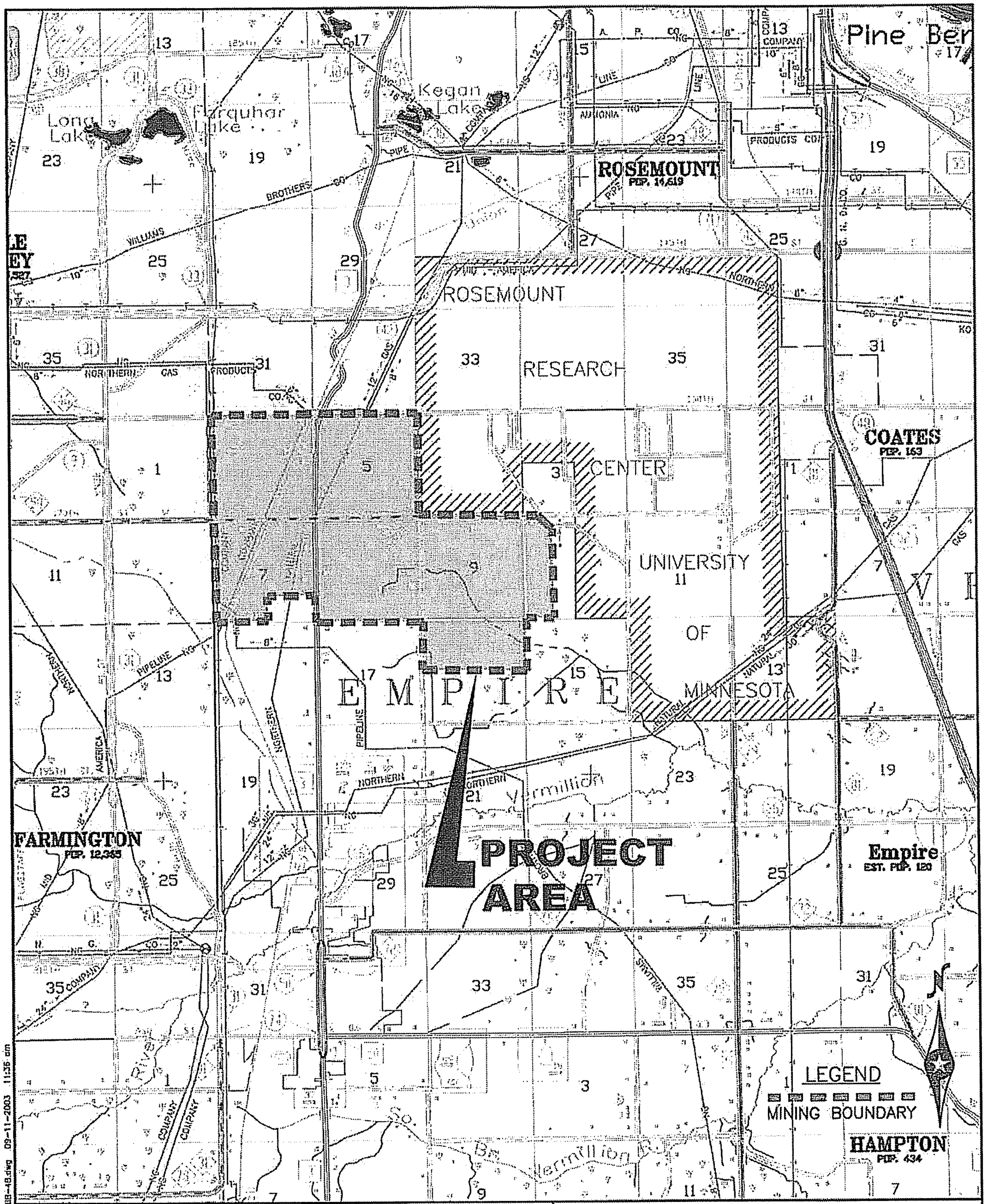
Appendix D

Empire Township EIS



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SAND & GRAVEL MINING AND ACCESSORY USES
EMPIRE TOWNSHIP, DAKOTA COUNTY

VICINITY MAP

JULY, 2003

EXHIBIT NO. 1B

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Revised Groundwater Impact Study

Sand & Gravel Mining and Accessory Uses
Empire Township, Dakota County, MN

Empire
Township

October 24, 2005

Prepared by

URS

700 Third Street South, Suite 600
Minneapolis, MN 55415-1199

TABLE OF CONTENTS

TABLES

FIGURES

1.0 INTRODUCTION

1.1 Project Description

A consortium of mine operators and landowners (Mining Consortium) propose to open new aggregate mines and expand existing aggregate Mining Areas to include a total area of approximately 3,600 acres in the northwest portion of Empire Township, Dakota County. Proposed mining will be consistent with Empire Township Ordinance Number 450 as amended and shall generally be consistent with ongoing practices at existing mines within and adjacent to the Mining Area. Routine functions as well as ancillary operations are described in detail below.

Mining and Aggregate Processing

- Clearing and grubbing the site of vegetation and structures, as necessary
- Relocation of infrastructure, as necessary
- Excavation and transport of the raw aggregate materials
- Excavation, stockpiling, and transporting of other soils materials, including clay and topsoil, which may be present within the Mining Area for shipment to sites out of the Mining Area or for use in reclamation
- Washing, grading and stockpiling aggregate materials for sale or later internal use
- Transporting and stockpiling waste "fines" for potential later use in reclamation
- Transporting finished aggregate materials internally for subsequent processing and to construction sites beyond the Mining Area
- Transporting, accepting, and stockpiling clean, compactable fill materials, typically referred to as "backhauled", for potential later use in reclamation
- Transporting, accepting, and stockpiling clean organic soil materials (i.e., peat) for potential later use in reclamation
- Eventual redistribution, compacting, grading of overburden and clean fill materials to reclaim the sites

Ancillary Manufacturing

- Manufacture and transport of asphalt products
- Manufacture, stockpiling, warehousing and transporting of ready-mixed concrete, bagged mortar products, concrete block, concrete pavers, concrete pipe, concrete plank, etc.
- Importing, grading, processing and stockpiling aggregates to be blended with local aggregates in the production of various products which will increase the effective use of the local aggregates and extend the life of the resource
- Transporting, accepting and recycling products returned from construction sites, including "come-back" asphalt, ready-mixed

concrete, bagged mortar products, concrete block, concrete pavers, concrete pipe, concrete plank, etc.
- Transporting, accepting, stockpiling and processing recycled construction materials for inclusion in new products

General Operations and Administrative

- Offices and sales areas
- Equipment maintenance areas
- Fuel storage and refueling areas

Currently, various companies included in the Mining Consortium either own, lease, or have purchase options on a majority of the Mining Area. Those properties not currently controlled by the mining companies are included in this study in recognition that future mining could occur. The mine operators with current and/or future interest or ownership in the Mining Area include:

- Aggregate Industries North Central Regional (Aggregate Industries)
- Cemstone Products Company (Cemstone)
- Dakota County Transportation Department (Dakota County)
- Fischer Sand and Aggregate Company (Fischer)
- Heikes Property (Heikes)
- McNamara Contracting, Inc. (McNamara)
- Tiller Corporation (Tiller)
- Don Peterson (Peterson)

1.2 Purpose of this Study

The various mine operators have investigated the potential for aggregate production in this area. In addition, the Minnesota Geologic Survey (MGS), Minnesota Department of Natural Resources (DNR), Metropolitan Council (METC) and local governments have conducted studies of available mineral aggregates in the metropolitan area. These studies, together with investigations conducted by mining companies, have revealed extensive reserves of mineral aggregates in portions of Empire Township. Over the next 30 to 40 years the Mining Consortium proposes to mine and process approximately 200 million tons of sand and gravel reserves within the Mining Area.

A Scoping Environmental Assessment Worksheet (Scoping EAW) was prepared for the proposed project in October 2003. Following review of this document, the Minnesota Environmental Quality Board (EQB) designated the review process as a "Related Actions Environmental Impact Statement (EIS)", since multiple companies and property owners are involved. A Scoping Decision Document was published in February 2004 declaring the need for an EIS and an outline of what it would address.

The Scoping Decision Document required that additional analysis be completed for the Mining Area, addressing a number of topics, including groundwater. The original Groundwater Impact Study dated January 2005 was prepared to provide an analysis of reasonable worst-case groundwater impacts in the Mining Area, and to identify options for mitigating potential impacts. The findings of the original Impact Study were incorporated into Empire Township Draft EIS (March 2005) and Final EIS (June 2005). As a result of agency comments made on the EIS documents, revisions were made to the original impact study, and are incorporated into this Revised Groundwater Impact Study.

1.3 Project Location and Setting

The project is proposed for Empire Township, which lies in the central portion of Dakota County, MN (**Figure 1R**). The proposed Mining Area is in the northwest portion of the township, occurring in all or part of Township (T) 114N, Range (R) 19W Sections 5, 6, 7, 8, 9, 10 and 16.

1.4 Study Area

The Vermillion River is one of the primary discharge areas for groundwater. It is necessary to understand the relationship between the river and groundwater that discharges on both sides of the river to be able to understand surface water and groundwater interactions on and around the proposed Mining Area. Therefore, it is necessary that the Study Area cover a large area, as shown in **Figure 2R.**

The Study Area also includes Wellhead Protection Areas (WHPAs) and Drinking Water Supply Management Areas (DWSMAs) for the city of Rosemount, located immediately north of the Mining Area (**Figure 2R**). These are found in T115N, R19W, Sections 27, 29, 30, 31, 32, 34 and T114N, R19W, Section 6. Rosemount wells 3, 7, 8, and 9, in addition to rural wells 1 and 2 are currently utilized to provide the City's drinking water. Portions of the DWSMA and WHPA for Rosemount Well 8 extend approximately 3,000 feet into the northwestern portion of the proposed Mining Area, encompassing a majority of Section 6.

1.5 Previous Studies

The studies, reports and databases listed below were reviewed as a part of the Groundwater Impact Study. Unless specifically referenced in the text the information was reviewed by the author but not necessarily included in the report. As expected, there is a wealth of information concerning the Vermillion River Watershed and the aquifers that underlay Dakota County. The information available covers an extensive period of time and is of varying quality and completeness. The author attempted to use the best available information in completing this report while avoiding the use of dated or incomplete information. The most recent information included in this report is from *A Soil Boring & Monitoring Well Installation Report, Empire Township, Minnesota* and *Scoping Environmental Assessment Worksheet, Sand & Gravel Mining & Accessory Uses,* which summarizes an extensive amount of site specific geological data collected to evaluate the mineral deposits. The author was able to make great use of the County Well Index and the Scott Dakota County MODFLOW Model.

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2.0 GROUNDWATER METHODS AND ASSUMPTIONS

A three-dimensional numerical groundwater flow model was developed to simulate the groundwater flow system in the Study Area. The model was developed using the USGS computer program MODFLOW (McDonald and Harbaugh 1988; 1996). MODFLOW is a standard, state of the practice, well-documented model code that simulates groundwater flow through three-dimensional, heterogeneous, anisotropic aquifer systems by iteratively solving the finite-difference approximation of the equation for groundwater flow. For this study, the model is designed as a steady-state flow model, because groundwater flow within the Study Area is generally stable. In addition, a simulated steady-state flow field is adequate for simulating the long-term fate and transport of potential impacting factors from the Mining Area.

For this study, the objective of this modeling is to evaluate and quantify the potential of the aggregate mining operations on local water resources. As a first step in the modeling process, potential impacts of Mining operations were identified. These potential impacts include changing of the groundwater flow regime in the Vermillion River Basin, possibly resulting in impact to local wetlands, municipal supply wells in wellhead protection areas, and local brown trout population of the Vermillion River. In addition, potential thermal impacts caused by excavation and aggregate washing were considered. After identifying these potential impacts, the numerical model was designed, set up, and calibrated to simulate the presently existing groundwater conditions. The model was then applied to simulate changes in the system resulting from mining (see Section 4).

2.1 Numerical Flow Model Design

The numerical flow model is a mathematical representation of the conceptual flow model. The design of a numerical model basically consists of three parts: (1) the configuration of the model, which represents the configuration of the aquifer; (2) boundary conditions, including sources and sinks, which represent the interactions of groundwater with internal and external water bodies; and (3) the parameters, which represent various properties of the aquifer.

2.1.1 Model Domain and Discretization

The domain is rectangular, encompassing the proposed Mining Area in addition to the surrounding areas they may be impacted by future mining operations. The rectangular model domain consists of a variable grid of model cells varying in dimension from 350 by 350 feet, refined to 100 by 100 feet in the project area to better simulate the hydrologic complexities of this area. The model domain consists of three layers, representing the three hydrostratigraphic units described in Section 3.2: (Layer 1) Glacial Drift-St. Peter Sandstone; (Layer 2) Prairie du Chien Group; and (Layer 3) Jordan Sandstone. Each layer contains 190 rows and 265 columns, and 151,050 active model cells. The numerical model domain and grid are shown on **Figure 3R**.

The groundwater mounds are interpreted to occur in a fictional model layer 0, which interacts with actual model layer 1 in a manner like rainfall infiltration (see **Figure 17R**). Water from layer 0 might cascade down at the edge of the Glennwood Formation, but the correct amount and location of water entering the top of layer 1 can probably be modeled adequately by using typical values of infiltration as if the Platteville-Glennwood is not there. Head values measured in or above the Platteville would not be part of the calibration target. Hydraulic conductivity values in model layer 1 below the Glenwood would reflect the full thickness of the St. Peter, and be on the upper end of reported values, rather than the lower end.

2.1.2 External Boundary Conditions

The model external boundary conditions represent the hydrologic interaction between the areas inside and outside of the model. The perimeters of each model layer were designated as specified head boundaries according to the interpreted groundwater potentiometric surface (surface that represents the level to which water will rise in tightly cased well; the water table is a particular potentiometric surface for an aquifer) shown in **Figure 4R**. The groundwater contour lines indicate that groundwater flows into the model domain from west and southwest and flows out of the model domain along the east and northeast margins. Along these boundaries, prescribed head boundary conditions were specified as the head values from the interpreted potentiometric surface. This allows groundwater flux (flow through a prescribed area over a given time)to enter or exit through the specified head boundaries as indicated by the interpreted potentiometric surface.

2.1.3 Groundwater Recharge

Groundwater recharge (net flux into aquifer system is positive) was specified for area recharge and floodplain recharge, and simulated as an areally distributed (spatially distributed) specified flux using the MODFLOW Recharge Package.

This recharge distribution is modified from the distribution delineated by Barr Engineering (1999) in the Scott-Dakota County model using sand-content maps provided by MPCA Metro Modeling Group. The distribution is generally the same given differences in scales between the two models and respective studies. In addition, the recharge distribution emphasizes the importance of recharge from the floodplains and wetlands. Areal groundwater recharge from precipitation in the proposed Mining Area is approximately 4.5 in/yr.

There is no direct information available to define floodplain and wetland recharge rate. Nonetheless, the modeled floodplain recharge zone is delineated based on the 100-year floodplain and wetland distribution delineated in **Figure 2R**. The rate of floodplain recharge is calibrated as 9 in/yr. This rate represents the upper limit of recharge available from precipitation after allowing for evapotranspiration (Schoenberg, 1990). The distribution of recharge simulated in the model is depicted in Figure 18R.

2.1.4 Vermillion River and Associated Tributaries

The perennial portions of the Vermillion River and associated tributaries are represented as a head-dependent boundary condition using the MODFLOW River Package. Specification of model river cells is shown in **Figure 3R**. The purpose of this package is to simulate flow of water between surface water features and groundwater systems. The rate and direction of flow is dependent upon the head gradient between the river and groundwater. Flow between the river and aquifer is assumed to occur in one-dimension.

Based on field observations and streamflow data from the USGS gauging station located southeast of the project area, the river stage was assigned as 3.0 feet above the topographic surface. However, field observations suggest the river stage is approximately 1.0 foot in depth upstream near the confluence of North Creek. Flow rates (described in Section 3.6.1) were used as targets for model calibration. The conductance of the river cells was calibrated with specified constraints during model calibration.

2.1.5 Wetlands

Groundwater also discharges (next flux of water into the aquifer system is negative, i.e. losing water) to wetlands where the groundwater table intersects the ground surface. Wetlands were simulated using the MODFLOW DRAIN package. Specification of model drain cells is shown in **Figure 3R**. The purpose of this package is to simulate groundwater flow discharging to the wetlands. The distribution of the wetlands simulated as groundwater discharge features is based on a map of delineated groundwater dependent natural resources provided by EOR (2004a). The bottom elevations of the drain cells were specified approximately according to the topographic surface at the appropriate locations.

Because information for the wetlands is limited, the conductance for these features was specified between 2,500 to 5,000 ft^2/day, accordingly, without model calibration.

2.1.6 Pumping Wells

In the model, pumping wells are represented as a specified flux boundary using the MODFLOW Well Package. Wells are assigned to the model layer based on the stratigraphic position of the pumping well screen. For example, wells screened and pumping from the Jordan Sandstone are assigned to layer three of the groundwater model. Pumping rates are assigned based on rates provided by the Minnesota Department of Health in the Scott-Dakota County regional groundwater modeling report (Barr Engineering, 1999).

2.1.7 Hydraulic Parameters

In the numerical flow model, hydraulic parameters, such as distribution of hydraulic conductivity (a coefficient of proportionality describing the rate at which water can move through a permeable medium), vertical anisotropy (exhibiting properties with different values when measured in different directions) and conductance of model river cells were adjusted during model calibration. The final selected hydraulic parameters are discussed in Section 2.2.2.

2.2 Calibration Strategies

Model calibration is an important process to adjust various parameters, boundary conditions, and hydraulic stresses to make the model reflect actual site conditions. Parameter values are adjusted consistent with available data to match calibration targets to a reasonable degree. Model calibration is a process that allows examination and improvement of the conceptual model. Only a calibrated model is credible for use to perform model prediction simulations. The overall goal of model calibration was to make the model results match the observed flow conditions.

2.2.1 Calibration Targets

The flow model calibration targets include not only the measured hydraulic heads at monitoring wells, but also (1) the groundwater flow pattern, hydraulic gradients, and flow pathways; and (2) the measured or estimated flux. The flow model calibration targets included:

- Water levels from newly installed Empire monitoring wells and available water levels from the Minnesota County Well Index
- Estimated groundwater discharge rates to the Vermillion River between gauging stations BSC2 and USGS Station
- Estimated groundwater discharge rates to North Creek between gauging stations CHP3 and 801
- Estimated groundwater discharge rates to Center Creek between gauging stations PKN1 and 801
- General trend of vertical hydraulic gradients

2.2.2 Calibration Parameters

The flow model calibration parameters include:

- Horizontal hydraulic conductivity distribution in all three model layers
- Vertical anisotropy of horizontal hydraulic conductivity versus vertical hydraulic conductivity, (*i.e.*, Kx/Kz; Ky/Kz), assumed to be uniform over each layer
- Distributed conductance for all river cells
- Distributed conductance for all drain cells (wetlands)

During model calibration, the adjustment of these parameters is targeted to meet the various calibration targets (Section 3.2.1) and is bounded by specified upper and lower limits, which are chosen based on available information and understanding of the hydrogeologic system.

2.3 Flow Model Calibration Results

The model calibration results are evaluated from various aspects, including comparison to the observed hydraulic heads, groundwater potentiometric surface, horizontal and vertical hydraulic gradients, groundwater flow pathways, estimated flux, and overall mass balance.

2.3.1 Simulated Potentiometric Surface and Hydraulic Heads

Figure 5R presents the simulated groundwater contours in comparison with the interpreted contours from **Figure 4R**. The general flow patterns match reasonably well with flow converging from the west and southwest toward the Vermillion River and northeast toward the Mississippi River. The hydraulic gradient distributions generally match well also, with fairly consistent gradients away from the creeks and variable gradients near and along the floodplains. As expected, the model shows a relatively poor match at topographic highs (groundwater mounds) where data is unavailable, and the mounds represent perched conditions not sufficiently connected to the regional groundwater system. While the model simulated heads do not match the data exactly, the general flow pattern is well represented.

Comparison of measured hydraulic head values to those simulated by the model is the primary basis for judging the calibration results. The overall standard deviation versus the head range in the entire model domain is 0.047. The standard deviation versus the hydraulic head range of the model in Layer 1, where most of the wells are located, is 0.040; 0.057 in Layer 2; and 0.135 in Layer 3. Based on the rule of thumb that the standard deviation versus head range should be equal to or less than about 0.10, the calibration results are considered adequate.

The match of hydraulic heads in layers 2 and 3 is not as good as for Layer 1, however, the overall flow pattern to the northeast is well represented. The poorer fit in these layers is primarily due to the limited understanding of local heterogeneity in the deeper zones. In addition, there are a limited number of hydraulic head measurements in the deeper aquifers in this region. And those that do exist may be in question. For example, in an area where hydraulic heads should be approximately 820 ft based on average regional hydraulic gradients, two adjacent wells from the Minnesota County Well Index are located approximately 500 feet apart exhibit water levels of 795 feet and 915 feet – phenomenon that appears unrealistic given the general knowledge of the flow system. Consequently, the model predicted hydraulic head values for the lower model layers are subject to large uncertainties.

2.3.2 Simulated Vertical Hydraulic Gradients

The general spatial trend of vertical hydraulic gradients is important to migration of potential contaminants that may enter the groundwater system during mining operations; thus, it is necessary to be simulated in the model calibration. However, the local vertical hydraulic gradient is also controlled by the local heterogeneity, which is not well understood and not possible to be simulated adequately at the scale of this model. Therefore, comparison of model simulated and observed vertical hydraulic gradients focused on the general spatial trend and the direction of vertical gradients rather than gradient values.

The regional vertical gradients are simulated reasonably well, upward gradients along the Vermillion River and adjacent floodplains and downward gradients away from the river. Discrepancies between measured and simulated vertical gradient may be due to local heterogeneity beyond current understanding of the hydrologic system, or model errors. It should be noted that even though a comparison of magnitude of vertical gradient is not presented, it was utilized in critical areas in the model calibration.

2.3.3 Model Mass Balance

Under steady-state, the inflow to the model and outflow from the model should be balanced. For the calibrated model, the overall simulated water budget is as follows:

Table 2-1: Model Mass Balance Summary

Sources and Sinks	Inflow to Model		Outflow from Model	
	(ft^3/day)	(%)	(ft^3/day)	(%)
Specified Head Boundaries	1,258,057	35.7	2,157,159	61.0
Recharge	1,943,686	55.2	0	-
River	318,727	9.1	613,512	17.3
Drains (Wetlands)	0	-	766,034	21.7
Total	**3,520,470**	**100**	**3,536705**	**100**

Note: Percent Error is –0.0046

According to this water budget, the primary source of water to the groundwater system is groundwater recharge, including areal recharge and floodplain recharge. The primary groundwater discharge component is discharge to the rivers and lateral flow out of the model domain to the northeast through the specified head boundaries.

2.3.4 Simulated Groundwater Discharge to Vermillion River and Tributaries

Simulated groundwater discharge to creeks depends on the specified river stage elevations, calibrated creek conductance, simulated groundwater levels, and calibrated hydraulic conductivity of the aquifer. In addition, estimated discharge includes discharge to the river channel in addition to wetlands located along the banks of the river drainages which are interpreted to contribute to the overall discharge. Table 2-2 presents a summary of simulated discharge to select portions of the Vermillion River and associated tributaries.

Table 2-2: Summary of Model Simulated Groundwater Discharge to the Vermillion River and Associated Tributaries

River Segment	Model Simulated Net Discharge (ft^3/day)	Model Simulated Net Discharge (cfs)	Estimated Discharge[1] (cfs)	Estimated Discharge[2] (cfs)
Vermillion River, between BSC2 and USGS Station.[3]	621,947	7.2	3.6	10 - 25
North Creek, between CHP3 and 801	94,833	1.1	2.5	0.01 - 10
Middle Creek, between PKN1 and 801	184,228	2.1	2.3	25 –40

[1] Baseflow estimates based on average unit discharge of 1.20 cfs/mile obtained by the Minnesota Department of Health from the Metropolitan Council.
[2] Baseflow estimates from EOR (2004).
[3] Includes contribution from Unnamed Tributary 1.

As indicated in Table 3-3, North Creek discharge is within the range provided by EOR (2004) and comparable to the estimate of MDH. Simulated baseflow (flow solely attributed to groundwater flow) to Middle Creek is comparable to the estimate of MDH, but much lower than the estimate of EOR (2004). The baseflow estimate of 25 to 40 cfs for Middle Creek (EOR, 2004) may be unreliable. One of the gauging stations used for estimates was also used for an estimate of baseflow for a downstream section of the Vermillion that estimated a loss of 15 to 30 cfs. An unlikely scenario given that the majority of the upper reaches of the Vermillion River and its associated tributaries maintain a relatively uniform discharge rate of 0.01 to 10 cfs. Thus, the estimated discharge provided by MDH is considered a more reliable estimate at this time.

The baseflow estimate of the Vermillion of 7.2 cfs is lower than estimated range by EOR (2004), but is greater than the estimated discharge by MDH. To achieve discharge rates of 10 cfs or higher requires using river conductance values that are unrealistic. The discharge estimate of 7.2 cfs may be considered representative of very low baseflow conditions, which in turn, will add to the conservatism in estimates on the impacts to surface waters presented in Section 4.

The groundwater model only simulates a small portion of the Vermillion River. Total baseflow in the Vermilion River is the sum of the model-simulated discharge in addition to discharge to the river that is upgradient of the model domain. Estimates of discharge upgradient of the model domain using both information from EOR and MDH indicate approximately 30 cfs of baseflow in the Vermillion and its associated tributaries. This coupled with the 10.4 cfs of discharge in the model indicates a simulated baseflow of approximately 40 cfs observed at USGS gauging station 05345000. This is comparable to the 10-year average of 38 cfs (EOR, 2004).

Simulated baseflow to Butler Pond is approximately 0.18 cfs. However, this is primarily a man-made surface water feature and a net source of recharge. Simulated leakage to the aquifer is approximately 0.47 cfs.

2.3.5 Simulated Discharge to Wetlands

Simulated groundwater discharge to the wetland areas depends on the specified elevation, calibrated drain conductance, simulated groundwater levels, and calibrated hydraulic conductivity of the aquifer. Wetlands that are located along the banks of the perennial streams are interpreted to contribute to the overall baseflow in the river channels. This section is intended to evaluate the simulated flow rates to the wetlands located away from the major rivers.

The following are simulated discharge rates to select wetland locations within the model domain:

- Simulated discharge to wetlands north of Butler Pond is 1.80 cfs
- Simulated discharge to wetlands south of Butler Pond along the tributary is 0.75 cfs
- Simulated discharge to wetlands south of Butler Pond and west of the confluence of the Vermillion River and Unnamed Tributary 1 is 0.36 cfs
- Simulated discharge to wetlands south of Vermillion River is 0.15 cfs

No data are available regarding discharge rates to the local wetlands. Thus, the simulated flow rates cannot be verified. Therefore, assessment of potential impacts from the proposed mining operation presented in Section 4 should be considered in terms of a percent reduction in flow rates as opposed to changes in absolute flow rates.

2.3.6 Calibrated Hydraulic Conductivity Distribution

Model calibrated hydraulic conductivity distribution for Layer 1 is presented in Figure 7R. The range and general order of magnitude of calibrated hydraulic conductivity distributions is relatively consistent with the available hydraulic field test results. In general, the calibrated K-values for Layer 1 range from approximately 10 to 110 ft/day. As expected, higher hydraulic conductivities lie within in the floodplain alluvium and throughout the Superior Lobe tills. Lower conductivities correspond to areas of elevated topography and locations of “Old Gray” Till (discussed further in Section 3.1.2). Due to lack of sufficient data constraints, uniform values of 30 ft/day for Layer 2 and 40 ft/day for Layer 3 were used in the model. These are comparable to values used in previous modeling efforts accepted by The County (e.g. Barr Engineering, 1990) and are in agreement with mean values from aquifer tests conducted in Apple Valley, northwest of the proposed mining area (Barr Engineering, 2002).

The model calibrated hydraulic conductivities represent large-scale effective hydraulic conductivities. There is strong correlation between the interpreted potentiometric surface and the calibrated hydraulic conductivities. In the calibrated hydraulic conductivity of layer 1, as shown in **Figure 7R**, higher hydraulic conductivities are generally associated with flatter hydraulic gradients and lower hydraulic conductivities are associated with steeper hydraulic gradients.

A comparison of simulated versus observed hydraulic heads in all three model layers is presented in **Figure 6R**. The small-scale heterogeneity that affects contaminant migration cannot be simulated by the calibrated hydraulic conductivities, because the effects of such small changes cannot be seen in the hydraulic head distribution or interpreted potentiometric surface.

The calibrated hydraulic conductivity distribution is a function of the combined effect of hydraulic gradients represented in the potentiometric surface, applied groundwater recharge rate, and specified layer thickness. Any uncertainty or inconsistency between model setup and field conditions that are related to these components might introduce uncertainty or inconsistency to the calibrated hydraulic conductivity distribution.

2.3.7 Calibrated Anisotropy

The vertical anisotropy is expected to be significant based on observations of vertical hydraulic gradients throughout the Study Area and the depositional processes of the formation. The model calibrated vertical anisotropy ratios of Kx versus Kz for layers 1, 2, and 3 are 10, 100, and 50, respectively. These ratios are distributed uniformly over each of the layers. Ratio of 50 was used for Layer 1 where St. Peter aquitard is present – approximating the affects of the underlying aquitard. A ratio of 100 was used where both the Glenwood-Platteville Formations and St. Peter Sandstone are present to represent the combined effect of both units. A ratio of 100 was used for Layer 2 owing to the horizontal, tabular nature of the dolomite in the Prairie du Chien Group. These ratios are within the upper ranges of anisotropy ratios estimated by Schoenberg (1994).

Sensitivity analyses were performed to assist with a calibration. When a ratio of 100 (200 for Layer 2) was used, the hydraulic head of Layer 1 can be matched well, but the simulated heads for layers 2 and 3 were unreasonably low. Likewise, when ratios of 1 to 5 were used (lower range of estimates by Schoenberg [1994]), the magnitudes of simulated vertical hydraulic gradients were smaller than observed vertical gradients.

2.4 Sensitivity Analysis

The calibrated model is predisposed by uncertainty owing to the inability to define the exact spatial distribution of parameter values within the model domain. A sensitivity analysis provides a mechanism to evaluate the model response to variations in model input data and establish the effect of uncertainty of the calibrated model. Parameters with a high sensitivity are indicative of conditions for which small changes in the value of the parameter can cause large changes in an observation (e.g. head, flow rates). Thus, parameters with high sensitivities have a small range of values for which a calibrated model is possible.

Since the surface water resources are integral to this study, and likewise, calibrated values of hydraulic conductivity in some areas of the model domain exhibit values lower than expected, a sensitivity analysis of flux rates to select surface water discharge points was evaluated with respect to variations in hydraulic conductivity. Table 2-3 provides a summary of variations in discharge rates to select surface water locations due to order-of-magnitude variations in calibrated hydraulic conductivity.

Table 2-3: Sensitivity of Groundwater Discharge due to Variations in Hydraulic Conductivity

Surface Water Discharge Area	**Simulated Discharge (cfs)**		
	Calibrated Model	**K x 0.1**	**K x 10**
Vermillion River, between BSC2 and USGS Station	7.2	2.41	10.05
North Creek, between CHP3 and 801	1.1	0.74	1.45
Middle Creek, between PKN1 and 801	2.1	1.09	2.22
Wetlands North of Butler Pond	1.80	0.62	2.05
Butler Pond	0.18	0.06	0.42
Wetlands South of Butler Pond	0.75	0.41	0.81

Variations of hydraulic conductivity by and order-of-magnitude yield corresponding deviations in discharge rates that vary by a factor of 2 to 5. The amount of water discharging from the system cannot decrease or increase substantially as the primary source of water to the groundwater system in this area is infiltration from precipitation. As such, precipitation-based recharge is the most sensitive parameter within the numerical, a conclusion also reached in the Scott-Dakota County model developed by Barr Engineering (1999). However, this value was not varied from the assigned value in the model, as the recharge rates assigned in Section 2.1.3 represent the potential maximum amount of recharge to the groundwater system.

While flux rates to surface water bodies are comparable to observed ranges when using a hydraulic conductivity value of ten times the calibrated value, the lower flow rates are more indicative of very low baseflow conditions, which adds to the conservatism in estimates on impacts to surface waters as presented in Section 4.

2.5 Model Limitations

The following limitations of the model should be recognized in understanding the model results or before applying the model to future uses.

- The model simulated flow field represents average flow conditions that do not vary over time, and the simulated volumetric fluxes and contaminant migration represent long-term average conditions without consideration of seasonal fluctuation.
- The calibrated hydraulic conductivity distribution is a function of the combined effect of hydraulic gradients represented in the

potentiometric surface, applied groundwater recharge rate, and specified layer thickness. Any uncertainty or inconsistency between model setup and field conditions that are related to these components might introduce uncertainty or inconsistency to the calibrated hydraulic conductivity distribution.

- The model simulated aquifer heterogeneity is limited by two factors: the model grid size and the heterogeneity that can be reflected in the hydraulic head distribution or interpreted potentiometric surface. The level of detail of heterogeneity, if beyond the above factors, may not be simulated in the model, even though it may have significant influence on hydrologic impacts or contaminant migration.
- Hydraulic conductivity and variations in recharge of the rejected sand that is backfilled in the excavations are unknown. Assumptions were made based on the changes, but the absolute values of these parameters is unknown. If the actual values of these parameters differ significantly from those proposed here, the results of this model may not be directly applicable.
- The simulated TDS and temperature plumes are highly dependent upon the assumed TDS and temperature at the source locations. Thus, the simulated plumes are subject to the uncertainties associated with source conditions.
- The simulated extent of TDS and temperature plumes is based on assumed effective porosity as well as assumed dispersivities. Because these two parameters are assumed based on literature values instead of site-specific information, the simulated extent of these “plumes” is subject to uncertainties associated with these assumptions.
- The calculated mass loading of TDS and temperature to the surface water features depends on simulated fluxes. As there is some uncertainty in these simulated fluxes to Butler Pond and the neighboring wetland features, the model-simulated mass loading may be overestimated.
- The transport code MT3D used for this study does not explicitly simulate heat transfer. This process is approximated in this study using principles in the conservation of mass. This is intended to provide a baseline to analyze the effects of temperature. Any analysis of the effects of temperature with this model in further detail than that described herein may be unreliable.

3.0 EXISTING CONDITIONS

3.1 Geology

Geologic units in Dakota County in the vicinity of Empire Township can be classified into three major categories: (1) Precambrian volcanic and crystalline rocks; (2) Cambrian through Ordovician sedimentary rocks; and (3) Quaternary unconsolidated deposits which include glacial outwash, glacial till, and alluvial deposits.

3.1.1 Bedrock Geology

A stratigraphic column of the bedrock geology in Dakota County is shown on **Figure 9R** and the distribution of the bedrock geologic units is depicted in **Figure 10R**. The general characteristics of the bedrock units pertinent to this study which include Platteville-Glenwood Formations, St. Peter Sandstone, Prairie du Chien Group, and Jordan Sandstone are summarized below. The thickness and textural characteristics of these units can vary from place to place but, in a general sense, are relatively uniform.

Other bedrock units present in Dakota County include the Ordivician Decorah Shale, St. Lawrence Formation, Franconia Formation, Ironton-Galesville Sandstones, Eau Claire Formation, Cambrian Mt. Simon-Hinkley Sandstones, and Precambrian Solor Formation. These are not discussed herein as some units are not present within the immediate Study Area or they are not connected to the hydrogeologic system being studied (see Section 3.2).

Platteville and Glenwood Formations

The Ordovician Glenwood Formation is green, sandy shale that overlies the St. Peter Sandstone, where present. The Glenwood Formation ranges in thickness up to 15 feet. The Ordovician Platteville Formation is a fine-grained dolostone and limestone (Mossler, 1990). The Platteville Formation is reported to be approximately 10 feet thick. Both units are present as small isolated flat-topped mesas within the Study Area.

St. Peter Sandstone

The upper half to two-thirds of the Ordovician St. Peter Sandstone is fine- to medium-grained quartzose sandstone that generally is massive to very thick bedded. The lower part of the St. Peter Sandstone contains multicolored beds of sandstone, siltstone, and shale with interbeds of very coarse sandstone. The base is a major erosional contact (Mossler, 1990). Quaternary erosion by glaciers has removed much of the St. Peter Sandstone and younger Paleozoic rocks from central and southern Dakota County, leaving remains of the St. Peter Sandstone as isolated outcrops, typically capped by the Platteville-Glenwood Formations, which are more resistant to erosion.

Prairie du Chien Group

The Ordovician Prairie du Chien Group contains the Shakopee Formation (upper) and the Oneota Dolomite (lower). The Shakopee Formation is a dolostone that forms approximately half to two thirds of the Prairie du Chien Group and is commonly thin bedded and sandy or oolitic. The Shakopee Formation contains thin beds of sandstone and chert. The Oneota Dolomite forms approximately one third to one half of the Prairie du Chien Group and is commonly massive to thick bedded. Both formations are karsted and the upper contact may be rubbly. The Prairie du Chien Group is approximately 145-feet thick near St. Paul (Mossler, 1990).

Jordan Sandstone

The upper part of the Cambrian Jordan Sandstone is medium- to coarse-grained, friable, quartzose sandstone that is trough cross-bedded. The lower part is primarily massively bedded and bioturbated. The Jordan Sandstone is approximately 90 feet thick near the Minnesota River and thickens to over 200 feet in southern Dakota County (Mossler, 1990).

3.1.2 Quaternary Geology

The Quaternary geology surrounding the Mining Area is primarily outwash and till deposits related to the advance of the Superior and Des Moines glacial lobes. Superior till and outwash predominate the Mining Area, but there is also some Des Moines till/outwash near the southern portion of the Mining Area (**Figure 11R**). The Superior Lobe deposits are typically red in color, containing oxidized basalt cobbles and other mafic igneous rocks. The Superior Lobe sediments contain very little limestone and dolomite from marine deposits. Superior lobe tills are generally rich in sand with lesser portions of silt and clay. The Des Moines Lobe sediments are rich in shales, marine carbonates, and granitic rocks. Des Moines Lobe tills are very clay-rich. The area surrounding the Vermillion River channel is primarily filled with floodplain alluvium, but also contains till from the Superior and Des Moines lobes. In addition, there also exist some isolated exposures of pre-late Wisconsin deposits such as the “Old Gray” Till which is observed in isolated exposures on some of the topographic highs surrounding the Mining Area.

3.1.3 Structural Geology

The regional dip of the Paleozoic units is toward the north, reflecting the position of Dakota County on the southeastern margin of the Twin Cities basin. The Twin Cities basin developed in the Middle Ordovician, as a result of many small folds and faults in step-fashion. Individual folds have amplitudes of as much as approximately 100 feet and individual faults have displacements (throws) of 50 to 150 feet.

The two major structures are the Vermillion anticline and the Empire fault, both located north and parallel to the Vermillion River (Mossler, 1990). Maximum displacement (throw) of the Empire Fault is approximately 100 feet. A number of smaller faults have axis that trend northwest-southeast. No faults are visible in outcrop in the Study Area.

3.2 Hydrogeologic Setting

3.2.1 Hydrostratigraphic Units

Hydrostratigraphic units comprise geologic formations of similar hydrogeologic properties. Several geologic units might be combined into a single hydrostratigraphic unit or a geologic formation may be subdivided into a number of aquifers and aquitards. The hydrostratigraphy forms the framework of the conceptual model of the groundwater flow system. The geologic units that have been selected for the aquifers and aquitards are shown on **Figure 9R**. The following discussion is a summary of rationale for their selection (Barr Engineering, 1999).

Prairie du Chien-Jordan Aquifer

In early hydrologic studies, the Prairie du Chien Group and the Jordan Sandstone are typically treated as a single aquifer system in the Twin Cities area; the Prairie du Chien-Jordan Aquifer. However, chemical and isotopic studies (Tipping, 1992), artificial recharge studies (Reeder, 1976), and aquifer testing (Barr Engineering, 1990) indicate that while hydraulic head measurements and hydraulic properties of these aquifers may be relatively similar, they are two distinct units that respond independent of one another. Groundwater flow in the Prairie du Chien Group is primarily through fractures, joints, and solution features. Groundwater flow in the Jordan is primarily intergranular but secondary permeabilities have developed due to fracturing (Schoenberg, 1990).

Jordan Sandstone

In Dakota County, many high-capacity wells are completed solely within this unit. The unit is approximately 100 feet thick but may thicken to the south. The degree of cementation of the Jordan Sandstone varies (Tipping, 1992). Hydraulic conductivity can vary, depending upon the degree of cementation.

The Jordan Sandstone sub-crops beneath glacial drift and alluvium in major river valleys, which are the primary discharge zones. In these areas, hydraulic head can be expected to be at or slightly above the elevation of the river. Discharge via high-capacity wells is also a significant discharge route. Recharge is primarily through leakage from the overlying Prairie du Chien Group.

Prairie du Chien Group

The areal extent of the Prairie du Chien Group is similar to that of the underlying Jordan Sandstone. Horizontal hydraulic conductivity values are in the same range as those of the Jordan Sandstone. Flow in the Prairie du Chien Group is heavily controlled by fracturing, jointing, and solution cavities. The top of the Prairie du Chien Group is an erosional surface.

Unlike deeper hydrostratigraphic units, the Prairie du Chien Group can be unconfined where the drift is thin or absent. Recharge is primarily through leakage from the overlying glacial drift. Discharge is to the glacial drift in the valleys of major rivers.

Glacial Drift-St. Peter Aquifer

The hydrogeologic characteristics of glacially deposited sediment are very complex. At a given location, these sediments may contain several interfingering sand-gravel layers with till; however these discrete zones may not show any correlation, even in relatively small areas. Consequently, the modeling of discrete zones of saturation is typically not possible, given the limited amount of reliable data on stratigraphy, hydraulic characteristics, and hydraulic head. Thus, for this system, transmissive sediments are therefore considered to be one single heterogeneous aquifer system, which is assumed to be hydraulically connected.

Locations were the upper St. Peter Sandstone is present may be included as part of the Glacial Drift Aquifer (Barr Engineering, 1999). The upper part of the St. Peter Sandstone is poorly cemented, granular, and may be used to supply domestic wells. The lower portion of the St. Peter Sandstone is shaley and functions as an aquitard over the Prairie du Chien Group (Palen, 1990). The St. Peter Sandstone has been eroded away over much of Scott and Dakota Counties and is present in complete thickness only where overlain by the Glenwood and Platteville Formations. In those areas where the St. Peter Sandstone is not present, glacial drift overlies the Prairie du Chien Group. In these areas, the St. Peter-basal till aquitard is composed of glacial till or other glacial drift, which allow varying rates of leakage.

The Glacial Drift-St. Peter Aquifer is in relatively good hydraulic connection with local streams and lakes. Recharge is primarily by infiltrating precipitation. Discharge is to streams, lakes, and leakage to underlying aquifers.

3.2.2 Groundwater Flow

Groundwater generally moves from upland areas of recharge downgradient to lowland areas of discharge. In the Study Area, groundwater movement is generally from west-southwest to east-northeast in accordance with the hydraulic gradients defined by potentiometric surfaces. The interpreted potentiometric surfaces for the Glacial Drift-St. Peter, Prairie du Chien, and Jordan aquifers are depicted in **Figure 4R**.

The potentiometric contours for the shallow Glacial Drift-St. Peter aquifer were derived based on water level measurements from the Minnesota County Well Index, boreholes used to delineate the depth and extent of aggregate mining deposit, in addition to the five newly installed Empire Township monitoring wells (**Figure 2R**). In addition, groundwater contours are constrained by the surface topography of wetland areas that have been delineated as groundwater dependent resources and represent groundwater discharge areas (see Section 2.6).

Groundwater elevations in the shallow aquifer throughout Dakota County are generally stable, exhibiting fluctuations of less than three to four feet (EOR, 2004). Depth to groundwater in the Mining Area is generally in excess of 20 feet. In some localities, depth to groundwater may be more than 50 feet. In the vicinity of the Vermillion River and other groundwater discharge areas, depth to groundwater is essentially negligible with some areas exhibiting artesian conditions.

Usable data were not available for a majority of wells in the vicinity of the Mining Area. In addition, numerous wells have anomalously low water levels and exhibit evidence of pumping during water level measurement. Thus, depicted contours have been represented to illustrate the more regional flow pattern and do not emphasize the smaller, more local variations. Dates on which water levels were taken vary considerably, thus the potentiometric surface represented in **Figure 4R** is generalized from a non-synoptic data set.

The most obvious feature in the groundwater potentiometric map is a groundwater mound in the southern portion of the proposed Mining Area. While no shallow groundwater wells exist, this feature has been interpreted based on water levels in borings drilled to access the depth of the aggregate deposit which indicate a northeast gradient as opposed to the expected southward gradient directed toward the Vermillion River. In addition, in an unconfined hydrologic system, the groundwater table should, for the most part, represent a subdued replica of the topography (Freeze and Cherry, 1979). This groundwater mound forms a groundwater divide that is roughly coincident with the surface water divide forming the Mississippi and Vermillion River watershed boundaries (Almendinger and Mitton, 1995). Additional groundwater mounds have been interpreted in local topographic highs to the east of the Mining Area. While data supporting the inferences of these groundwater mounds may be adequate, it is likely that these mounds may represent perched water conditions due to the low permeability of the underlying geologic units. Thus, these mounds may not be sufficiently connected to the regional groundwater system, and will be treated as such.

Groundwater contours for the Prairie du Chien and Jordan aquifers shown in **Figure 4R** are similar to those presented by EOR (2004). These contours were developed from linear kriging (an interpolation technique for obtaining estimates of surface elevations from a set of control points) of well data from the Minnesota County Well Index and a DNR observation network.

Groundwater contours in all aquifers conform to general groundwater flow pattern delineated in a regional study by Palen (1990).

3.2.3 Hydraulic Gradients

As shown on the groundwater potentiometric surface of the Glacial Drift-St. Peter aquifer (**Figure 4R**), the horizontal hydraulic gradient is approximately 0.002

feet/feet and does not vary substantially throughout the Study Area. To the northeast, hydraulic gradients increase slightly to 0.003 feet/feet as groundwater approaches the discharge area of the Mississippi River. To the west of the Mining Area boundary, the hydraulic gradient is 0.001 feet/feet. This may be indicative of more permeable strata in the subsurface, but this is speculative as the available hydraulic head data west of the Mining Area is limited.

Vertical hydraulic gradients vary substantially throughout the Study Area and some spatial trends in vertical gradients have been observed. Generally, measured hydraulic head differences between shallow and deep aquifers at wells clustered together (**Figure 4R**) show downward gradients in upland areas away from the river and upwards gradient in the vicinity of the river. This suggests that groundwater recharge by direct infiltration of precipitation occurs in most of the areas away from the creeks, whereas groundwater discharge occurs at the creeks and along the floodplains. It also suggests that the convergence of groundwater flow toward the Vermillion River occurs horizontally as well as vertically. This is supported by strong upward hydraulic gradients, even artesian flow conditions, observed along the river. However, local vertical hydraulic gradients may vary significantly and not follow this spatial trend. Upward flow gradients have been observed in areas away from the creeks and vice versa, suggesting that local vertical gradients are influenced by local heterogeneities.

3.3 Groundwater Recharge

Groundwater recharge occurs throughout the Study Area as a result of surface water infiltration. Infiltration of direct precipitation is dependent upon the rate and duration of precipitation, the soil type and soil cover, land use, evapotranspiration, and topography. In a steady-state model, the resulting infiltration rate is typically estimated on an annual basis - although seasonal estimates are sometimes utilized. Groundwater recharge in the upland areas and lowland areas along the floodplains can be considered separately as areal recharge and floodplain recharge, respectively.

The predominant source of recharge for the deeper aquifers in Dakota County is regional flow from areas outside the County and downward leakage from the Glacial Drift/St. Peter aquifer.

3.3.1 Areal Recharge

Areal groundwater recharge occurs as a result of surface water infiltration primarily during early springtime. Precipitation in the Minneapolis-St. Paul metropolitan area averages between 26 and 32 inches per year, of which approximately 19 to 23 inches is returned to the atmosphere by evapotranspiration while about 7 to 9 inches per year are available for recharge and overland runoff (Schoenberg, 1994). Schoenberg (1990) estimated that the annual groundwater flow to streams is 1.60 to 4.30 inches of precipitation per year, with an average of 4.1 inches per year. Assuming that long-term groundwater recharge is approximately equal to long-term groundwater discharge to streams, annual recharge from precipitation is approximately 1.5 to 4.5 inches per year. Thus, about 6 to 15 percent of precipitation infiltrates to groundwater.

3.3.2 Floodplain and Wetland Recharge

The occurrence and amount of groundwater recharge along the river and tributary floodplains are expected to be of greater magnitude than areal recharge. Infiltration occurs along the floodplains as a result of direct precipitation and flooding caused by surface water runoff. The distribution of the 100-year floodplains and wetlands within the Study Area is depicted in **Figure 2R**.

Infiltration along the floodplain and wetlands may occur frequently in response to surface water flooding events. Infiltrated water will partially be evaporated from the soil and transpirated by the vegetation along the drainages, and partially percolate to groundwater. The rate of floodplain recharge is unknown, but it is expected to be greater than areal groundwater recharge.

3.4 Hydraulic Properties of Aquifer(s)

Hydraulic conductivity, specific yield (or storage coefficient), and effective porosity are commonly used to characterize the hydraulic properties of an aquifer. In this study, the flow conditions are considered relatively stable; thus, specific yield, which is related to temporal variation of groundwater, is not discussed. Site-specific data for effective porosity are not available.

3.4.1 Hydraulic Conductivity Distribution

Hydraulic Conductivity data for the hydrostratographic units in this region is limited, but sufficient data in these units has been gathered in the northern portion of Dakota County (Schoenberg, 1990; 1994). Hydraulic conductivity data for the aquifer units was obtained from several permeameter, slug, and aquifer tests.

The following table presents the range of values for various geologic units in the area:

Table 3-1: Summary of Hydraulic Conductivity Measurements

Aquifer Unit	Hydraulic Conductivity (ft/day)	Number of measurements
Alluvium	8 to 61	8
Glacial Till	$4x10^{-5}$ to 26	12
St. Peter Sandstone	0.3 to 94	8
Prairie du Chien	50	1
Jordan Sandstone	19 to 107	3

Hydraulic conductivity of the geologic materials in the saturated zone above the St. Lawrence-Franconia aquitard varies in both the horizontal and vertical directions, reflecting the heterogeneity of the flow system.

3.4.2 Anisotropy

Hydraulic conductivity distribution in an aquifer is not only heterogeneous but may also be anisotropic. Vertical anisotropy is evidenced by vertical hydraulic head differences observed over the entire Study Area (**Figure 4R**), which suggests that the vertical hydraulic conductivity is smaller than the horizontal hydraulic conductivity, (*i.e.*, the vertical anisotropy is high). The vertical anisotropy is likely attributed to the physical layering of different geologic units. It is not uncommon for layered heterogeneity to lead to regional anisotropy on the order of 100:1 or even greater (Freeze and Cherry, 1979). The site-specific vertical anisotropy ratio for the Study Area is calibrated through modeling.

3.5 Surface Water

3.5.1 Vermillion River and Associated Tributaries

The Vermillion River is located approximately two miles south of the southern boundary of the proposed Mining Area. The Vermillion River begins in Scott County and flows into Dakota County, ultimately discharging into the Mississippi River near the city of Hastings, Minnesota. The drainage area to the Vermillion River at the gauging station is approximately 129 square miles. The Vermillion River is a zone of groundwater discharge in the Study Area and becomes a source of groundwater recharge downstream closer to the Mississippi (Palen, 1990; Almendinger and Mitton, 1995)

North Creek is located approximately one mile west of the west boundary of the proposed Mining Area. North Creek extends from the City of Lakeville into the City of Farmington and Empire Township, and acts as a major tributary to the Vermillion River. The total area of the North Creek watershed is approximately 15,774 acres, including drainage areas from Lakeville, Farmington, Apple Valley, Rosemount, Burnsville and Empire Township. This creek is perennial throughout much of its length, but has several ephemeral branches in its headwaters. Middle Creek is another perennial tributary to the Vermillion River that drains the highland area west of Flagstaff Avenue in southern Lakeville.

South of the Mining Area is an unnamed tributary to the Vermillion River, hereafter referred to Unnamed Tributary 1. This is a perennial tributary that drains the Butler Pond area. Butler Pond is a man-made surface water feature located just outside the southeast border of the proposed Mining Area. It is estimated to be approximately 10 feet deep. Local residents have indicated that this pond does not completely freeze during coldest winter months suggesting that it may be fed, in part, by groundwater flow. A small portion of Unnamed Tributary 1 north of Butler Pond is considered to be groundwater fed based on mapping of adjacent vegetation, but is ephemeral throughout most of the proposed Mining Area (EOR, 2004).

To the east of the Mining Area is an unnamed tributary to the Vermillion River that is ephemeral and typically dry (denoted as Unnamed Tributary 2 in Figure 1).

Detailed analysis was performed at Site 4 on this tributary by Almendinger and Mitton (1995). It was noted that more than 70 percent of the time, this stream was dry and more than 90 percent of the time, the groundwater table was below the stream level, indicating this tributary is a zone of recharge. Hydraulic gradient between nested wells in the vicinity of these drainages indicate downward gradients representative of a recharge area.

The following table presents a summary of stream flow data taken in mid-July of 2004 indicating representative flow rates observed at several of the gauging stations depicted in **Figure 2R** (EOR, 2004).

Table 3-2: Summary of Stream Gauging Measurements in the Vicinity of the Proposed Mining Area

Gauging Station	River Branch	Flow (cfs)
ANN1	Unnamed Tributary 1	1.30
CHP3	North Creek	6.49
CHP2	North Creek	7.81
BCS2	Vermillion River	69.04
801	Middle Creek	51.4
804	Vermillion River	31.0
807	Vermillion River	37.4
808	North Creek	10.7
USGS	Vermillion River	84.0

3.5.2 Wetlands

Wetlands within the Study Area as delineated by the Empire Township Wetland Inventory are depicted in **Figure 2R**. Two types of wetlands are typically present in Dakota County: those that are discharge areas, and those that are recharge, for at least part of the year (Palen, 1990). Discharge areas occur in the floodplains of the Minnesota and Mississippi Rivers, along the Vermillion River and its major tributaries, and in isolated areas along the Cannon River.

Wetlands surrounding the proposed Mining Area consist of both discharge and recharge wetlands. A study using field investigation and GIS analysis is currently underway by Emmons and Olivier Resources, Inc. (EOR) to delineate the extent of groundwater dependent resources in Scott-Dakota County. This includes determining the quantity and extent of wetlands discharging groundwater. A preliminary map of these wetlands was provided to aid in this evaluation. The wetlands delineated as probable groundwater discharge areas are located along the banks of the Vermillion River and North Creek in addition to several flatland areas in the vicinity of Butler Pond. These consist of mixed hardwood swamp, willow swamp, wet prairie, and wet meadow. Each of these plant communities was analyzed with relation to the water table, Vermillion River, and other groundwater dependent resources to determine their likelihood of being groundwater dependent.

The wetlands not delineated in the EOR study are considered to be wetlands that recharge the groundwater system. Recharge to the shallow aquifer occurs when the wetland collects rain or spring snowmelt. Although the bottom of the wetland may restrict infiltration because of accumulations of organic matter, higher rates of recharge occur around its edges where sand or sandy till is temporarily inundated. Slow, steady leakage may also occur though the organic sediments as well, even though they are not very permeable (Palen, 1990).

3.6 Summary of Conceptual Model

The conceptual model utilized in this study is consistent with conceptual models developed in previous studies (Barr Engineering, 1999) and is depicted in **Figure 12R**. For this study, the groundwater flow system includes three discrete aquifers: the Glacial Drift/St. Peter Sandstone; the Prairie du Chien Group; and the Jordan Sandstone. The St. Lawrence-Franconia aquitard forms the lower bounds of the uppermost groundwater flow system. Deeper aquifers such as the Ironton-Galesville and Mt. Simon-Hinkley are not included, as interaction with these aquifer units is considered negligible. In this conceptual model, there is a leaky aquitard between each aquifer unit. Between the glacial drift/St. Peter aquifer and the underlying Prairie du Chien Group, the aquitard consists of the basal portion of the St. Peter Sandstone and glacial till. Between the Prairie du Chien Group and the Jordan Sandstone, an aquitard layer is present in the basal portion of the Oneota Formation (Prairie du Chien Group).

The primary source of recharge to the Glacial Drift/St. Peter Sandstone aquifer is infiltrating precipitation. The primary source of recharge for the Prairie du Chien Group and Jordan Sandstone aquifers is leakage from adjoining aquifer. Lakes and ponded water in wetlands are generally perched above the water table and leak water down into the aquifer as a function of the resistance of the lake's bottom sediment and the unsaturated drift material below the lakes.

Discharge of groundwater occurs at the Vermillion and Mississippi Rivers and their adjacent wetlands. Pumping wells also remove water from the aquifer units.

4.0 MINING IMPACT ANALYSIS

4.1 Mining and Production Operations

Mining of sand and aggregate is proposed to begin in 2006 and finish in approximately 2040. For each mining year, project operations include those outlined in Section 1.1. Approximately five production plant facilities will be located across the proposed Mining Area. Each plant site will require an industrial groundwater supply well, supplying water for production operations. Required flow rates will vary based on specific plant operations. Specifically, water may be used for sand and aggregate washing, concrete product production, equipment maintenance, concrete truck washout and site dust control. Water from the groundwater supply wells will be used initially to fill wash ponds. Once the ponds are filled, the supply wells will only supplement recycled site stormwater and wash water, as necessary. Generally, aggregate washwater will be pumped from on-site, shallow sump pits, not traditional deep production wells.

Site stormwater, sand/aggregate wash water and concrete truck wash water will typically be detained in a triple stage series of on-site detention ponds at each plant location. Water for the production facilities will be pumped from the third detention pond for reuse. The detention ponds will typically be constructed above the groundwater and will essentially function as sedimentation and infiltration ponds, removing the majority of the suspended solids. Pond depths will typically range between 10 feet and 20 feet with pond areas ranging between approximately one and three acres. Stormwater and wash water will enter the on-site detention ponds via overland flow, pressure or gravity piping.

Upon completion of mining operations, the excavations will be backfilled with unused materials, back-hauled fill, overburden materials and topsoil. The preliminary end use grading plan (**Figure 13R**) identifies approximate final grading elevations, location and sizes of the proposed end use ponds. Rejected sand from the production operations will typically be placed on the bottom of the mining excavation, facilitating groundwater infiltration and subsurface flow. In areas where mining excavations extend below the groundwater table, except at end use pond locations, the excavations will be backfilled with rejected sand then overburden and topsoil to the end use grades. During reclamation, the proposed Mining Area will be restored to the proposed end use grades and returned to agricultural land.

Rejected sand from production areas typically consists of 15 percent to 30 percent of the total sand/gravel excavation volume. Based on a total estimated sand/gravel excavation of 200 million tons and an assumed unit weight of 115 pounds per cubic foot (lb/ft^3), an estimated total sand/gravel volume of approximately 130 million cubic yards is anticipated. Based on a typical value of rejected sand that is 15 percent to 30 percent of the total excavated volume, approximately 19 million to 39 million cubic yards of rejected sand is anticipated. If spread uniformly across the proposed 3,590 acre Mining Area, the depth of reject sand would range from approximately three to seven feet.

Eleven end use ponds, with surface areas totaling approximately 240 acres, are proposed across the Mining Area (**Figure 13R**). The ponds sizes vary from approximately 6 acres to 90 acres, with depths ranging between approximately 1 foot and 42 feet. The ponds, developed from mining excavations below the groundwater, will consist mainly of groundwater. In areas where end use ponds are proposed, the excavations will not be backfilled and the ponds will fill with groundwater. Typically, the bottom of the groundwater ponds will correspond to the bottom of sand/aggregate deposit with some exceptions. This is of particular interest for Ponds 1 and 2, which are located within the southern extent of the DWSMA and WHPAs for the city of Rosemount. As indicated in Figure 13, Pond 1 is to be excavated to a depth of 42 feet, with a base elevation of 860 feet amsl, while Pond 2 is to be excavated to a depth of 18, with a base elevation of 908 feet amsl. The depths of the excavated pounds will be limited to the Glacial-St. Peters aquifer and no excavation of material from the Prairie du Chien or Jordan aquifers is expected.

Separate stormwater ditches, constructed outside of the groundwater end-use ponds and separated by berms, will provide stormwater diversion and prevent direct mixing of stormwater and groundwater, reducing the potential for groundwater contamination. In areas where stormwater drains directly to protected surface waters, perimeter stormwater ponds will function as flow-through, non retention-based swales, diverting stormwater flows around the groundwater ponds to prevent stormwater/groundwater mixing and minimize flow impacts to the surface waters. Depending on the soil infiltration and atmospheric evaporation rates, these ponds will essentially function as a combination of infiltration and sedimentation basins, removing the majority of the suspended solids during settling and groundwater infiltration. The summer months will expose the pond water to warm air temperatures and extended hours of solar radiation. This has the potential of increasing the ambient temperature of the water and increasing the total dissolved solid (TDS) concentration through evaporation.

The greatest potential for impacts exists during the end use plan as the ponds alter the groundwater flow field, which may increase flow to local surface water features, potential trout habitats, and wetlands. Additionally, infiltration of water with elevated TDS and temperature may impact the groundwater resource. Infiltration of water thus impaired could potentially have adverse impacts on the surface water and wetland features. Conceivably, similar water quality impacts may even affect WHPAs as delineated to the north of the Mining Area. Therefore, the reasonable worst-case modeling for evaluating the end use plan assumes that the stormwater ponds shown in Figure 12 capture and retain all of the stormwater

4.2 Simulation of Hydrologic Impacts of End Use Ponds

The end-use ponds are modeled as a groundwater fed surface water bodies and in turn, act as a source and sink for the groundwater system. Groundwater enters the ponds from the upgradient side of the pond, for the most part from the south-southwest. While in the pond, the water is then affected by meteoric processes such as possible increased TDS concentration due to evaporation, and increased overall temperature due to heating by ambient temperatures. This water then re-enters the groundwater system on the downgradient side of the pond, to the north-northeast. Using the calibrated flow model developed for this study, the groundwater ponds were simulated as head dependent flux boundaries using the General Head Boundary Package. Interaction between these ponds is dependent on the relative hydraulic head relationships between the General Head cells and the surrounding groundwater system. Conductance for the general head boundaries representing the groundwater ponds were specified to be relatively higher values (on the order of 100 ft/day) compared to the calibrated hydraulic conductivity surrounding the boundary cells. Values were assigned in this manner because groundwater discharge to and from the ponds is controlled by the surrounding lithologies and the general head conductance should not limit flux. The water level elevation of these ponds was estimated based on the interpreted groundwater contour map (**Figure 4R**). These estimated elevations are depicted in **Figure 13R**.

The stormwater ponds surrounding the end-use ponds are intended to act as swales and prevent surface water runoff from entering the larger ponds. Thus, the only source of water to the ponds is groundwater discharge and direct precipitation into the pond itself. Precipitation in the metro area ranges from 26 to 32 inches and evapotranspiration is on average 23 inches (Allmendinger and Mitton, 1995). This suggests for the most part that during dry years, precipitation and evaporation to the ponds will essentially be balanced (i.e. minimum precipitation and maximum evaporation). But, during wet years, when precipitation is at a maximum and evaporation is at a minimum, this could be an increase of water to the ponds of just less than one foot. To maintain conservatism in the study, two feet were added to the water elevation in the ponds as noted above to facilitate increased leakage of “affected” water to the groundwater system. It should be noted, that this may be overly conservative as this is representing “wet” conditions, whereas the simulated flow to surface water features (i.e. rivers, wetlands) in the model are intended to represent dry or low flow conditions.

The elevation of water in the ponds should be approximately that of the groundwater elevation prior to excavation of the pond. Expected elevations of the ponds denoted in **Figure 13R** are based on the potentiometric surface map depicted in **Figure 4R**. However, these values represent elevations expected to occur in the field. As expected, simulated heads in the proposed mining area of the calibrated model may differ from actual, in some cases by a few feet. Elevations assigned to the boundary conditions representing the end-use ponds were adjusted to account for the differences in model-simulated and actual heads expected as indicated in **Figure 13R**. Assigning a head value in the ponds above the water table ensures continued leakage of the end-use pond water into the groundwater system. This approach was taken because it will likely add more than actual affected water to the system, adding even more conservatism to the model prediction for hydraulic impacts and contaminant migration.

Potential leakage from the surface water/stormwater ponds was simulated using the River Package with a constant stage and the base of the water body as the base of the respective pond. As these ponds are located above the groundwater table, downward flux to the groundwater is controlled by the depth of the pond and the hydraulic conductivity of the base of the pond. The water elevation and base of the stormwater ponds in the model were assigned based on the estimated elevations depicted in **Figure 13R**. A hydraulic conductivity of 0.1 ft/day (equates to a conductance value of approximately 250 ft^2/day) was assumed for the base of the ponds. While this is intended to represent silts and other fine material that will eventually settle and line the base of the ponds limiting leakage to the groundwater, this value of hydraulic conductivity is probably higher than the actual value, and thus provides a conservative scenario for assessing impacts to the groundwater system.

For model simulations, the rejected sand was assumed to have hydraulic conductivity of 30 ft/day, a typical value for loosely consolidated sands, with the inclusion of some fine materials (Freeze and Cherry, 1979). Likewise, it is assumed that this sand will be loosely consolidated following initial backfill and may facilitate additional recharge to the groundwater system in the immediate vicinity. Thus, the average recharge rate was assumed to increase from approximately 4.5 inches/yr to 6 inches per year in the area of the reject sand.

The model simulations indicate a slight rise in elevation in areas directly beneath and adjacent to proposed end use ponds that is generally on the order of 2.0 to 3.0 feet (see **Figure 14R**). For the most part, water level increases are less than one foot as distance increases away from these ponds. **Table 4-1** summarizes the changes in flux to select surface water localities following the implementation of the end use plan.

Table 4-1: Summary of Changes in Groundwater Discharge at Select Surface Water Localities after Implementation of the Mining End Use Plan

Surface Water Feature	Original Flux (cfs)	New Flux (cfs)	Difference	Percent Change
North Creek[1]	1.10	1.18	0.08	6.8
Wetlands North of Butler Pond	1.80	1.85	0.05	2.7
Butler Pond	0.15	0.19	0.02	21.1
Wetlands South of Butler Pond	0.75	0.79	0.04	5.0

[1] Flow from gauging station CHP3 to 801

Using the conservative, worst-case changes produces minimal impacts to the estimated groundwater fluxes to select surface water features surrounding the proposed mining area. Groundwater flow rates to Butler Pond and the surrounding wetlands are estimated to increase between 0.02 and 0.05 cfs, resulting in a 2.7 to 21.1 percent change in flow. Groundwater flow to North Creek is estimated to increase 0.08 cfs, reflecting a 6.8 percent increase in flow. These changes in the simulated long-term, average estimated flow rates are less than the observed seasonal and yearly fluctuations. Given the conservative, worst-case assumptions, hydraulic impacts to these surface water features are estimated to be negligible.

4.3 Simulation of Potential TDS and Temperature Impacts

The computer code MT3DMS, a modular three-dimensional multi-species transport model (Zheng and Wang, 1998), was used to simulate fate and transport of water introduced to the groundwater system from the stormwater ponds in the end use plan. MT3DMS does not simulate heat transport. However, the governing equations work on the underlying principle in which mass/energy is conserved. Therefore, it may be used to approximate the fate and transport of solar-heated stormwater infiltration mixing with ambient groundwater. The model does not simulate conductive cooling of the recharge water as it flows within the relatively cooler aquifer matrix. Thus, the results provided in this study are considered to be very conservative, illustrating a worst-case scenario for evaluating the effects of temperature and TDS.

4.3.1 Input Parameters Transport Simulations

The following sections describe the rationale for selecting the input parameter values for the transport model.

Transport Parameters

To use the MT3DMS transport model, some additional parameters are necessary, which include porosity and dispersivity. Porosities of 0.3, 0.09, and 0.21 were used for Layers 1,2, and 3 of the model, respectively. These values are based on recommendations of the Minnesota Department of Health and are similar to porosities used by Barr Engineering (1999) to evaluate well capture zones in the Scott-Dakota County regions flow model. No field data was available for dispersivities in the Scott-Dakota County area. Therefore, literature values were taken from regional-scale studies in similar rock types and aquifer thicknesses (Gelhar *et al*., 1992). Longitudinal, transverse, and vertical dispersivities assigned to Layers 1 and 3 were 100 feet, 30 feet, and 0.1. Similarly, dispersivities assigned to Layer 2 were 60 feet, 12 feet, and 0.1 feet, respectively.

Groundwater

Sampling of the newly installed Empire Township wells, in addition to data from Almendinger and Mitton (1995), indicate that average groundwater TDS is approximately 500 mg/L. The average groundwater temperature from these wells is approximately 11°C.

Surface Water

The median TDS in the Vermillion is also approximately 500 mg/L, the same as the surrounding shallow groundwater (Almendinger and Mitton, 1995). However, ambient temperatures are variable through the year with temperatures as low as 2°C during winter months to average temperatures as high as 19.5°C during July.

Analogue for End Use Ponds

Shanahan Pond is a mining-related surface water body, located approximately 10 miles from the proposed Mining Area at Latitude 44°51'15", Longitude 93°06'21". It is interpreted to be fed, at least in part, by groundwater, and therefore should prove as an adequate analogue as to how the end-use ponds will react to temperature and TDS increases attributed to solar radiation and evapo-concentration. The pond is about 7 feet deep and chemical properties were sampled at this pond at a depth of three feet.

Average TDS based on specific conductance data indicates that the average TDS of Shanahan Pond is 80 mg/L. This is more than five times lower than average TDS in groundwater and local surface water. Thus, the pond is likely being recycled with fresh stormwater and has limited time to be affected by evapo-concentration effects. To maintain conservatism in this analysis, a TDS concentration of 1,000 mg/L was assigned to represent pond water heavily impacted by evapo-concentration. Note that the TDS concentration of the ponds (~1,000 mg/L) is more than ten times the summer TDS of the analogue pond (80 mg/L) and twice the ambient groundwater TDS (~500 mg/L). Figure 15R illustrates the distribution of iso-concentration contours of the net increase in TDS in the local groundwater during the 40 years following implementation of the end use plan, assuming the end-use ponds have a TDS concentration of 1,000 mg/L.

As expected, Shanahan Pond exhibits temperature fluctuations similar to those of the Vermillion River. During winter months, water temperature is approximately 2°C, identical to that of the Vermillion River. However, during July, temperatures rise as high as 26.5°C. To evaluate the worst-case scenario, the end-use ponds were assumed to have an elevated temperature 26.5°C throughout the year. **Figure 16R** illustrates the distribution of isotherms of the net increase in temperature in the local groundwater during the 40 years following implementation of the end use plan.

Note that while the surface water ponds/swales may allow infiltration of moderate amounts of surface water, it is expected that this water may not have enough residence time to experience significant increases in temperature or TDS prior to infiltration. Thus, these surface water bodies are modeled solely as a hydraulic source to the groundwater system but with no appreciable amount of temperature or TDS added to the system.

4.3.2 Simulated Impacts to Surface Water and Wetlands

Surface water TDS concentrations and temperature increases were calculated simply by dividing the mass flux of TDS (or temperature) by the groundwater flux to the surface water feature, both estimated by the model, at selected time intervals. The basic assumptions for calculations of TDS (or temperature increases) in the surface water features were that flow was presumed to be solely attributed to groundwater discharge, thus, overland flow and surface water runoff to the creeks was not accounted for in the calculations. These assumptions provide a very conservative, “worst-case” scenario in which to estimate the concentration of TDS or temperature increase in the surface water.

The following tables summarize the simulated TDS and temperature increases at select localities after implementation of the mining end use plan.

Table 4-2: Summary of Simulated TDS Increases at Select Surface Water Localities after Implementation of the Mining End Use Plan

Surface Water Locality	Simulated Discharge (ft^3/day)	Simulated Cumulative Mass Loading (mg/L)*(ft^3/day)	TDS Concentration Increase (mg/L)
North Creek[1]	102,734	26,384	3.9
Wetlands North of Butler Pond	159,893	5,756,112	36
Butler Pond	16,416	85,363	5.2
Wetlands South of Butler Pond	68,246	245,049	3.6

[1] Includes the entire perennial section of North Creek north of gauging station CHP3

Table 4-3: Summary of Simulated Temperature Increases at Select Surface Water Localities after Implementation of the Mining End Use Plan

Surface Water Locality	Simulated Discharge (ft^3/day)	Simulated Cumulative Mass Loading (°C)*(ft^3/day)	Temperature Increase (°C)
North Creek[1]	102,734	7,385	0.07
Wetlands North of Butler Pond	159,893	180,872	1.13
Butler Pond	16,416	1,806	0.11
Wetlands South of Butler Pond	68,246	6,852	0.10

[1] Includes the entire perennial section of North Creek north of gauging station CHP3

Assuming a very conservative scenario in which the end-use ponds have an elevated TDS of 1,000 mg/L, ten times the TDS concentration of a local analogue pond and twice the average concentration of local groundwater and surface water concentrations. Likewise, thermal impacts were simulated using conservative, worst-case assumption in which there is no conductive heat loss to the aquifer. Model results indicate TDS concentration increases ranging between 3.6 to 36 mg/L and temperature increases ranging between 0.07 and 1.13 ºC to the local surface water and wetland features (as shown in Tables 4-2 and 4-3). These estimated changes in TDS and temperature are well below the range of seasonal fluctuations and within the range of variability related to sampling error. Therefore, given the conservative, worst-case assumptions, impacts related to temperature and TDS to these surface water features are deemed to be negligible.

4.3.3 Wellhead Protection and Drinking Water Supply Management Areas

The WHPAs and DWMAs for Rosemount Wells 3, 7, 8, and 9, in addition to Rural Wells 1 and 2 are depicted on **Figure 2R**. These wells pump from the Jordan Aquifer (Layer 3 of the model). **Figure 19R** depicts the extent of simulated TDS and temperature increase in the Jordan aquifer. After 40 years, there is evidence of leakage of the potentially affected end-use pond water down to the Jordan aquifer. The model estimates that TDS will increase approximately 5 to 85 mg/L and will increase in temperature approximately 0.2 to 2.0 °C within the WHPAs and DWMAs delineated for the Rosemount wells. However, for the most, maximum increases are localized in a small portion of the WHPA and DWMA with increases in TDS and temperature primarily on the order of 30 to 50 mg/L and less than 1.0 °C, respectively. The greatest increase in TDS and temperature are localized in the center of the proposed mining area (see **Figure 19R**) where the end-use ponds are clustered. Impacts are lesser toward the edges of the proposed mining area.

The model-predicted TDS increase is likely overestimated due to the conservative initial concentration for the ponds. Likewise, the simulated temperature increase is unlikely as the model does not account for conductive heat loss that will occur as the water migrates through a few hundred feet of aquifer material. This is also compounded by the vertical discretization of the model domain. The relative thickness of the model layers is set up to represent the relative aquifer thickness, which may be subject to numerical dispersion. This in turn, will facilitate an increase in simulated downward leakage of the affected water the lower aquifer. This adds to the conservatism of the contaminant transport model. Therefore, given the conservative, worst-case assumptions related to simulating the end use plan, impacts to the WHPAs are likely to be minimal.

4.3.4 Wash Ponds

Gravel washing and detention ponds created during production operations will not remain in place upon final site reclamation. Only the end use ponds shown in **Figure 13R** will remain. Potential groundwater TDS and temperature impacts from production detention ponds exist; however, the potential impacts are reduced since the detention pond water will be continuously recycled. Furthermore, impact of these ponds is expected to be less than that of the end use ponds due to the much smaller numbers, size, and areal extent in which they cover. Any mitigation measures taken to minimize impacts resulting from the end use ponds should be sufficient to mitigate potential impacts incurred, if any, from the wash ponds. After 40 years, the simulated effects of TDS and temperature have minimally impacted the surface water, wetlands, and the WHPAs with eleven larger ponds in the end use plan. Therefore, the potential impact from the smaller wash ponds is considered to be negligible in comparison. Also, the wash ponds tend to form a very tight silt/clay liner after a short period of time, further minimizing potential impacts (Hansen, 1999).

4.4 Dewatering

Based on the interpreted groundwater contour map of the shallow aquifer (**Figure 4R**) and the interpreted depth and extent of the aggregate deposit, portions of the aggregate deposit will be subject to underwater mining.

Localized dewatering used to facilitate excavation of sand and gravel below groundwater was considered. Should localized dewatering occur, it would likely be accomplished utilizing shallow well points or sump pits. The methodology of dewatering is assumed to be similar to that previously evaluated for the Lauer property within the proposed Mining Area (SEH, 2003). It consists of a pumping scenario that utilizes between 12 and 18 wells equally spaced around a circle with a diameter of approximately 1,000 feet. The total pumping rate to dewater this area is estimated to range between 600 and 1,200 gallons per minute (gpm). Dewatering discharge would be pumped to on-site infiltration basins with no direct off-site discharge to North Creek, the Vermillion River or other protected surface waters.

There are two main areas of concern when dewatering during future mining operations. Dewatering the southwest corner of the proposed Mining Area near the future location of End Use Pond 10 (**Figure 13R**) may impact flows to North Creek, and the southeast corner of the Mining Area near the future location of Pond 11 may impact flows to Butler Pond and the neighboring wetlands.

Simulations were conducted using 15 wells equally spaced around a circle with a diameter of approximately 1,000 feet. Pumping rates of 600 gpm and 1,200 gpm equally distributed between the wells were evaluated. **Table 4-4** summarizes the hydraulic impacts to select surface water localities.

Table 4-4: Summary of Changes in Groundwater Discharge at Select Localities During Select Dewatering Scenarios

Surface Water Locality	Initial Flux (ft^3/day)	Flux during Dewatering at 600 gpm (ft^3/day)	Percent Change	Flux during Dewatering at 1,200 gpm (ft^3/day)	Percent Change
North Creek[1]	102,734	96,189	6.3	93,693	8.8
Wetland North of Butler Pond	159,893	129,033	19.3	125,953	21.2
Butler Pond	16,416	8,513	48.1	7,822	52.4
Wetland South of Butler Pond	68,246	41,046	39.9	38,029	44.3

[1] Includes the entire perennial section of North Creek north of gauging station CHP3

Modeling estimates that fluxes to the local surface water and wetlands near the southern boundary of the proposed mining area will experience reduction in flux rates ranging from 6.3 to 52.4 percent (see Table 4-4). These results suggest that dewatering may be feasible in the northern portion of the proposed Mining Area with minimal impacts on surface water features. Dewatering in other portions of the Mining Area has potential for impacts to surface waters and should only be permitted after further study and monitoring to ensure minimal impacts.

As indicated at the Lauer Property by SEH (2003), if pumping cannot occur in the lower aquifer, it will only be feasible to partially dewater the deposit, as it is not feasible to drawdown the aquifer to the impervious boundary. Therefore, it may be necessary to terminate mining of the deposit short of the bottom or excavate a portion of the aggregate deposit in wet conditions. It is recommended to focus dewatering efforts where the bottom of the deposit is the lowest (e.g. location of future end use ponds), as this will have the most beneficial impact and will likely reduce dewatering efforts in the surrounding areas.

5.0 MITIGATION OPTIONS

Sand and gravel operators utilize substantial quantities of groundwater in the processing of aggregate, production of concrete and asphalt products and for dust suppression. Use of groundwater resources by mine operators must be balanced with existing and future uses of the groundwater resource including base flow to the Vermilion River watershed, agriculture irrigation and potable well usage. Sand and gravel mining frequently occurs in areas where the targeted sand and gravel deposits provide a shallow, productive aquifer. In many cases, mining may remove overburden and near surface layers of soils and aggregate deposits that would otherwise act as a level of protection to the underlying groundwater. In addition, many sites from which aggregate is extracted are later used as landfills, industrial plants sites or for unrestricted residential development. Changes can occur in groundwater chemistry, water elevation, flow direction, gradient and groundwater temperature ultimately upsetting the delicate balance in both the local and regional environmental setting. Services provided by groundwater can thus be adversely impacted by sand and gravel mining and the final end use conditions after mine reclamation. In order to minimize potential impacts and ensure that mining and ancillary processes can proceed under desirable cost-benefit conditions, the following Mitigation Options are suggested as components of the mining operations plan and end use plan.

5.1 Mitigation Measures

5.1.1. Permitting

Mining operators shall obtain all applicable permits concerning the design, drilling, installation, use and abandonment of groundwater production and dewatering wells per Dakota County Ordinance Number 114. Production wells, dewatering wells and sumps shall comply with all Dakota County Rules and Regulations and Minnesota Department of Health Rules and regulations. Mine Operators shall obtain Minnesota Department of Natural Resources groundwater use allocations for all production wells. Production and end use ponds shall comply with all appropriate and or applicable requirements including Dakota County Ordinance Number 50 concerning Shoreline and Floodplain Management.

5.1.2. Unsaturated Zone

Mine operators shall comply with Empire Township Ordinance Number 450 and 450a, “An Ordinance Establishing Regulations and Standards for Mineral Extraction” or the amended versions thereof. The mining permits and the reclamation plans will specifically address and control the amount of acreage that can be exposed to extraction and the amount of total acreage that can be utilized by an operator at any one time. This portion of the ordinance is an important component of the protection of groundwater because it limits the amount of exposed surface area where the underlying saturated zone containing groundwater is at greatest vulnerability. The ordinance further requires operators return overburden and topsoil in adequate quantities to protect the underlying groundwater as a part of the site reclamation.

5.1.3. End Use Planning

The current 2020 comprehensive plan identifies the proposed Mining Area as Agriculture. During the mining period the Township will periodically update the future land use plan. Non-agriculture land uses will require careful analysis because of the shallow depth to the water table. The Township will be required to perform new environmental review of certain proposed developments according to Minnesota Environmental Rules. It is recommended that the Township consider an Alternative Urban Areawide Review for future non-agriculture land uses of larger mined tracks as the mining activities begin to cease operations. The End Use Plan should ensure the presevation of surface water drainage as identified in Figure 12, "Sand and Gravel Mining and Accessory Uses" or as the abovementioned plan may be modified. Any future land uses must carefully consider that in many cases groundwater will be less than 10 feet below the surface making the site vulnerable to contamination. Future end uses shall include consideration of the importance of the Rosemount Wellhead Protection Program and the Vermillion River Watershed.

5.1.4. Environmental Monitoring and Contingency Plan

Mine operators shall draft a surface and groundwater monitoring program for each separate mine operation and for each separate location. At a minimum it is anticipated that the monitoring plan shall include the monitoring of all surface water bodies including stormwater retention ponds, wash ponds and make-up water sumps. At a minimum, the plan shall include the installation and monitoring of both up-gradient and down-gradient monitoring wells capable of evaluating changes in groundwater elevation, temperature and dissolved solids. The operating plan shall be approvable by all local government authorities including Empire Township, the Rosemount Wellhead and Source Water Protection Plan Administrator, Dakota County Environmental Management and the Vermillion River Watershed Joint Powers Organization (JPO). The plan shall list contingencies that the mine operator will implement based on observed groundwater impacts.

The mine operators shall fund a separate long-term monitoring program that includes long-term monitoring and reporting of:

- The existing Empire groundwater monitoring wells
- Vermillion River and tributaries of the Vermillion River within Empire Township, which include, but are not limited to North Creek, Unnamed Tributaries 1 and Butler Pond
- Adjacent wetlands.

Information shall be used by the operators to validate the numerical model simulations and ensure that unanticipated changes in site conditions are promptly addressed. The Environmental Monitoring and Contingency Plan is intended to address the inherent uncertainties associated with trying to simulate future conditions using a numerical groundwater model.

5.1.5. Improve Current Understanding of Layer 2 and Layer 3

The understanding of current site conditions for the underlying deeper aquifers could be improved by installing several nested pairs of groundwater monitoring wells at the site. The wells could be used to verify current assumptions concerning hydraulic conductivity, gradient and water quality in the Prairie du Chien and the Jordan aquifers. The additional wells would certainly add an additional level of confidence in the current understanding of the localized groundwater flow system. The wells could also serve as an early warning system or sentry network for changes at the site. These wells would be included in the long-term monitoring program for the Empire Aggregate Mine Sites described above.

5.1.6. Stormwater Treatment

This topic is covered in the Surface Water Impact Study. In addition to the traditional best management plans (BMPs) for addressing suspended solids entrained in stormwater it is suggested that the mine operators investigate the use BMPs that can address dissolved solids in process water and stormwater. Dissolved solids are typically generated by the dissolution of stored aggregate by rain events or in the aggregate washing process. Stormwater rich in dissolved minerals (hardness) can adversely impact services provided by surficial groundwater. Based on the model simulations it is not anticipated that dissolved solids will present a problem but the operators should have a contingent remedy available in case modeling simulations under predict future conditions.

5.1.7. End Use Stormwater Ponds

The mine operators can significantly mitigate or eliminate groundwater elevation increases, thermal impacts and total dissolved solids increases attributed to the reclamation end use plan by changing the configuration of the proposed end use stormwater ponds to diversion swales. The diversion swales will divert stormwater and minimize infiltration as opposed to enhance infiltration of high TDS laden stormwater. Lower infiltration rates will minimize groundwater elevation increases, mitigate thermal impacts and eliminate any increases in TDS. This is a simple and cost effective mitigation effort that should be included in the Reclamation End Use Plan.

5.1.8. Vegetative Cover

The mine operators can minimize thermal inputs to the groundwater by installing and maintaining trees and tall bushes near end use ponds. This is a traditional method for managing summertime increases in pond water by implementing a shade management plan.

5.1.9. Security

Mine operators shall ensure, per Empire Township Ordinance 405, that areas where aggregate has been mined are adequately secured until reclamation is complete. This is particularly important in areas that are included in the Rosemount Wellhead Protection Program. The End Use Plan shall include provisions for protecting groundwater resources from potential releases of chemicals by direct infiltration or contamination of the end use ponds followed by infiltration into the groundwater resource.

6.0 EXECUTIVE SUMMARY

The following section provides a general summary of the Groundwater Impact Study prepared for Empire Township. The contents of each chapter are briefly summarized. However, a significant amount of the information provided in the study is not discussed in this chapter. It is recommended that the reader review the document in its entirety to understand the methodology, results and conclusions made in preparing the groundwater analysis.

6.1 Project Description and Purpose

A consortium of mine operators and landowners propose to open new mines and expand existing aggregate mining areas to include a total area of approximately 3,600 acres in the northwest portion of Empire Township, Dakota County. Mining would be conducted in a similar manner to the current practices at existing mines within and adjacent to the Mining Area.

The various mine operators have investigated the potential for aggregate production in this area. In addition, the Minnesota Geologic Survey (MGS), Minnesota Department of Natural Resources (DNR), Metropolitan Council (METC) and local governments have conducted studies of available mineral aggregates in the metropolitan area. These studies, together with investigations conducted by mining companies, have revealed extensive reserves of mineral aggregates in portions of Empire Township. Over the next 30 to 40+ years the Mining Consortium will remove and process approximately 200 million tons of sand and gravel reserves within the Mining Area.

A Scoping Environmental Assessment Worksheet (Scoping EAW) was prepared for the proposed project in October 2003. Following review of this document, the Minnesota Environmental Quality Board (EQB) designated the review process as a "Related Actions Environmental Impact Statement (EIS)", since multiple companies and property owners are involved. A Scoping Decision Document was published in February 2004 declaring the need for an EIS and an outline of what it would address.

The Scoping Decision Document required that additional analysis be completed for the Mining Area, addressing a number of topics, including surface water. This Impact Study has been prepared to provide an analysis of potential surface water and wetland impacts in the Mining Area, and to identify options for mitigating these potential impacts. The findings of this Impact Study will be incorporated into the EIS.

6.2 Project Methodology and Assumptions

A three-dimensional numerical groundwater flow model was developed to simulate the groundwater flow system in the Study Area. The model was developed using the USGS computer program MODFLOW (McDonald and Harbaugh 1988; 1996). For this study, the model is designed as a steady-state flow model, because groundwater flow within the Study Area is reasonably stable. In addition, a simulated steady-state flow field is adequate for simulating the long-term fate and transport of potential impacting factors from the Mining Area.

For this study, the objective of this modeling is to evaluate and quantify the potential adverse impacts of the aggregate mining operations on local water resources. Steps in the modeling process included:

- The numerical model was designed, set up, and calibrated to simulate existing groundwater conditions.
- The model was then applied to simulate changes in the system resulting from mining
- Evaluation of potential impacts of mining operations were identified, including changing of the groundwater flow regime in the Vermillion River Basin, possible impact to local wetlands, municipal supply wells in wellhead protection areas, and local brown trout population of the Vermillion River
- Evaluation of potential thermal impacts caused by excavation and aggregate washing were considered

6.2.1 Numerical Flow Model Design

The numerical flow model is a mathematical representation of the conceptual flow model. The design of a numerical model basically consists of three parts: (1) the configuration of the model, which represents the configuration of the aquifer; (2) boundary conditions, including sources and sinks, which represent the interactions of groundwater with internal and external water bodies; and (3) the input parameters, which represent various properties of the aquifer. The aquifer configuration, boundary conditions and input parameters included in the numerical flow model included:

- Model domain and discretization – impact area and geologic layers included in the model
- External boundary conditions – representing hydrologic interaction between areas inside and outside of the model
- Groundwater recharge – recharge distribution, including areal and floodplain recharge
- Vermillion River and associated tributaries – consideration of the rate and direction of flow and the head gradient between the river and groundwater
- Wetlands - distribution of wetlands simulated as groundwater discharge features
- Pumping wells - represented as a specified flux boundary
- Hydraulic parameters – adjustment of factors such as distribution of hydraulic conductivity, vertical anisotropy and conductance of model river and drain (wetland) cells

6.2.2 Calibration Strategies

Model calibration is an important process to adjust various parameters, boundary conditions, and hydraulic stresses to make the model reflect actual site conditions. Parameter values are adjusted consistent with available data to match calibration targets to a reasonable degree. Model calibration is a process that allows examination and improvement the conceptual model. Only a calibrated model is credible for use to perform model prediction simulations. The overall goal of model calibration was to make the model results match the observed flow conditions.

To calibrate the model, a set of calibration targets was first established. The flow model calibration targets include not only the measured hydraulic heads at monitoring wells, but also (1) the groundwater flow pattern, hydraulic gradients, and flow pathways; and (2) the measured or estimated flux. The flow model calibration targets included:

- Water levels from newly installed Empire monitoring wells and available water levels from the Minnesota County Well Index
- Estimated groundwater discharge rates to the Vermillion River between gauging stations BSC2 and USGS Station
- Estimated groundwater discharge rates to North Creek between gauging stations CHP3 and 801
- Estimated groundwater discharge rates to Center Creek between gauging stations PKN1 and 801
- General trend of vertical hydraulic gradients

During model calibration, the adjustment of hydraulic parameters is targeted to meet the various calibration targets and is bounded by specified upper and lower limits, which are chosen based on available information and understanding of the hydrogeologic system.

The model calibration results are evaluated from various aspects, including comparison to the observed hydraulic heads, groundwater potentiometric surface, horizontal and vertical hydraulic gradients, groundwater flow pathways, estimated flux, and overall mass balance. For a detailed discussion of calibration results, see Section 2.3.1.

6.2.3 Model Limitations

The following limitations of the model should be recognized in understanding the model results or before applying the model to future uses.

- The model simulated flow field represents average flow conditions that do not vary over time, and the simulated volumetric fluxes and contaminant migration represent long-term average conditions without consideration of annual variation or seasonal fluctuation.

- The calibrated hydraulic conductivity distribution is a function of the combined effect of hydraulic gradients represented in the potentiometric surface, applied groundwater recharge rate, and specified layer thickness. Any uncertainty or inconsistency between model setup and field conditions that are related to these components might introduce uncertainty or inconsistency to the calibrated hydraulic conductivity distribution.
- The model simulated aquifer heterogeneity is limited by two factors: the model grid size and the heterogeneity that can be reflected in the hydraulic head distribution or interpreted potentiometric surface. The level of detail of heterogeneity, if beyond the above factors, may not be simulated in the model, even though it may have significant influence on hydrologic impacts or contaminant migration.
- Hydraulic conductivity and variations in recharge of the rejected sand that is backfilled in the excavations are unknown. Assumptions were made based on the changes, but the absolute values of these parameters is unknown. If the actual values of these parameters differ significantly from those proposed here, the results of this model may not be directly applicable.
- The simulated TDS and temperature plumes are highly dependent upon the assumed TDS and temperature at the source locations. Thus, the simulated plumes are subject to the uncertainties associated with source conditions. Initial TDS and temperature inputs were worst-case.
- The simulated extent of TDS and temperature plumes is based on assumed effective porosity as well as assumed dispersivities. Because these two parameters are assumed based on literature values instead of site-specific information, the simulated extent of these “plumes” is subject to uncertainties associated with these assumptions.
- The calculated mass loading of TDS and temperature to the surface water features depends on simulated fluxes. As there is some uncertainty in this simulated fluxes to Butler Pond and the neighboring wetland features, the model simulated mass loading may be over estimated.
- The transport code MT3D used for this study does not explicitly simulate heat transfer. This process is approximated in this study using principles in the conservation of mass. This is intended to provide a baseline worst-case to analyze the effects of temperature. Any further analysis or refinement of the effects of temperature with this model in further detail than that described herein may be unreliable.

6.3 Existing Conditions

6.3.1 Geology

Geologic units in Dakota County in the vicinity of Empire Township can be classified into three major categories: (1) Precambrian volcanic and crystalline rocks; (2) Cambrian through Ordovician sedimentary rocks; and (3) Quaternary unconsolidated deposits which include glacial outwash, glacial till, and alluvial deposits.

Bedrock Geology

The general characteristics of the bedrock units pertinent to this study include Platteville-Glenwood Formations, St. Peter Sandstone, Prairie du Chien Group, and Jordan Sandstone. The thickness and textural characteristics of these units can vary from place to place but, in a general sense, are relatively uniform.

Platteville and Glenwood Formations

The Ordovician Glenwood Formation is green, sandy shale that overlies the St. Peter Sandstone, where present. The Glenwood Formation ranges in thickness up to 15 feet. The Ordovician Platteville Formation is a fine-grained dolostone and limestone (Mossler, 1990). The Platteville Formation is reported to be approximately 10 feet thick. Both units are present as small isolated flat-topped mesas within the Study Area.

St. Peter Sandstone

The upper half to two-thirds of the Ordovician St. Peter Sandstone is fine- to medium-grained quartzose sandstone. Quaternary erosion by glaciers has removed much of the St. Peter Sandstone and younger Paleozoic rocks from central and southern Dakota County, leaving remains of the St. Peter Sandstone as isolated outcrops, typically capped by the Platteville-Glenwood Formations, which are more resistant to erosion.

Prairie du Chien Group

The Ordovician Prairie du Chien Group contains the Shakopee Formation (upper) and the Oneota Dolomite (lower). The Prairie du Chien Group is approximately 145-feet thick near St. Paul (Mossler, 1990).

Jordan Sandstone

The upper part of the Cambrian Jordan Sandstone is medium- to coarse-grained, friable, quartzose sandstone that is trough cross-bedded. The Jordan Sandstone is approximately 90 feet thick near the Minnesota River and thickens to over 200 feet in southern Dakota County (Mossler, 1990).

Quaternary Geology

The Quaternary geology surrounding the Mining Area is primarily outwash and till deposits related to the advance of the Superior and Des Moines glacial lobes. Superior till and outwash predominate the Mining Area, but there is also some Des Moines till/outwash near the southern portion of the Mining Area (**Figure 10R**). Superior lobe tills are generally rich in sand with lesser portions of silt and clay. Des Moines Lobe tills are very clay-rich. The area surrounding the Vermillion River channel is primarily filled with floodplain alluvium, but also contains till from the Superior and Des Moines lobes. In addition, there also exist some isolated exposures of pre-late Wisconsin deposits such as the "Old Gray" Till which is observed in isolated exposures on some of the topographic highs surrounding the Mining Area.

6.3.2 Hydrogeologic Setting

Hydrostratigraphic Units

Hydrostratigraphic units comprise geologic formations of similar hydrogeologic properties, which are combined or divided into aquifers or aquitards. These hydrostratigraphic units include:

- Prairie du Chien-Jordan Aquifer – treated as a single aquifer system in early studies, but more recently identified as two distinct units
    - Jordan Sandstone - sub-crops beneath glacial drift and alluvium in major river valleys, which are the primary discharge zones
    - Prairie du Chien Group - groundwater flow primarily through fractures, joints, and solution features
- Glacial Drift-St. Peter Aquifer – relatively good hydraulic connection with local streams and lakes; recharge primarily by infiltrating precipitation; discharge to streams, lakes and leakage to underlying aquifers

Groundwater Flow

Groundwater generally moves from upland areas of recharge downgradient to lowland areas of discharge. In the Study Area, groundwater movement is generally from west-southwest to east-northeast.

The contours for the shallow Glacial Drift-St. Peter aquifer were derived based on water level measurements from the Minnesota County Well Index, boreholes used to delineate the depth and extent of aggregate mining deposit, in addition to the five newly installed Empire Township monitoring wells (**Figure 2R**). In addition, groundwater contours are constrained by the surface topography of wetland areas that have been delineated as groundwater dependent resources and represent groundwater discharge areas (see Section 2.6). Groundwater elevations in the shallow aquifer throughout Dakota County are generally stable, exhibiting fluctuations of less than three to four feet (EOR, 2004). Depth to groundwater in the Mining Area is generally in excess of 20 feet. In some localities, depth to groundwater may be more than 50 feet. In the vicinity of the Vermillion River and other groundwater discharge areas, depth to groundwater is essentially negligible with some areas exhibiting artesian conditions.

Hydraulic Gradients

The horizontal hydraulic gradient is approximately 0.002 feet/feet and does not vary substantially throughout the Study Area. To the northeast, hydraulic gradients increase slightly to 0.003 feet/feet as groundwater approaches the discharge area of the Mississippi River. To the west of the Mining Area boundary, the hydraulic gradient is 0.001 feet/feet. This may be indicative of more permeable strata in the subsurface, but this is speculative as the available hydraulic head data west of the Mining Area is limited.

Vertical hydraulic gradients vary substantially throughout the Study Area and some spatial trends in vertical gradients have been observed. Generally, measured hydraulic head differences between shallow and deep aquifers at wells clustered together (**Figure 4R**) show downward gradients in upland areas away from the river and upwards gradient in the vicinity of the river. This suggests that groundwater recharge by direct infiltration of precipitation occurs in most of the areas away from the creeks, whereas groundwater discharge occurs at the creeks and along the floodplains. It also suggests that the convergence of groundwater flow toward the Vermillion River occurs horizontally as well as vertically. This is supported by strong upward hydraulic gradients, even artesian flow conditions, observed along the river. However, local vertical hydraulic gradients may vary significantly and not follow this spatial trend. Upward flow gradients have been observed in areas away from the creeks and vice versa, suggesting that local vertical gradients are influenced by local heterogeneities.

6.3.3 Groundwater Recharge

Groundwater recharge occurs throughout the Study Area as a result of surface water infiltration. Infiltration of direct precipitation is dependent upon the rate and duration of precipitation, the soil type and soil cover, land use, evapotranspiration, and topography. In a steady-state model, the resulting infiltration rate is typically estimated on an annual basis - although seasonal estimates are sometimes utilized. Groundwater recharge in the upland areas and lowland areas along the floodplains can be considered separately as areal recharge and floodplain recharge, respectively.

The predominant source of recharge for the deeper aquifers in Dakota County is regional flow from areas outside the County and downward leakage from the Glacial Drift/St. Peter aquifer.

Areal Recharge

Areal groundwater recharge occurs as a result of surface water infiltration primarily during early springtime. Assuming that long-term groundwater recharge is approximately equal to long-term groundwater discharge to streams, annual recharge from precipitation is approximately 1.5 to 4.5 inches per year. Thus, about 6 to 15 percent of precipitation infiltrates to groundwater.

Floodplain and Wetland Recharge

The occurrence and amount of groundwater recharge along the river and tributary floodplains are expected to be of greater magnitude than areal recharge. Infiltration occurs along the floodplains as a result of direct precipitation and flooding caused by surface water runoff. The rate of floodplain recharge is unknown, but it is expected to be greater than areal groundwater recharge.

6.3.4 Hydraulic Properties of Aquifer(s)

Hydraulic conductivity, specific yield (or storage coefficient), and effective porosity are commonly used to characterize the hydraulic properties of an aquifer. In this study, the flow conditions are considered relatively stable; thus, specific yield, which is related to temporal variation of groundwater, is not discussed. Site-specific data for effective porosity are not available.

6.3.5 Surface Water

Vermillion River and Associated Tributaries

The Vermillion River is located approximately two miles south of the southern boundary of the proposed Mining Area. The Vermillion River begins in Scott County and flows into Dakota County, ultimately discharging into the Mississippi River near the city of Hastings, Minnesota. The drainage area to the Vermillion River at the gauging station is approximately 129 square miles. The Vermillion River is a zone of groundwater discharge in the Study Area and becomes a source of groundwater recharge downstream closer to the Mississippi (Palen, 1990; Almendinger and Mitton, 1995)

North Creek is located approximately one mile west of the west boundary of the proposed Mining Area. North Creek extends from the City of Lakeville into the City of Farmington and Empire Township, and acts as a major tributary to the Vermillion River. The total area of the North Creek watershed is approximately 15,774 acres, including drainage areas from Lakeville, Farmington, Apple Valley, Rosemount, Burnsville and Empire Township. This creek is perennial throughout much of its length, but has several ephemeral branches in its headwaters. Middle Creek is another perennial tributary to the Vermillion River that drains the highland area west of Flagstaff Avenue in southern Lakeville.

There are two unnamed tributaries to the Vermillion River in vicinity of the Mining Area. Unnamed Tributary 1 lies south of the Mining Area. This is a perennial tributary that drains the Butler Pond area. Local residents have indicated that this pond does not completely freeze during coldest winter months suggesting that it may be fed, in part, by groundwater flow. Small portion of Unnamed Tributary 1 north of Butler Pond is considered to be groundwater fed based on mapping of adjacent vegetation, but is ephemeral throughout most of the proposed Mining Area (EOR, 2004).

Unnamed Tributary 2 lies to the east of the Mining Area is ephemeral and typically dry. Detailed analysis indicates this tributary is a zone of recharge. Hydraulic gradients between nested wells in the vicinity of these drainages indicate downward gradients representative of a recharge area.

The following table presents a summary of stream flow data taken in mid-July of 2004 indicating representative flow rates observed at several of the gauging stations depicted in **Figure 2R** (EOR, 2004).

Table 6-1: **Summary of Stream Gauging Measurements in the Vicinity of the Proposed Mining Area**

Gauging Station	River Branch	Flow (cfs)
ANN1	Unnamed Tributary 1	1.30
CHP3	North Creek	6.49
CHP2	North Creek	7.81
BCS2	Vermillion River	69.04
801	Middle Creek	51.4
804	Vermillion River	31.0
807	Vermillion River	37.4
808	North Creek	10.7
USGS	Vermillion River	84.0

6.3.6 Wetlands

Wetlands within the Study Area were identified by the Empire TownshipWetlands Inventory (EWI). Wetlands surrounding the proposed Mining Area consist of both discharge and recharge wetlands. A study using field investigation and GIS analysis is currently underway by Emmons and Olivier Resources, Inc. (EOR) to delineate the extent of groundwater dependent resources in Scott-Dakota County. The wetlands identified as probable groundwater discharge areas are located along the banks of the Vermillion River and North Creek in addition to several flatland areas in the vicinity of Butler Pond. These consist of mixed hardwood swamp, willow swamp, wet prairie, and wet meadow.

The wetlands not delineated in the EOR study are considered to be wetlands that recharge the groundwater system. Recharge to the shallow aquifer occurs when the wetland collects rain or spring snowmelt, and water infiltrates downward.

6.3.7 Summary of Conceptual Model

The primary source of recharge to the Glacial Drift/St. Peter Sandstone aquifer is infiltrating precipitation. The primary source of recharge for the Prairie du Chien Group and Jordan Sandstone aquifers is leakage from adjoining aquifer. Lakes and ponded water in wetlands are generally perched above the water table and leak water down into the aquifer as a function of the resistance of the lake’s bottom sediment and the unsaturated drift material below the lakes.

Discharge of groundwater occurs at the Vermillion and Mississippi Rivers and their adjacent wetlands. Pumping wells also remove water from the aquifer units.

6.4 Mining Impact Analysis

The following section summarizes the results of the numerical modeling effort to assess potential impacts related to proposed mining operations.

6.4.1 Hydrologic Impacts Related to the End Use Plan

The model estimates that groundwater levels may raise between 2.0 and 3.0 feet with water table increases of 0.1 and 0.5 near the boundaries of the proposed Mining Area. This change in the groundwater elevations is interpreted to be the maximum potential impacts due to hydraulic impacts of the end use plan and considered to be a very worst-case scenario. These results are based on the use of a comparatively high hydraulic conductivity for the material lining the base of the stormwater ponds in addition to the assumption that these ponds will be used entirely as detention ponds as opposed to their primary intended use as stormwater diversion structures. Use of these as diversion structures will limit the amount of hydraulic head that will drive infiltration downward to the aquifer and will minimize the amount of groundwater level rise.

Using the conservative, worst-case assumptions, mining changes produce minimal impacts to the estimated groundwater fluxes to select surface water features surrounding the proposed mining area. Groundwater flow rates to Butler Pond and the surrounding wetlands are estimated to increase between 0.02 and 0.05 cfs, resulting in a 2.7 to 21.1 percent change in flow. Groundwater flow to North Creek is estimated to increase 0.08 cfs, reflecting a 6.8 percent increase in flow. These changes in the simulated long-term, average estimated flow rates are less than the observed seasonal fluctuations. Given the conservative, worst-case assumptions, hydraulic impacts to these surface water features are estimated to be negligible.

6.4.2 Impacts related to TDS and Temperature

The numerical model was used to evaluate potential TDS and temperature impacts to local surface water and wetlands features. A conservative scenario was used in which the stormwater ponds have an elevated TDS of 1,000 mg/L, ten times the TDS concentration of a local analogue pond and twice the average concentration of local groundwater and surface water concentrations. Likewise, thermal impacts were simulated using conservative, worst-case assumption in which there is no conductive heat loss to the aquifer. Model results indicate TDS concentration increases ranging between 3.6 to 36 mg/L and temperature increases ranging between 0.07 and 1.13 ºC to the local surface water and wetland features (see tables 4-2 and 4-3). These estimated changes in TDS and temperature are well below the range of seasonal fluctuations and within the range of variability related to sampling error. Therefore, given the conservative, worst-case assumptions, impacts related to temperature and TDS to these surface water features are deemed to be negligible.

6.4.3 Impacts Related to Potential Dewatering

The methodology of dewatering is assumed to be similar to that exhibited at the Lauer property in Empire Township (SEH, 2003). Simulations were conducted using 15 wells equally spaced around a circle of diameter of approximately 1,000 feet. Pumping rates of 600 gpm and 1200 gpm equally distributed between the wells were evaluated. Modeling estimates that fluxes to the local surface water and wetlands near the southern boundary of the proposed mining area will experience reduction is flux rates ranging from 6.3 to 52.4 percent (see Table 4-4). These impacts to the local surface water features are considered to be minimal to moderate. It is therefore recommended that dewatering during mining be limited to areas in the northern portion of the proposed Mining Area where impacts to the local surface water and wetlands are deemed to be negligible.

6.4.4 Impacts to the Wellhead Protection Area

The model estimates that the TDS will increase approximately 5 to 85 mg/L and will increase in temperature approximately 0.2 to 2.0 °C within the WHPAs and DWMAs delineated for the Rosemount wells. However, for the most, maximum increases are localized in a small portion of the WHPA and DWMA with increases in TDS and temperature primarily on the order of 30 to 50 mg/L and less than 1.0 °C, respectively. However, given the conservative, worst-case assumptions related to simulating the end use plan, impacts to the WHPAs are likely to be minimal.

6.4.5 Mining Impact Conclusions

Numerical modeling was performed to evaluate potential hydraulic, chemical (e.g. TDS), and thermal impacts on local wetlands, surface waters that may act as trout habitat, and wellhead protection areas. As indicated in the previous section, input parameters to evaluate these impacts have been selected using conservative assumptions to arrive at the worst-case scenario. While the worst-case assumption is assumed, model predications indicate that the potential adverse impacts to the aforementioned resources are negligible.

6.5 Mitigation Options

In order to minimize potential impacts and ensure that mining and ancillary processes can proceed under desirable cost-benefit conditions, the following Mitigation Options are suggested as components of the mining operations plan and end use plan.

- Permitting - Mining operators shall obtain all applicable permits concerning the design, drilling, installation, use and abandonment of groundwater production and dewatering wells per MDNR, MDH and Dakota County Ordinance Number 114.
- Unsaturated Zone - Mine operators shall comply with Empire Township Ordinance Number 450 and 450a, “An Ordinance Establishing Regulations and Standards for Mineral Extraction” or the amended version thereof.
- The current 2020 comprehensive plan identifies this area as Agriculture. During the 35-year mining period, the Township may periodically update the future land use plan. Any non-agriculture land uses identified within the Mining Area will require careful analysis because of the shallow depth to the water table. The Township will be required to perform new environmental review of non-agriculture

developments according to Minnesota Environmental Rules. It is recommended that the Township consider an Alternative Urban Areawide Review for future non-agriculture land uses of larger mined tracks as the mining activities begin to cease operations. The End Use Plan should ensure the preservation of surface water drainage as identified in Figure 12. The ultimate end use drainage features shall be preserved in the post mining land plan by enforcement of the then current planning and zoning ordinances and building codes. Any future land uses must carefully take into consideration that in many cases groundwater will be less than 10 feet below the surface making the site vulnerable to contamination. Future end uses shall include consideration of the importance of the Rosemount Wellhead Protection Program and the Vermillion River Watershed.

- Environmental Monitoring and Contingency Plan - mine operators shall draft a surface and groundwater monitoring program for each separate mine operation and for each separate location. At a minimum it is anticipated that the monitoring plan shall include the monitoring of all surface water bodies including stormwater retention ponds, wash ponds and make-up water sumps. At a minimum, the plan shall include the installation and monitoring of both up-gradient and down-gradient monitoring wells capable of evaluating changes in groundwater elevation, temperature and dissolved solids.
- The mine operators shall fund a separate long-term monitoring program that includes long-term monitoring and reporting of:
    - The existing Empire groundwater monitoring wells
    - Vermillion River and tributaries of the Vermillion River within Empire Township
    - Adjacent wetlands
- Improve the current understanding of Layer 2 and Layer 3 - install several nested pairs of groundwater monitoring wells at the site. The wells could also serve as an early warning system or sentry network for changes at the site. These wells would also be included in the long-term monitoring program described above.
- Stormwater treatment – Best Management Practices (BMPs) as described in the Surface Water Impact Study.
- End use ponds - mine operators can significantly mitigate or eliminate groundwater elevation increases, thermal impacts and total dissolved solids increases attributed to the reclamation end use plan by changing the configuration of the proposed end use ponds from retention ponds to diversion swales.
- Vegetative cover - mine operators can minimize thermal inputs to the groundwater by installing and maintaining trees and tall bushes near end use ponds.
- Security - Mine operators shall ensure, per Empire Township Ordinance 405, that areas where aggregate has been mined are adequately secured until reclamation is complete. This will protect

groundwater resources from potential releases of chemicals that could infiltrate and contaminate the resources. This is particularly important in areas that are included in the Rosemount Wellhead Protection Program.

6.6 Definitions

Anisotropy	exhibiting properties with different values when measured in different directions
Areally	spatially distributed
Baseflow	flow in a stream, river or creek solely attributed to groundwater discharge
Discharge	a condition in which the net flux of water into the aquifer system is negative, hence water is leaving the aquifer system
Discretization	how the model domain is divided up into space and time
Flux	flow of a volumetric quantity of a liquid through a prescribed area over a given time
Hydraulic Conductivity	a coefficient of proportionality describing the rate at which water can move through a permeable medium
Potentiometric Surface	a surface that represents the level to which water will rise in tightly cased wells

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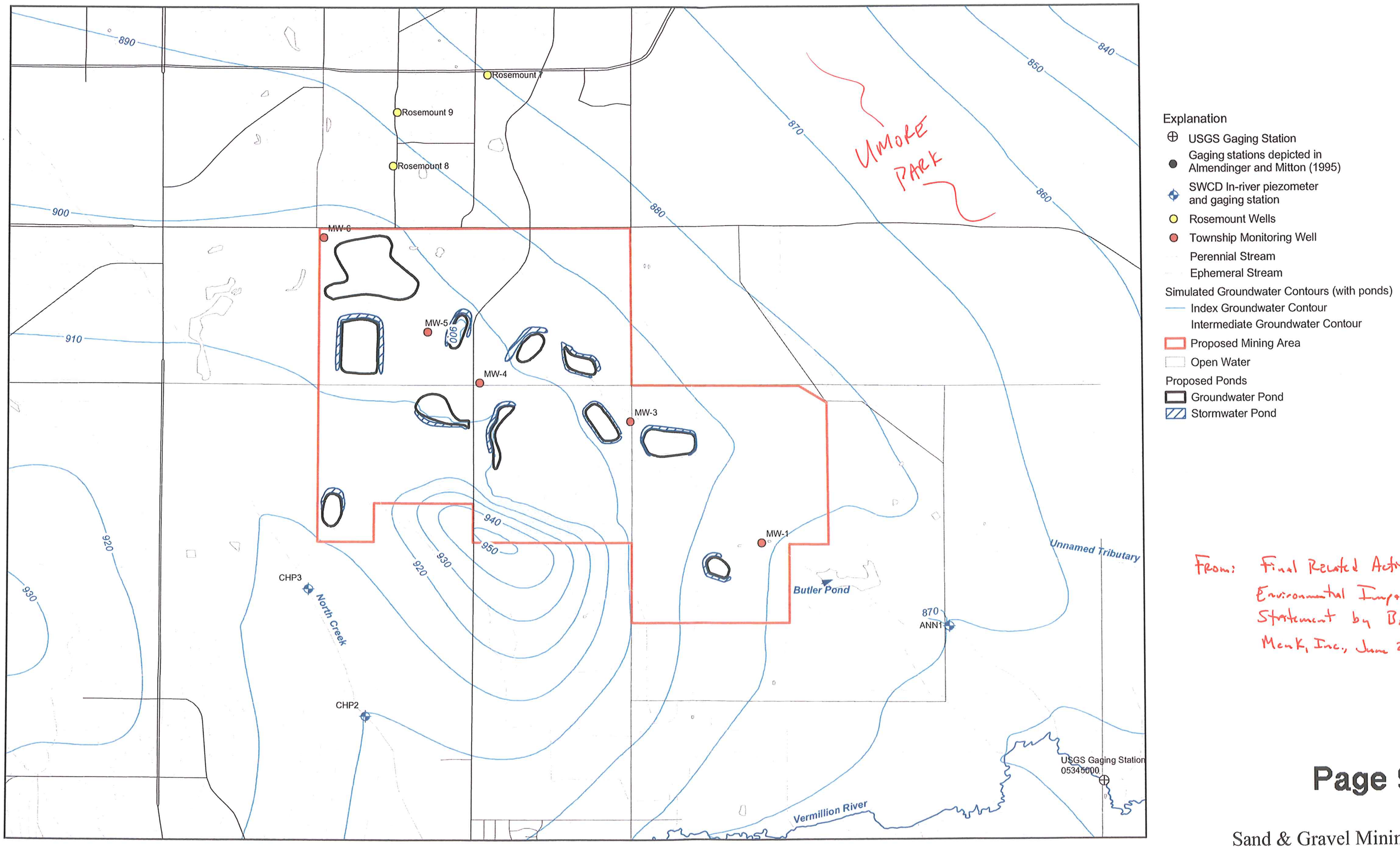

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Page 9

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Empire Township

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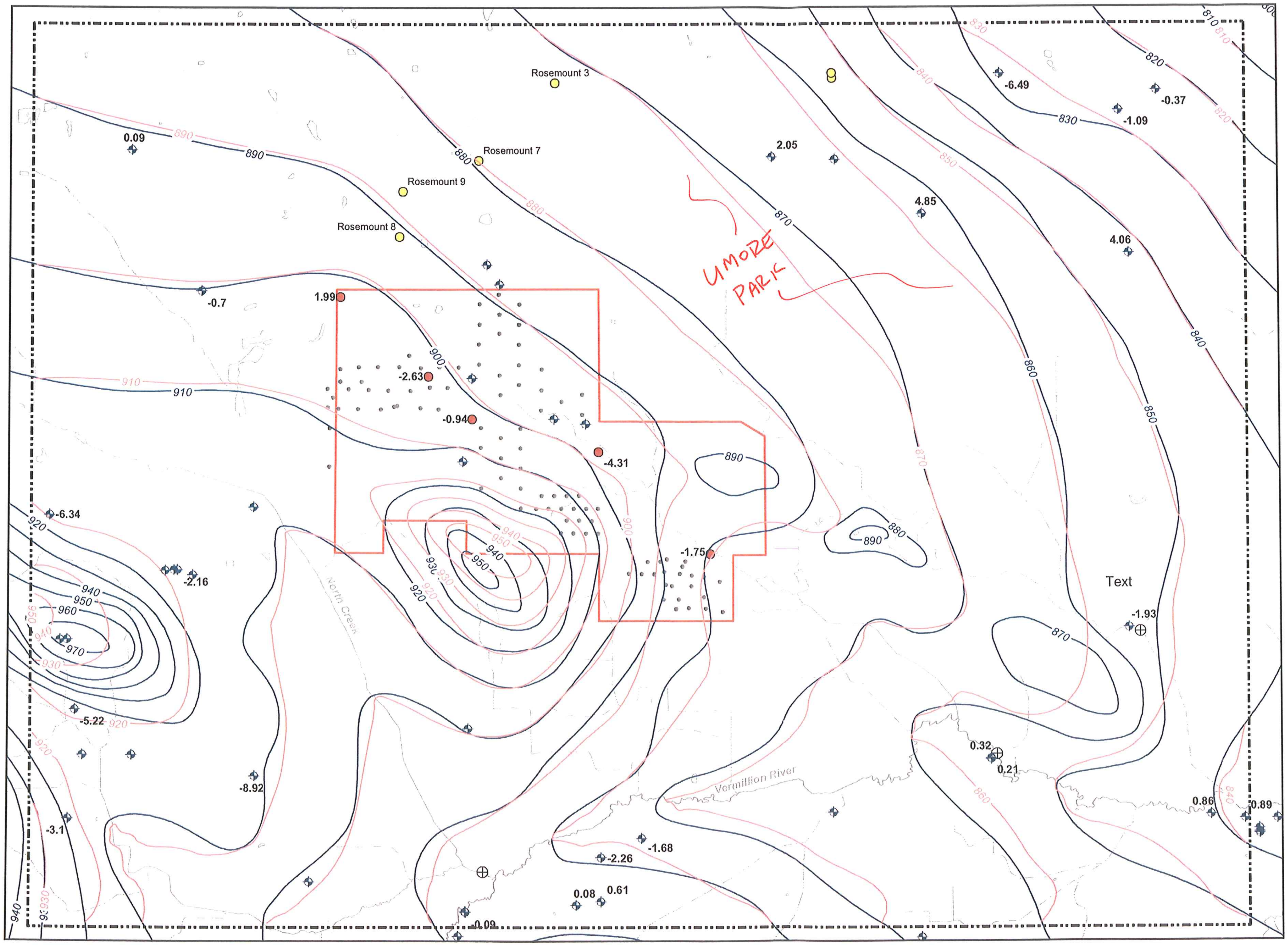
Figure 14
Simulated Reasonable Water Levels
After End-Use Plan Implementation



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Sand & Gravel Mining
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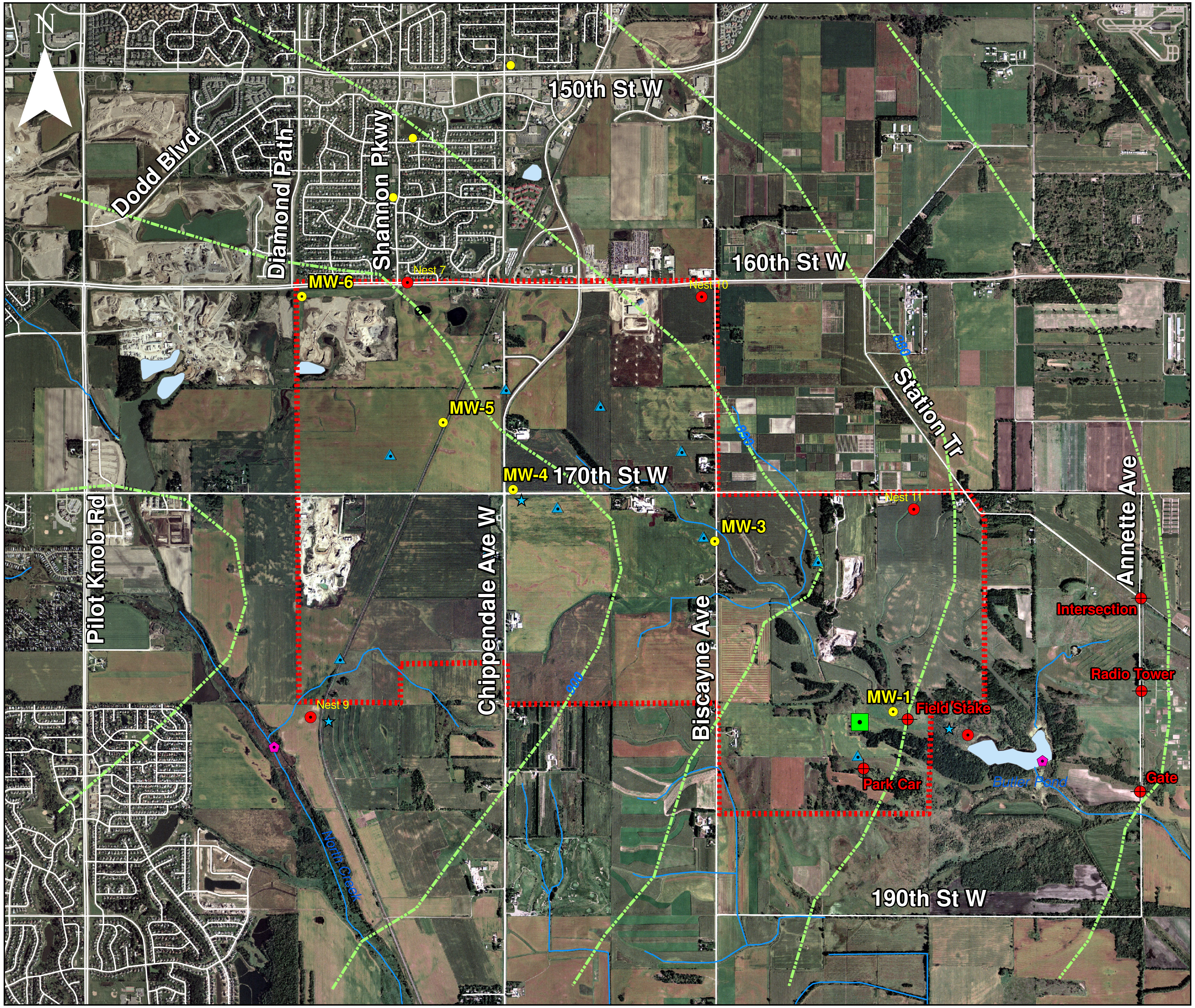
Figure 5 Revised Page 6

Interpreted vs. Simulated Groundwater Contours for Model Layer 1



Legend

- ⊕ Landmarks
- ● Existing_mon_wells_June_2008
- ★ Rain/Tipping Buckets
- ⬟ Surface-Water Level/Temp Monitoring Stations
- 🟩 Runoff Monitoring Station
- △ Pond Shallow Wells (20 ft and 50 ft from Pond) (location is approximate)
- ● Proposed Well Nests
- ‐·‐ Predicted Water-Table Contours (feet, MSL) at Year 40
- ○ City of Rosemount Water Supply Wells
- ▭ Proposed Mining Area Boundary (tentative location, site conditions permitting)

Notes: Proposed well locations, surface-water level monitoring locations, and tipping-bucket locations are approximate

Miles
0 0.45 0.9

Feet
0 3,200 6,400

Figure 2-1-MPM

WELL LOCATIONS
MW-1 THROUGH MW-5

(Groundwater and Surface Water Monitoring Plan: Proposed Location of Wells and Tentative Location of Runoff Monitoring Station)