KENNECOTT UTAH COPPER

South Facilities
KUCC Flow and Transport Model Modifications and Updates

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Appendix to: Final Design for Remedial Action at South Facilities Groundwater

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1.0 Purpose and Scope of Groundwater Modeling Updates

The Groundwater Modeling studies for Kennecott Utah Copper Corporation (KUCC) Southwestern Jordan Valley (SWJV) flow and transport modeling have been an on-going effort beginning with the South Facilities Remedial Investigation and Feasibility Study (RI/FS) in 1998. As is typical for a complex groundwater-modeling program, the modeling objective has continued to be refined, and knowledge of the system and the questions to be addressed evolve. To better support evaluation and design studies, KUCC has updated the model both with improved pre- and post-processing software and by providing for new hydrogeologic and groundwater data. The result is accurate and useful predictions, particularly for the Bingham Creek region where contaminated groundwater-containment design is focused.

This document outlines the changes and updates in the KUCC numeric modeling process to date and reflects the model status as of the Final Design Report for Remedial Action at South Facilities Ground Water. This supplements previous modeling reports provided as part of the RI/FS and Remedial Design and Remedial Action (RD/RA) processes and addresses the recent modeling changes since reporting in the course of the RD/RA and related Work Plans.

2.0 Feasibility Study Issues

As outlined in Section 5.0 of the South Facilities Feasibility Study (FS), the EPA and Technical Review Committee (TRC) recommended that Kennecott gather additional data. The additional data outlined in the FS that falls under the groundwater studies and modeling efforts described in the Remedial Design Work Plan (RDWP) are:

- Optimization of extraction well placement, design, completion depths and extraction rates, all of which are dependent on aquifer characteristics
- Modification of the Kennecott flow and transport models to address boundary conditions and investigate the feasibility of incorporating density-driven flow modeling

Specific items discussed include:

- Background and current model status
- Model rediscretization and recalibration
- Density modeling investigation
- Model sensitivity analyses
- Groundwater modeled recharge and injection, and
- Groundwater extraction scenarios (optimization)

3.0 Background

As part of additional studies related to the Kennecott Utah Copper Corporation (KUCC) South Facilities RI/FS and RD/RA pertaining to the southwestern Jordan Valley, KUCC has continued optimization of its coupled groundwater flow and transport model. The current modeling has improved analysis of groundwater flow and contaminant migration, including most importantly the evaluation of water-level trends and containment options regarding aquifer contamination.

KUCC has made previous upgrades to the original RI/FS flow and transport model, including incorporation of a head-dependant (general head) boundary along the western edge of the model, which replaced the constant flux boundary used in the original modeling due to TRC suggestions. Also, the eastern model boundary was expanded from the Jordan River to the base of the Wasatch Mountains, allowing for evaluation of the model's ability to simulate the possibility of flow beyond the previous Jordan River boundary. Updated field data have also been incorporated into the model, as new data became available, especially concerning water level and contaminant information. Summaries and updates of these improvements have been reported as part of the RI/FS and RD/RA processes and in conjunction with the TRC. Since this report is provided as an extension of this previous work of the ongoing KUCC modeling effort, the mathematics and nuances of the numeric modeling process will not be restated. However, these details are fully described as part of the South Facilities RI/FS in Appendix G titled "*Numerical Simulation of Groundwater Flow in Southwestern Jordan Valley, Utah*."

KUCC's regional model of the SWJV covers approximately 170 square miles, bounded by the Oquirrh and Traverse mountains (on the west and south, respectively) and by the Wasatch Mountains and approximately 6000 South street (east and north, respectively).

4.0 KUCC Regional Model

The current regional SWJV flow and transport model was converted from the current KUCC expanded regional model using the Groundwater Modeling System (GMS) software developed at Brigham Young University in partnership with the U.S. Army Engineer Waterways Experiment Station. GMS was selected as upgrade software for its pre- and post-processing functionality and its compatibility with the previous KUCC models using MODFLOW (groundwater flow modeling) and MT3D (contaminant transport modeling). GMS is a comprehensive graphical user environment for performing groundwater flow and transport simulations, among other abilities.

The current KUCC model has been incorporated into GMS using two approaches. The first was a direct import of the KUCC expanded regional model data using the GMS import features. In essence, the model remains identical (with the exception of a few manual changes that GMS required as per differences in how the Processing Modflow software and GMS software each handle information). This first step allowed for the model to be run with both software packages, allowing for direct comparisons. The second modeling approach in GMS involves the creation of a conceptual model in GMS using the KUCC model data.

Since many of the tools and features of GMS cannot be utilized with a model that is directly imported using the first approach, an additional conceptual model needed to be constructed (using the same model data from the expanded regional model). The conceptual-model approach provides for Feature Objects in the model for generating an improved model representation to various characteristics. Feature Objects in GMS have been patterned after Geographic Information Systems (GIS) objects such as nodes, arcs and polygons, and are compatible with Arc/Info and ArcView features. This provides for improved functionality and features for working with the KUCC expanded regional model.

The GMS model was created with data from the KUCC expanded regional model and thus has a nearly identical vertical layer distribution and hydrogeologic conditions to the KUCC expanded regional model. The aquifer is divided into 8 layers, where generally: Layer 1 represents the shallow unconfined aquifer located in the eastern part of the study area, Layer 2 represent the confining layer, separating the shallow unconfined and principal aquifer, and Layers 3-8 represent the principal aquifer. The GMS predictive model, like the KUCC expanded regional model, has an updated head-dependant western boundary for a more accurate representation of bedrock recharge behavior along that margin. Other numeric and hydrogeologic features of the model remain the same as the previous model.

Having incorporated an equivalent, functional regional model in GMS, the next step in providing improved model simulations for the remedial process was to develop a more focused model, specifically for simulations of the Bingham Creek region, as a complement to the larger regional model. Primary benefits of the localized model include:

- Faster simulations in the area of principal concern, and
- Stochastic investigations for risk analyses, such as capture zones and threshold simulations that have improved scenario probabilities.

Figure 1 shows the approximate GMS model boundaries in relation to the Salt Lake valley.

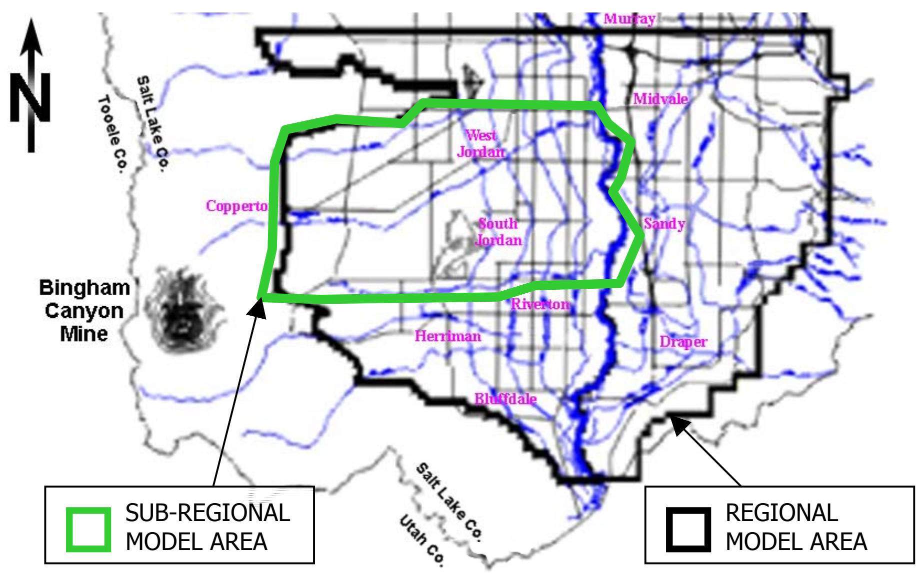

Figure 1. Approximate GMS model boundaries.

5.0 Model Calibrations

5.1 Steady-State Calibration

Steady-state calibration comparisons with the GMS conceptual model were performed in much the same manner as in the KUCC South Facilities RI/FS modeling process, with the same data and conditions for the years 1967 through 1996, and with new data (whenever available) through 2001. Because the data used to reconstruct the model in GMS are essentially the same data used to construct the original and expanded KUCC models, it was expected that the steady-state calibration would be very similar to that of the previous models' calibrations. In fact, this was indeed the case, with a few relatively minor differences. These differences are attributable to the methods that GMS uses for reading and interpolating the original input data with regard to hydrologic and other parameters. When reconstructing the model using the GMS conceptual approach, there are areas where previous data points failed to coincide with values in the previous model. GMS provides improved automation and interpolation schemes, specifically regarding the ability to alleviate problems associated with inputs by allowing for known values in Feature Objects to be designated, and GMS then assists in the process. This also provides for boundary conditions that more accurately simulate real world situations than could be previously represented. Such nuances in the way the conceptual model had to be put together with the KUCC model data influenced the flow model and subsequent calibrations when compared with the previous expanded regional model. Comparisons of the overall modeling results however, show that the GMS conceptual model is very similar in simulations and predictions to that of its predecessor, since the same data sets were used in the creation of each.

The process of steady-state calibration was primarily focused on achieving results in line with those of the previous model's calibration to provide a useful benchmark for further simulations. At the time of calibration comparison process, the GMS software upgrade and subsequent newer tools and features were not available. Therefore, improvements to calibration were not as much of a priority as was matching of the previous calibration. Once the GMS model was converted and tested with respect to the expanded regional model, improvements in model accuracy could become a focus. The newer features of the GMS upgrade have now been installed, and with them, improvements to model parameters are expected to be evaluated in the coming months. The further analyses will pursue, wherever possible sensitivity analysis as a significant part of the ongoing modeling.

This calibration with the previous steady-state results was directed towards achieving a reasonable match with the most recent and available (measured) water levels, estimated and known discharges, and the flow through the general-head boundaries. Vertical gradients were not considered during steady-state calibration due to the absence of data for comparison. Other calibration variables in the steady-state calibration also were investigated, including horizontal and vertical hydraulic conductivity, and aerial and bedrock recharge. Irrigation and lawn watering seepage, irrigation canals seepage, river boundary parameters were not used as calibration variables. Much of the calibration process focused on the inflow from the head-dependent western margin in matching water levels.

Throughout the process, results from each model run were compared with the available measured water levels found in the KUCC model domain. For the steady-state comparison, a total of 32 observation sites were available, all of which were located in the principal aquifer in layers three and four. Data were not available within the study area for the water table within the shallow unconfined aquifer, so data from the previous KUCC model were used for the default, as with previous modeling. The shallow unconfined aquifer could only be analyzed by evaluating the groundwater flow along the Jordan River.

For each model run, an analysis of the observed versus computed water levels was conducted to determine the accuracy of the simulation. Three methods were used for determining the level of accuracy. The first method involved calculating the mean of the residuals. This provides a measure of the bias of the distribution, indicating whether the simulation was over- or under-estimating the water table as a whole. The second method involved the calculation of the root-mean-square or standard deviation of the residuals, which provides a measure of the squared differences in measured and computed water levels, a sensitive test of the range of differences. The third method involved calculating the standard error between the observed and computed values. The standard error calculates the mean of the absolute values of the residuals. This provides a more realistic measure of the average difference between the observed and computed values.

Calibration targets for the observed versus computed heads were established by evaluating several parameters in each area of the model domain. The horizontal gradient was considered to be the most critical due to the steep water table along the western edge of the model domain. Flows from the shallow unconfined aquifer discharging to the Jordan River were also checked in the steady-state calibration comparisons.

Another calibration target involved matching flow through the northern model boundary. Flows through this boundary could not be independently calculated due to a lack of data concerning the geometry of the aquifer and the associated aquifer properties. The original basis for calibration was a comparison with the USGS model of the same area. This comparison was undertaken by comparing the total flow discharging from the model with the percentage leaving the northern boundary. A calibration target of ± 5 percent of the computed values of the USGS model was determined to be acceptable and was achieved.

Results of the steady-state calibration for 32 modeling points comparing the original RI/FS modeling results and the KUCC expanded regional model with the GMS conceptual model are shown in Table 1. Calibration data was very comparable to results seen from the previous modeling calibrations.

Table 1. Steady-State Flow Model Calibration Comparisons (data in feet).

	Original RI/FS Model	Regional KUCC Model	GMS Model
Average Mean Error	NA	7.1	8.6
Average Mean Absolute Error	11.2	11.4	11.9
Root Mean Squared Error	14.5	14.7	14.9
Single Max. Difference Lower than Measured	37.0	26.9	31.2
Single Min. Difference Higher than Measured	32.0	45.3	44.0

5.2 Transient-State Calibration

The GMS transient-state calibration relied predominately on matching the observed water level changes that have occurred within the SWJV from 1965 through 1998 to 2001 (dependant on latest available data) as in previous KUCC modeling. As with the steady-state calibration, transient runs were expected to be very similar to previous model results due to the fact that the same data was used to construct the GMS model, and this proved to be the case. Although the data were not identical to the KUCC regional model in the steady-state results, the differences were attributable to the expected data processing differences of GMS as previously noted.

Greater water-level declines have been simulated within certain modeled areas than were obtained for earlier modeling efforts due to excessive pumping of groundwater for municipal and industrial needs since earlier simulations were completed. The transient-state model also simulated former leakage rates from the former Large Bingham Reservoir located at the mouth of Bingham Canyon. Groundwater discharge to the Jordan River, flow through the northern boundary, and vertical gradients were also examined throughout the transient-state calibration. Parameters regarded as calibration variables included horizontal and vertical hydraulic conductivity, specific yield, storage coefficient and the recharge to the aquifer from the Large Bingham Reservoir. As with the steady-state process, the primary focus for the transient calibration of the GMS model centered on achieving comparable results to those of the previous KUCC regional model. Parameters were adjusted in areas where interpolation of data ended up differently enough to cause a change between GMS and previous model results. There were only a handful of areas where this was necessary to achieve the desired parameters.

As with the steady-state cases, improvements to the calibration were not as much of an initial priority as was matching (at minimum) the results from calibration of the previous expanded regional model. Again, the newer features of the GMS upgrade have since been installed and with them, improvements to model parameters are expected to be evaluated in the coming months. The improved model parameters, wherever possible, will be evaluated in conjunction with a thorough sensitivity analysis.

The transient-state calibration concluded when a reasonable match was observed between computed and measured values based on previous results. Figures 2 through 4 are time series graphs for a sample of the locations where the transient simulations were evaluated.

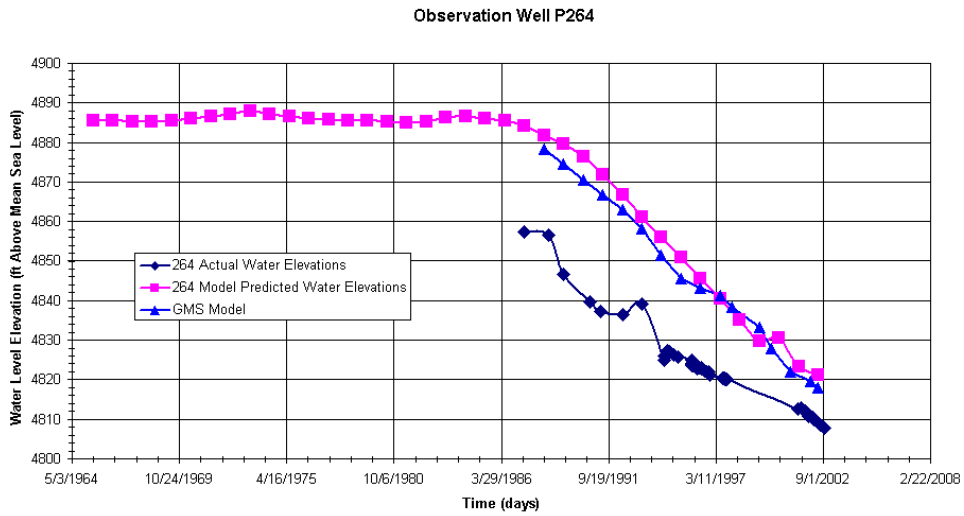

Figure 2. Transient calibration comparisons at well P264.

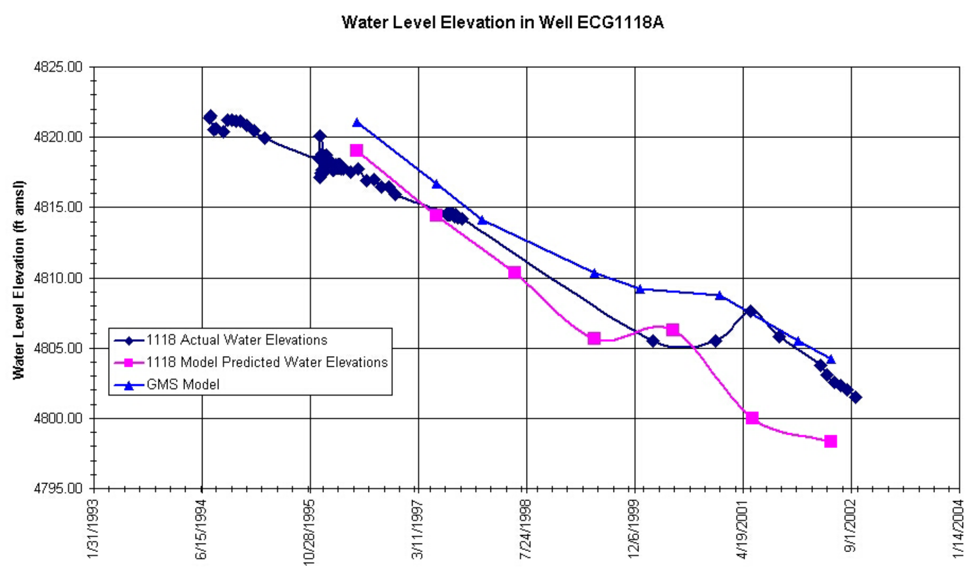

Figure 3. Transient calibration comparisons at well ECG1118A.

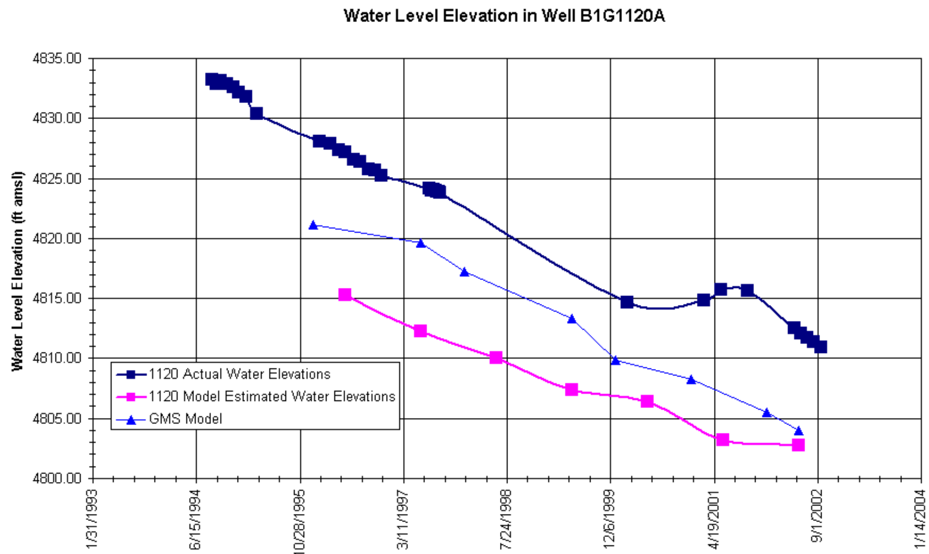

Figure 4. Transient calibration comparisons at well 1120A.

6.0 Sub-Regional Model

In order to better optimize well pumping rates and locations for plume containment, as well as to more accurately represent (and predict) plume movement, a subset model has been created from the larger regional model. Among other advantages, the subset model generally provides for faster and easier parameter changes, as well as the ability to modify and compare results of previous efforts while still being refined.

The area of interest centers on the Bingham Creek groundwater plumes and extends to the Jordan River. Figure 5 shows the current boundary for the sub-regional model with respect to the larger regional model.

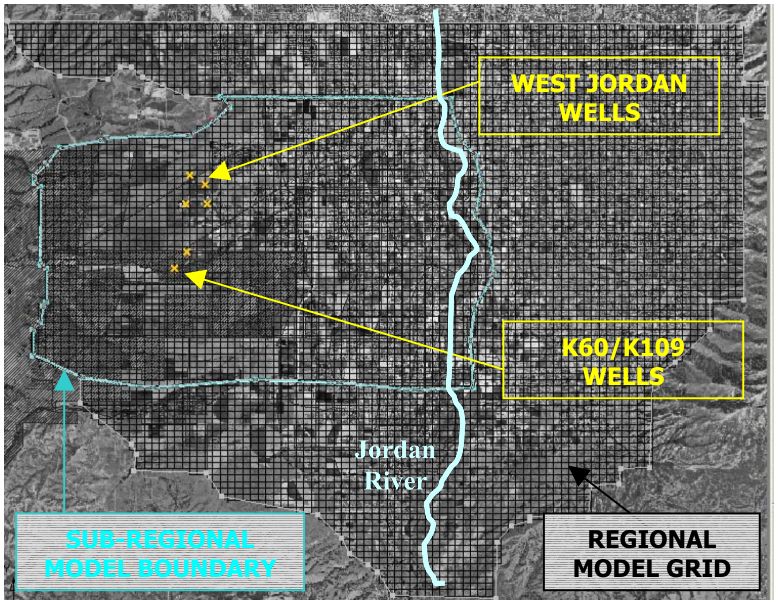

Figure 5. Current sub-regional model boundary.

The sub-regional (local) model improves options and focus in the modeling, specifically, providing for smaller grid cell sizes and enhanced flexibility in well geometry and related components (cell sizes vary, but are smaller, particularly in the active well containment region, than in the larger regional model). GMS provides regional-to-local conversion options for this task. The sub-regional model is being further refined and improved with the installation of the new GMS upgrade software features. This endeavor has shown to be useful in accomplishing a focused approach in the effort to provide a more manageable tool for groundwater estimation accompanied with the regional model.

7.0 Bedrock Influx Investigations

As noted in previous reports, KUCC has taken a closer look into bedrock influx along the western general head boundary of the regional model (Oquirrh range front) due to its influence on flows in the areas of interest. The model's eastern boundary (the Wasatch range) has not been as rigorously investigated due to its distance from this project. The western model boundary as defined by KUCC modeling in the RI/FS process was found to be consistent with United States Geologic Survey (USGS) modeled estimates based on their regional valley model. Evaluation of bedrock flows along the Oquirrh boundary has been revisited with regard to modeling modifications and updates. Model-estimated heads and/or hydraulic conductance values evaluated along the Oquirrh Mountain boundary were likely providing for the possibility of over-prediction for valley recharge via bedrock inflow under previous assumptions. It has generally been observed that a reduction of inferred inflow along some of the portions of the Oquirrh Mountain boundary are appropriate to more closely simulate drawdown and water-level data. Adjustment and refinements in modeling parameters, including hydraulic heads and conductivities, have been and will continue to be assessed for improvements.

Horizontal-flow exchange (inflow versus outflow of the present GMS model) was compared to Hely and others (1971), as well as USGS and the previous KUCC expanded regional model. Jordan River flow was also investigated simultaneously with horizontal exchange to achieve a balanced representation between these two parameters. Evaluation of potentiometric maps, flow directions and drawdown for steady-state and transient calibrations showed no notable problems.

The following table outlines the statistics of the GMS model's head-dependent western boundary compared to previous model statistics for the same zones. The zones listed in Table 2 are superimposed on the expanded model and shown in Figure 6 for reference. Positive values reflect where the influxes from the boundary into the model are increased in the current simulations compared to earlier modeling.

Table 2. Western Specified Flux Boundary vs. the Current Head-Dependent Boundary.

	Original RI/FS Model **Specified Influx (cubic feet per day)**	**Approximate Head-Dependent Percent Difference vs. Specified Flux** (Previous KUCC Expanded Model)		**Approximate Head-Dependent Percent Difference vs. Specified Flux** (GMS Model)	
		Year 1	**Year 50**	**Year 1**	**Year 50**
Zone 1 (Layer 3)	729,972	-6.9	-2.2	-5.8	-3.5
Zone 2 (Layer 3)	269,500	1.8	11.7	2.5	10.6
Zone 3 (Layer 3)	292,994	4.1	5.0	3.6	2.4
Zone 1 (Layer 4)	187,960	4.5	56.8	4.8	19.1
Zone 2 (Layer 4)	70,190	5.7	13.5	5.3	20.3
Zone 3 (Layer 4)	195,510	7.5	17.2	6.9	14.0

The results of these comparisons show that as drawdown in the western portion of the model increases, flow into the model from this boundary generally increases due to the increased gradient, as expected compared to the characteristics of the original constant flux boundary. Because this is only true to a limited extent in the actual system, due to limitations with aquifer matrix and available water, adjustments to these parameters in the model have been made to more closely represent actual conditions. It should be noted that the values listed for the "Previous KUCC Expanded Model" in the previous table are for the initial investigation and that heads and conductance values along the western margin have been adjusted in subsequent KUCC expanded model and are currently closer to those values reflected in the GMS model.

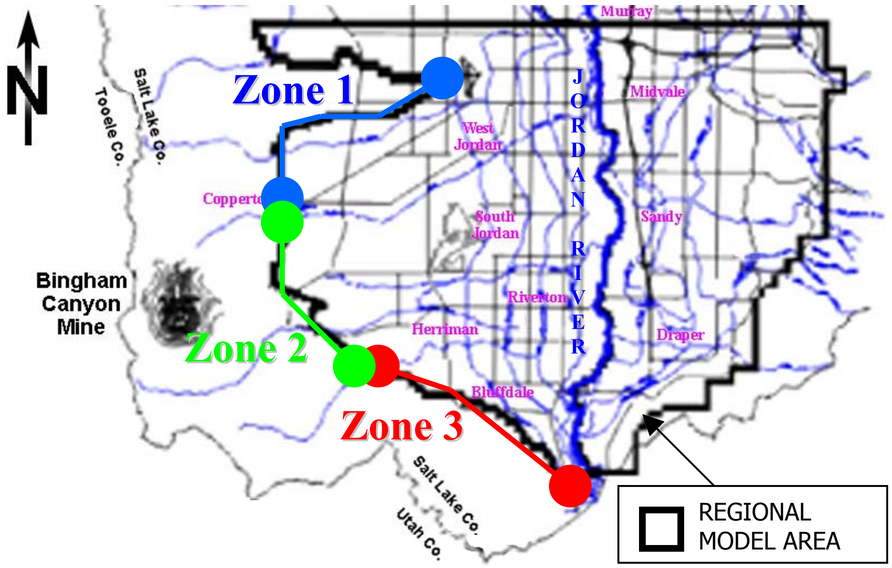

Figure 6. Evaluation zones for flow used in comparing head-dependent vs. specified flux boundaries for previous models.

GMS released an upgrade to their software in late 2002, providing compatibility for the MODFLOW 2000 code and analysis tools that will aid greatly in understanding the behavior and limitations of such issues and allow for further refinement. This release was expected at the beginning of 2002, causing KUCC to delay its plans for a completed analysis of bedrock influx (and other analyses). However, the understanding of the qualitative nature concerning bedrock influx via collected data is presently better understood when compared with the RI/FS model and is in line with best known ranges. As with the rest of the KUCC modeling process, investigations and improvements will continue whenever new data become available.

Previous comparisons of current groundwater elevations in the valley seem to suggest that the recharge estimates used in the original USGS and KUCC models were higher than what would be expected to report via bedrock recharge along the mountain-valley boundary (specifically for Region VIII).

Evaluation of the USGS model for Region VIII (approximately between 7800 South and 11800 South and KUCC well K60 to the western model boundary) concluded that approximately 4400 acre-feet per year (afy) of bedrock recharge is simulated entering the valley aquifer, while 2560 afy of meteoric recharge reports to Region VIII (from the area between KUCC well K60 to the western model boundary) for a total of approximately 6960 afy. The USGS bedrock recharge is simulated using non-changing constant flux cells along the boundary and is constant for each model-simulated year.

The same evaluation for the KUCC sub-regional model concluded that (for year 2000) approximately 4975 afy of bedrock recharge is simulated entering the valley aquifer for the Oquirrh front along the Region VIII north-south boundary). Also, about 1800 afy of meteoric recharge reports to Region VIII. Bedrock and areal recharge together was approximately 6775 afy. The bedrock recharge is simulated using head-dependant flux cells that allow the amount of recharge entering the model to vary as the groundwater elevations change over time. The transient calibration model (1966-2000) had previously showed bedrock recharge as high as 8500 afy reporting by year 2000, but it did not very accurately simulate the highly variable water level elevations along the Oquirrh-SWJV model boundary as observed in actual regional water level data. The heads along the boundary were then manually adjusted to more closely resemble recent regional water level points. Lowering the water level elevations along the head-dependant boundary, as well as necessary adjustments to localized hydraulic conductivity to more realistically match actual data, resulted in predicting an expected decrease in bedrock recharge along Region VIII. The current boundary conditions of the model are within accepted ranges established in previous modeling, and result in flows thought to be more realistic than previous modeling estimates. However, a more thorough evaluation using the latest GMS software is under investigation concerning further refinement to this aspect of the model.

Based on this work to date, it is believed that estimates for recharge along Region VIII for the USGS model (and perhaps for the existing GMS model) might still be higher than what actually exists in the present and future system. Influences on the recharge in this region having long-term effects must be kept in mind such as:

- ✓ KUCC's eastside collection system
- ✓ Discontinuation of the active leaching of the waste rock dumps
- ✓ Changes in groundwater withdrawals in the vicinity of the mine and Oquirrh front.

These items too will continue to be updated in the model as data becomes available.

8.0 Density Modeling Investigations

Some reviewers of the modeling in the RI suggested that prediction of the highly acidic portion of the Bingham Creek groundwater plume might be better predicted with incorporation of a modeling code that could address variable density (such as the finite-element based FEMWATER). If density effects could be deemed significant, then better plume predictions might lead to slightly better plume containment and optimization strategies.

Incorporation of the FEMWATER modeling code for inclusion into the GMS modeling was investigated based on both its potential and practical advantages and disadvantages. Initial investigations found that the process of incorporating this code (even for the smaller sub-regional model, and much more so for a larger domain) would be very time and labor intensive. Further discussions with GMS users, staff and authors have recommended against the procedure in the practical sense. The GMS team argued that creation of a fully constructed, calibrated, and functioning finite-element, density-coupled model would likely provide less of a benefit, in light of time and complexity of the process, than the potential for practical modeling gains based on other model refinements. A large amount is known empirically about the acid plume's location and hydrogeologic characteristics and KUCC has several years of field-scale data on plume containment and contingency planning. Therefore, the RD modeling effort focused on the practical issues concerning optimization and containment scenarios in those portions of the plume generally uninfluenced by density-driven flow. It is in these zones where plume migration has greatest potential to affect KUCC's commitment to preventing sulfate contamination above 1500 mg/L from migrating off KUCC property.

The acidic portion of the Bingham Creek groundwater plume (located immediately downgradient of the Bingham Creek Reservoirs) has been and will continue to be closely monitored and sampled as part of the RD groundwater-monitoring program. Data trends in the highest TDS core of the plume show that lateral migration continues to be constrained compared to other areas of contamination due the nature of the dense core of the plume in conjunction with aquifer geometry and to the hydrological conditions in which it exists.

These conclusions on density-modeling are not necessarily final, and it is understood by KUCC that incorporation of a code such as FEMWATER in conjunction with GMS for density-coupled modeling might in fact provide a better estimate of plume behavior in the localized center of the Bingham Creek contamination. However, at this time KUCC considers that the current model and its continual improvements and upgrades should remain the principal modeling focus.

9.0 Groundwater Injection Studies

Previous investigations concerning the possibility of incorporating groundwater injection into the remedial strategy and design have been done using the KUCC model. A modeling report was prepared concerning previous modeling scenarios ("Additional Modeling Studies for Plume Containment in Southwestern Jordan Valley, Utah"). A summary and presentation about these studies was provided for the South Facilities TRC in June of 1999 by KUCC, and the report was submitted to the members present at that meeting.

Additional groundwater injection scenarios have since been investigated, based in part on West Jordan City's expressed interest with incorporating groundwater injection as part of its future water-supply strategy. At the time of this report, details of West Jordan City and/or KUCC's plans concerning volume, quality, location, and other details remain uncertain. However, based on the assumption that this course of action remains feasible and desirable, KUCC ran model scenarios with ranges for volume, water quality, and location in the area between the West Jordan City municipal wells and KUCC sulfate wells (i.e. K60/K109 area). The results of the latest modeling still showed groundwater injection to be a viable hydraulic option for aiding in the Bingham Creek sulfate plume containment, as well as providing other hydraulic benefits to the aquifer in the region of injection such as controlling net drawdown. Further modeling may be done pertinent to long-term planning by the involved parties.

KUCC still recognizes that there are other water-quality and regulatory issues concerning injection that would need to be addressed if KUCC were to incorporate injection as part of its future remedial strategy. A meaningful discussion of the modeling of potential injection scenarios cannot be initiated until water-policy and planning decisions are made by non-Kennecott parties and additional technical studies are undertaken.

10.0 Sensitivity Analysis

A more formal and extensive sensitivity analysis of modeling parameters is being conducted with regard to the current modeling. This task has been hampered due to technical issues and delays, but is still slated for completion in the near term, and the expectation is to provide results of the analysis as a supplement document following the Final Design reporting.

Classifications of previous sensitivity analyses for the KUCC model showed that parameters generally fit into three groups that will be investigated: sensitive, moderately sensitive and insensitive. Model parameters deemed sensitive in previous KUCC modeling include aerial recharge, bedrock recharge, and the horizontal hydraulic conductivity representing the principal aquifer. Model parameters regarded to be insensitive included riverbed conductance, horizontal hydraulic conductivity of the shallow unconfined aquifer, and vertical hydraulic conductivity of the shallow unconfined aquifer. Results of the new sensitivity analysis are expected to be along these lines.

Investigation of the use of MODFLOW 2000 code for aiding in the sensitivity analysis is already in progress and considered beneficial, as the new GMS model and software provides for improved sensitivity and parameter estimation functionality over previous options. The GMS software was supposed to have been updated for compatibility with MODFLOW 2000 earlier this year, but unfortunately, programming delays have postponed this functionality. Findings of the formal sensitivity analysis will be outlined in a separate report and provided for interested parties upon its completion not later than the end of second Quarter, 2003.

11.0 Summary

Examples of the practical uses of the model are included as Figures 7 and 8. Figure 7 is a 30-year predictive model run of the estimated aquifer drawdown that is expected to occur based on the remedial extraction scenario. Figure 8 shows the corresponding sulfate concentrations at 30 years in the future based on the remediation plan.

The KUCC modeling effort continues to be revised and updated as an improved means for analysis of flow and contaminant transport throughout the remedial process. As with the previous versions of the KUCC models, the current GMS model was developed using data of an improved version (in this case, the expanded regional model) and compared via calibration data to that of the KUCC expanded regional model. The GMS conceptual model was created from data of the previous model, and therefore its behavior was benchmarked against calibration and other data from the previous model. Since the expanded regional model satisfied previous calibration criteria, the GMS model was checked for its performance versus that model and found to be in line with the same criteria. Following calibration data checks, the flow model was coupled with the contaminate transport code MT3D (Zheng 1996) to simulate the movement of sulfate, with focus toward the area of Bingham Creek contamination and compared again to its predecessor.

The model was checked for steady-state and transient-state simulations with particular regard to the KUCC expanded regional model and for comparative purposes with the original RI/FS model and USGS Salt Lake Valley model. The steady-state simulations were developed to represent conditions in 1965. The transient-state simulation represents conditions from 1966 through 1998-2001 (based on latest available data). Comparisons between the GMS and previous KUCC models were found to be in line with previous results and thus satisfy calibration targets.

A complete and formal sensitivity analysis of the GMS model has yet to be completed due to software and hardware issues that arose during the modeling process, but initial investigations showed that the GMS parameters behave similarly to the KUCC expanded regional model (as expected). Upon completion of a formal sensitivity analysis in GMS, results will be provided to interested parties in relation to KUCC's remedial process. Completion of work outlined in this report, along with sensitivity analysis, will not only satisfy the groundwater modeling elements identified in the RD Work Plan, but also will respond to the outstanding groundwater modeling issues identified in the FS.

Improvements to the current model are ongoing and will be performed on an as-needed basis into the future. Such items as density-coupled flow, model discretization, recharge and injection are all modeling issues that are still being investigated using the newer features of the recently upgraded modeling codes and software. The incorporation and comparison of new data with the modeling effort continues to be of particular importance as the remedial project progresses. Parties of interest will be kept abreast of these efforts as outlined by KUCC's commitments.

The following is a summary of the status of items and/or deliverables concerning the Groundwater Modeling Studies with the Final Design:

Task	**Status**	**Report Title**
GMS Model Incorporation	*Complete*	"KUC Flow and Transport Model Modifications and Updates"
Model Rediscritization and Recalibration	*Complete (Improvements ongoing)*	(Included in above)
Density-Driven Flow Assessment	*Complete (Investigations ongoing)*	(Included in above)
Groundwater Injection Assessment	*Complete (Investigations ongoing)*	(Included in above)
Sensitivity Analysis	*In Progress (Early 2003)*	"Sensitivity Analysis of the Modified and Updated KUC Model"

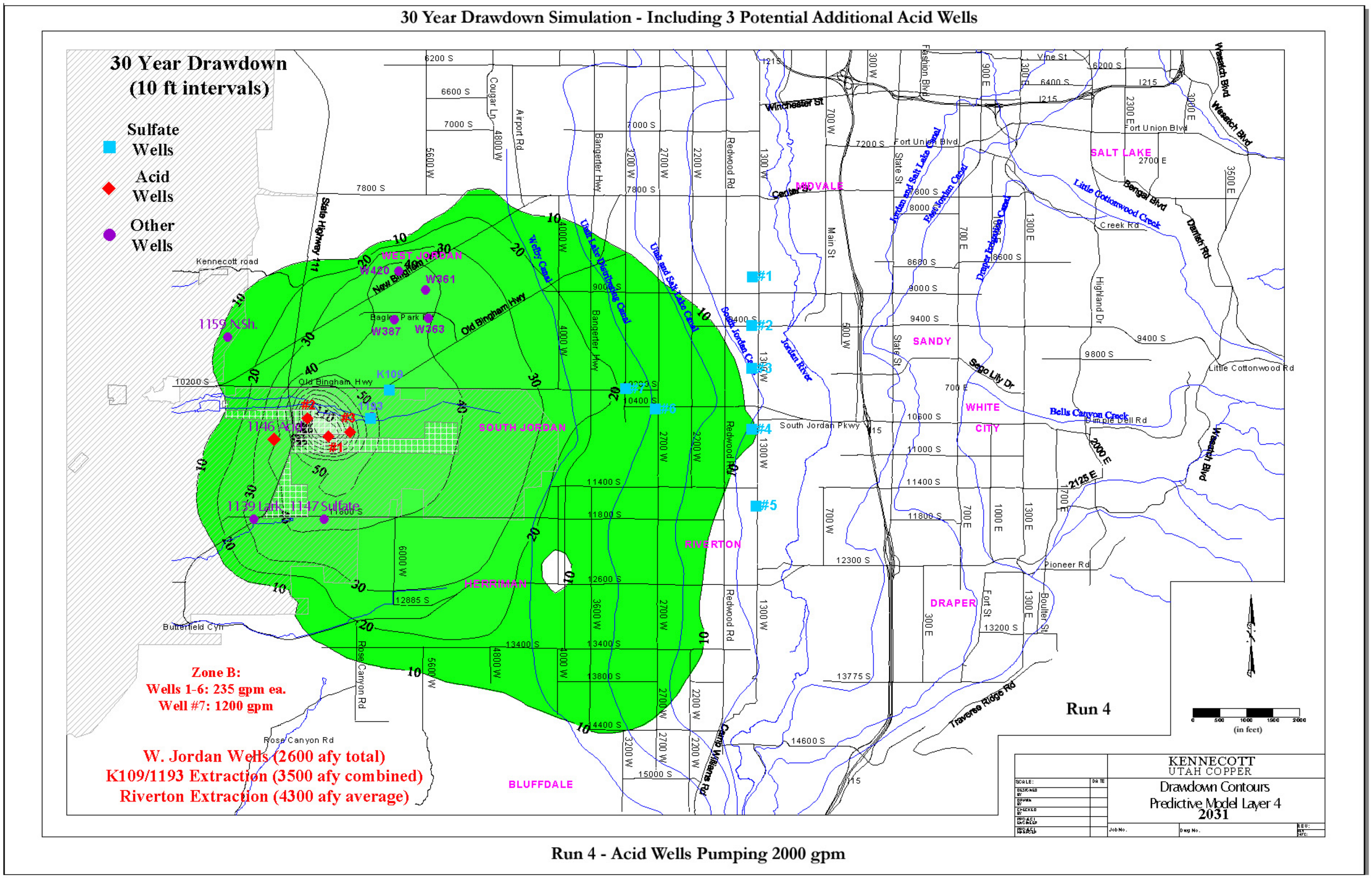

Figure 7. Model-predicted 30-year drawdown for selected containment scenario.

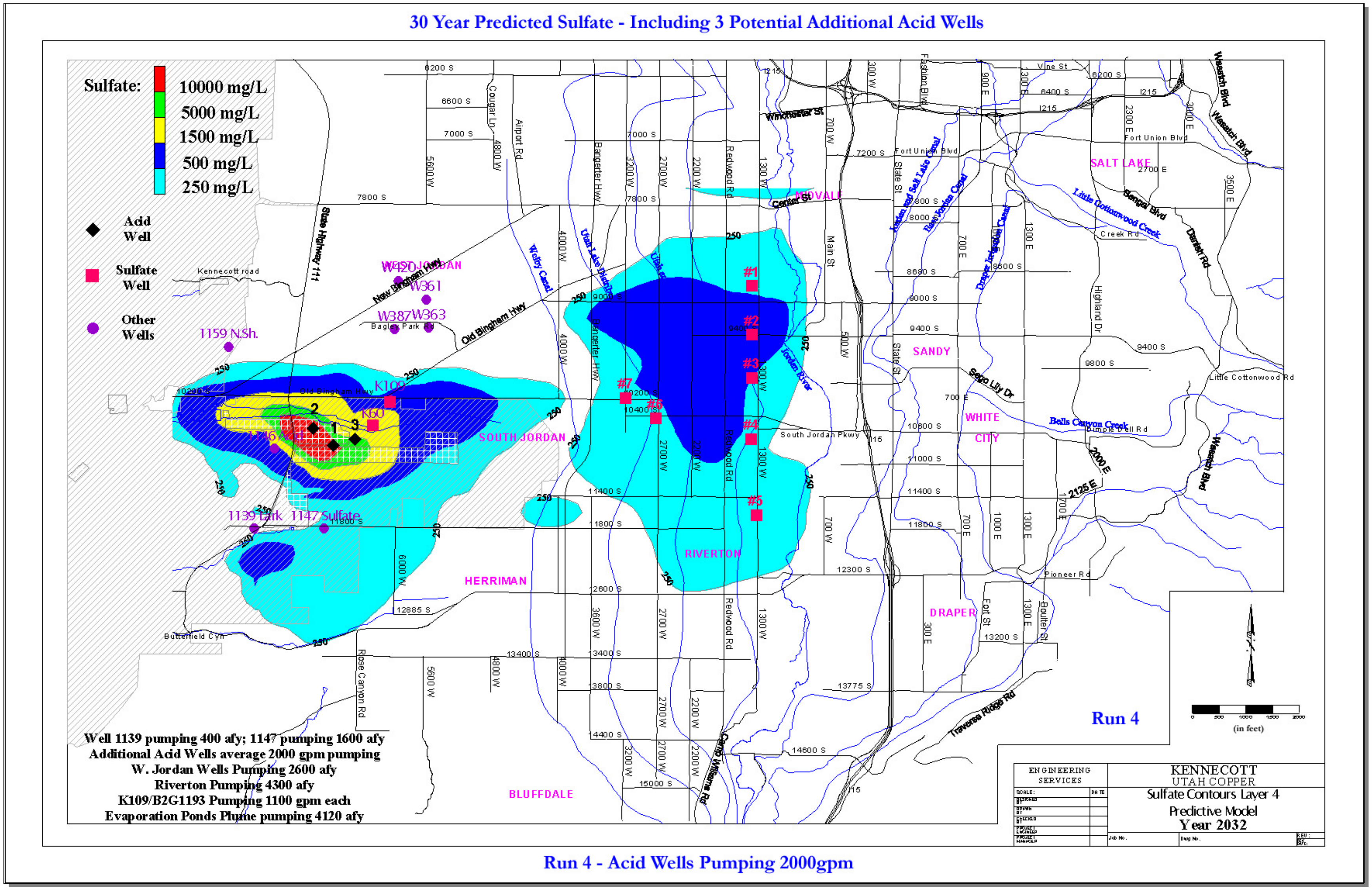

Figure 8. Model-predicted 30-year sulfate for selected containment scenario.

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