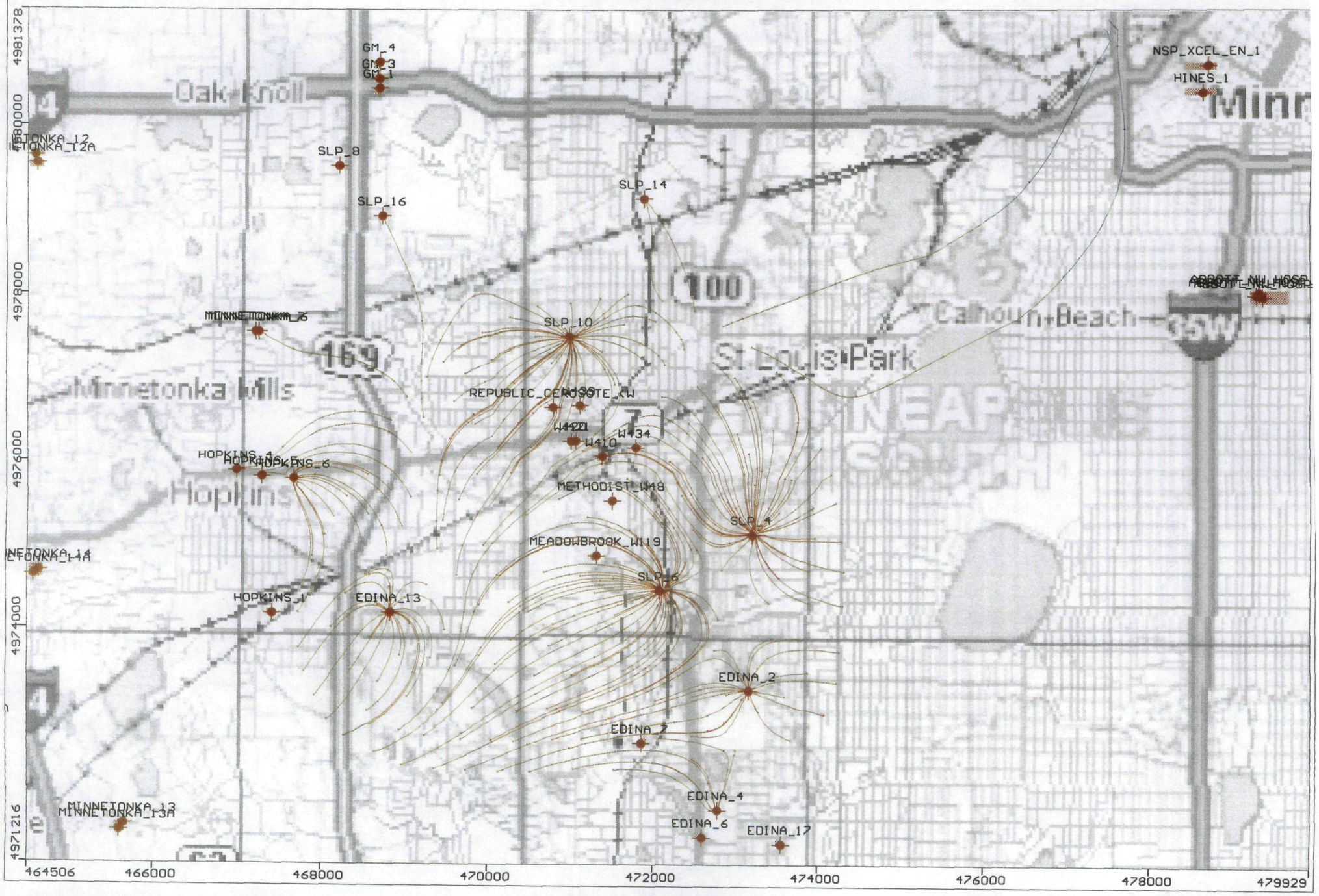

Figure 6-5. MODPATH Calculated Particles' Pathlines - Particles Originating within the Drift, Platteville, St. Peter and Prairie du Chien PAH and Phenolics' Plumes. Current Gradient Control System plus W434 and St. Louis Park Municipal Well No. 6 (SLP6) Turned-On (762gpm - 4,157 m3/day) Scenario - High Transmissivity Model Version.

Reilly Tar Site / Meadowbrook Ground Water Model
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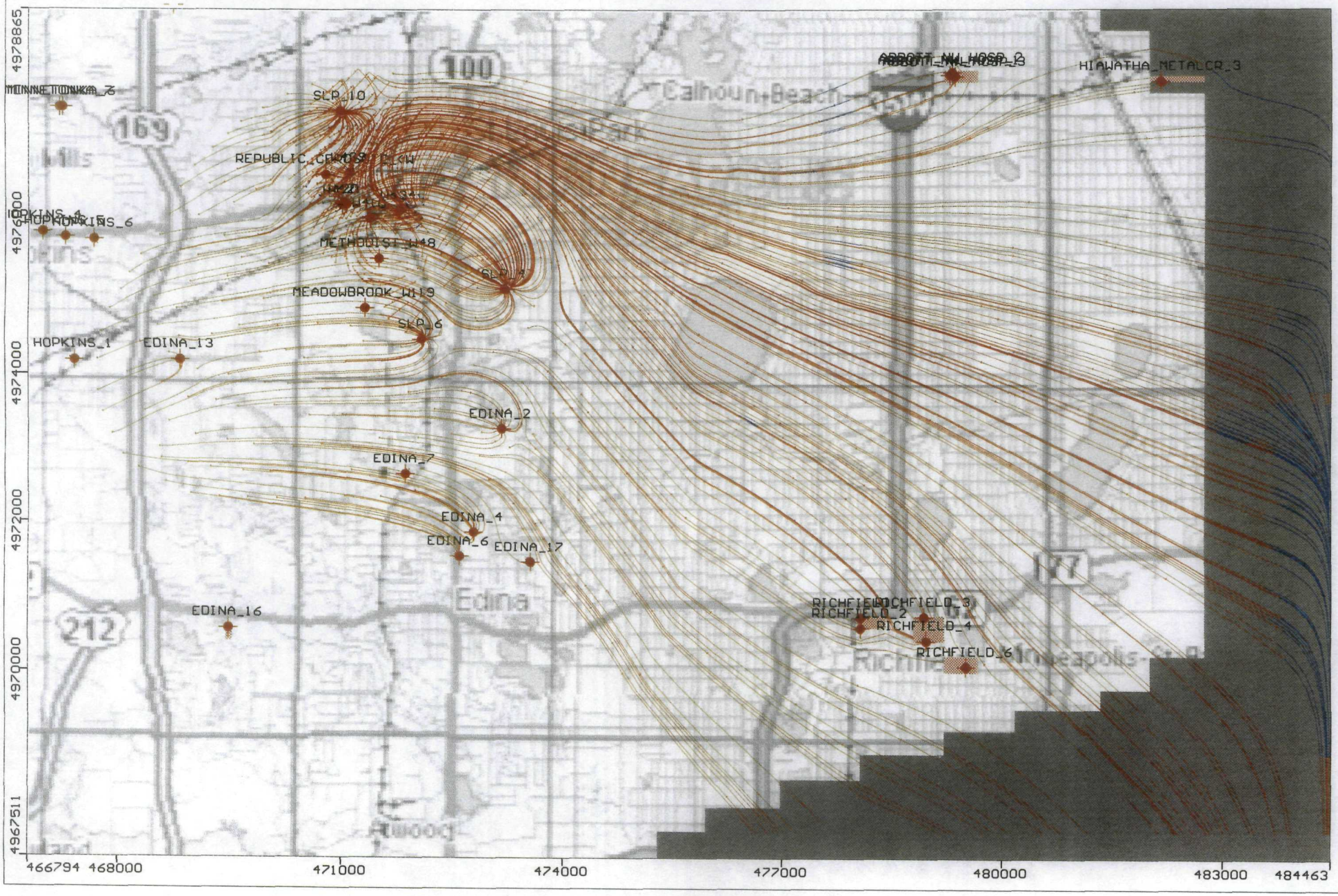

The Infrastructure Imperative

Appendix

Appendix A – Electronic Files (CDROM in Pocket)

The CDROM includes the two main sub-directories with the model files:

- Re7LLKSS – Low Transmissivity Model Version;
- Re7LHKSS – High Transmissivity Model Version.

Each of these main sub-directories contains sub-subdirectory which includes the files of transient model developed to simulate the 12 month long period of ground water flow and seasonal water level changes. The transient model files are named Re7LLKTRAN for Low Transmissivity Model Version and Re7LHKTRAN – High Transmissivity Model Version.