ENERCON Excellence—Every project. Every day	**CALCULATION COVER SHEET**	**CALC NO. TXUT-001-FSAR-2.4.12-CALC-038** **REV. 2** **PAGE NO. 1 of 40**

Title:	**Evaluation of Maximum Post-Construction Groundwater Level**	**Client: MNES** **Project: MITS187**

Item	**Cover Sheet Items**	**Yes**	**No**
1	Does this calculation contain any open assumptions that require confirmation? (If **YES**, identify the assumptions) See Section 4.0 for a description of the open assumptions surface grading contours.	☐	☒
2	Does this calculation serve as an "Alternate Calculation"? (If **YES**, identify the design verified calculation.) **Design Verified Calculation No.**________________________________	☐	☒
3	Does this calculation Supersede an existing Calculation? (If **YES**, identify the superseded calculation.) **Superseded Calculation No.**________________________________	☐	☒

Scope of Revision: Corrected Reference numbers and page numbers.

Revision Impact on Results: None.

Study Calculation	☐	Final Calculation	☒
Safety-Related	☒	Non Safety-Related	☐

(Print Name and Sign)

Originator: M. Elizabeth Rowan [signature]	Date: 03-7-13
Design Verifier: Caitlin Current [signature]	Date: 03-7-13
Technical Approver: Larry Lew, Ph.D., P.G [signature]	Date: 03-7-13
Project Management Approver: Joe Mancinelli [signature]	Date: 03-7-13

CALCULATION REVISION STATUS

REVISION	DATE	DESCRIPTION
0	09-21-12	Original Calculation
1	03-06-13	Incorporate revisions to numerical model and revise calculation for consistency with Conceptual Site Model
2	03-07-13	Correct Reference and page numbering

PAGE REVISION STATUS

PAGE NO.	REVISION	PAGE NO.	REVISION
1-5, 7	2		
6, 8-42	1		

APPENDIX REVISION STATUS

APPENDIX NO.	PAGE NO.	REVISION NO.	APPENDIX NO.	PAGE NO.	REVISION NO.
Appendix A	electronic files	1			
Appendix B	electronic files	1			
Appendix C	electronic files	1			
Appendix D	electronic files	1			

Calculation Design Verification Plan:

Apply CSP Number 3.01, Revision 6, Section 4.5, Design Review Method.
The calculation Design Inputs, Assumptions and Methodology will be verified to ensure that:

- They were appropriate and correctly applied, and
- They are reasonable for the purpose of completing an analysis of post-construction groundwater using numerical modeling software (MODFLOW).

The set-up and results of model files will be reviewed to make sure that:

- the transient flow model was correctly set-up and covers the stated duration;
- the flow model produced the same results as those delivered for review;
- the flow model converged properly;
- the flow model results are reproducible and consistent; and
- the model mass balance met industry standards.

The calculation methodology, results, and conclusions will be verified to ensure that:

- the calculation satisfied the objective;
- the calculation conclusions are valid; and
- the conclusions are supported by the calculation.

(Print Name and Sign for Approval – Mark "N/A" if not required)

Approver: Joe Mancinelli [signature]	**Date: 03-7-13**

Calculation Design Verification Summary:
Model results and calculations were verified by:

- Comparing reference materials against model setup, inputs and listed assumptions, both in the model itself and this CALC write-up;
- Independent calculation of values derived from inputs;
- Verification of model input consistency;
- Completion of model simulations on an independent computer to verify acceptable convergence and mass balance and consistency of results; and
- Independent creation of model output figures/graphs to verify the results.

Comments were provided pertaining to 1) clarification for statements of the references used for the model; 2) for select zones and select runs, incorrect parameter values were assigned in the model; and 3) for select model runs, inconsistent model results were reported. These comments have been addressed and the model files and outputs reflect corrected parameters. The calculation methodology and assumptions were found to be appropriate and correctly applied. The model results were found to be reproducible, reasonable, consistent, and accurate. Calculations were independently verified to be consistent and correct. Calculation logic, methodology, and presentation are considered acceptable.

Based On The Above Summary, The Calculation Is Determined To Be Acceptable.

(Print Name and Sign)

Design Verifier: Caitlin Current [signature]	**Date: 03-7-13**

ITEM	CHECKLIST ITEMS	Yes	No	N/A
1	**Design Inputs –** Were the design inputs correctly selected, referenced (latest revision), consistent with the design basis and incorporated in the calculation?	☒	☐	☐
2	**Assumptions –** Were the assumptions reasonably and adequately described, justified and/or verified, and documented?	☒	☐	☐
3	**Quality Assurance –** Were the appropriate QA classification and requirements assigned to the calculation?	☒	☐	☐
4	**Codes, Standards and Regulatory Requirements –** Were the applicable codes, standards and regulatory requirements, including issue and addenda, properly identified and their requirements satisfied?	☐	☐	☒
5	**Construction and Operating Experience –** Have applicable construction and operating experience been considered?	☐	☐	☒
6	**Interfaces –** Have the design interface requirements been satisfied, including interactions with other calculations?	☒	☐	☐
7	**Methods –** Was the calculation methodology appropriate and properly applied to satisfy the calculation objective?	☒	☐	☐
8	**Design Outputs –** Was the conclusion of the calculation clearly stated, did it correspond directly with the objectives and are the results reasonable compared to the inputs?	☒	☐	☐
9	**Radiation Exposure –** Has the calculation properly considered radiation exposure to the public and plant personnel?	☐	☐	☒
10	**Acceptance Criteria –** Are the acceptance criteria incorporated in the calculation sufficient to allow verification that the design requirements have been satisfactorily accomplished?	☐	☐	☒
11	**Computer Software –** Is a computer program or software used, and if so, are the requirements of CSP 3.02 met?	☒	☐	☐

COMMENTS:

(Print Name and Sign)

Design Verifier: Caitlin L Current (signature) Caitlin Current	**Date: 03-7-13**
Others:	**Date:**

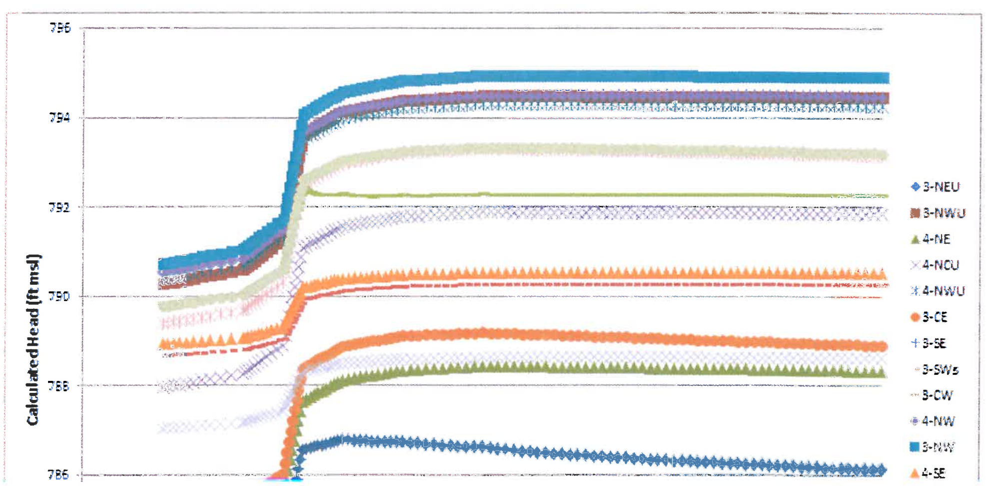
TABLE OF CONTENTS

1.0 PURPOSE AND SCOPE

This calculation documents the development and results of a numerical groundwater model for the Comanche Peak Nuclear Power Plant (CPNPP) Units 3 and 4. The groundwater model results will be used to demonstrate that the maximum post-construction groundwater elevation (determined by this groundwater analysis) complies with the US Advanced Pressurized Water Reactor (US-APWR) Design Control Document (DCD) criteria for "Groundwater Level," as discussed in Table 2.0-1R of the Final Safety Analysis Report (FSAR) of the CPNPP Units 3 and 4 Combined Operating License (COL) Application. This assessment examines the maximum groundwater elevation under an extreme climatic event, which is statistically highly unlikely to occur. For this calculation, the Probable Maximum Precipitation Event (PMP) was used to represent the extreme climatic event, with infiltration to the subsurface based on the amount of precipitation received during that event. These results are not relevant to the assessment of groundwater flow conditions for purposes of contaminant transport or identification of groundwater flow pathways.

2.0 SUMMARY OF RESULTS AND CONCLUSIONS

The effects of recharge from a theoretical maximum precipitation event in this model result in groundwater elevations below the DCD criterion elevation of 821 feet relative to mean sea level (ft msl) within the power block area. The resulting groundwater elevations calculated for informational observation points (locations shown in Figure 5-10) specified in the model are illustrated in Figure 2-1. Based on the calculated water levels in this analysis, the maximum groundwater level calculated around the nuclear island is 794.94 ft msl; this value was calculated at observation point 3-NW, at an elapsed time of approximately 5.0 days.



3.0 REFERENCES

1. Not used.
2. ENERCON, Probable Maximum Precipitation Calculation for Comanche Peak Nuclear Power Plant Units 3 and 4 Using HMR 51 & HMR 52, Calculation TXUT-001-FSAR-2.4.3-CALC-011, Rev. 4, February 26, 2013.
3. ENERCON, "Estimation of Conservative Bounding Fill and Infiltration Cap Properties and Determination of Above Grade Fill Extents," June 2012.
4. MHI, Grading and Drainage Plan, Document No. 4CS-CP34_20080060, Rev 4, Final, issued December 19, 2012.
5. Not used.
6. Not used.
7. Not used.
8. Not used.
9. Not used.
10. MHI, Nuclear and Turbine Island Excavation Plan and Sections, Document No. 4CS-CP34_20110023, Rev1, Final, issued December 14, 2012.
11. Not used.
12. Not used.
13. USGS MODFLOW 2005, Version 1.8.00, as implemented in Groundwater Modeling System (GMS), developed by Aquaveo, Version 8.2, 2012.
14. Harbaugh, A.W. 2005. MODFLOW-2005, The U.S. Geological Survey Modular Ground-Water Model – the Ground-Water Flow Process. Chapter 16 of Book 6, Modeling techniques, Section A. Ground Water. U.S. Geological Survey. Reston, Virginia.
15. Wolock, David M., Estimated Mean Annual Natural Ground-Water Recharge in The Conterminous United States, USGS NSDI, USGS Open File Report 03-311, 2003 digital data set accessed at http://water.usgs.gov/lookup/getspatial?rech48.grd.
16. USDA Natural Resources Conservation Service, Table 2-2a in Technical Release 55, Urban Hydrology for Small Watersheds, 210-VI-TR-55, Second Edition, June 1986.
17. ENERCON, Groundwater Monitoring Well Gauging and Squaw Creek Reservoir Elevation Assessment Report for the COL Application, Report Number TXUT-001-PR-019 Revision 0, February 11, 2013
18. Luminant, Comanche Peak Nuclear Power Plant (CPNPP) Combined License Application—Part2: Final Safety Analysis Report (FSAR). Revision 3. July 2012

4.0 ASSUMPTIONS

4.1. Excavations will be made into rock as a part of plant construction. To simplify modeling efforts, sloped excavation walls are depicted as vertical walls for representation of the top of rock surface in the groundwater flow model.

4.2. The model domain is spatially limited in area to focus on the evaluation of groundwater flow in and around the excavated portions of the CPNPP site adjacent to Squaw Creek Reservoir (SCR). The dimensions of the model domain were set to cover an area of approximately 3,318 ft by 2,091 ft (parallel to numerical model grid orientation) considered to be broad enough to allow adequate and unencumbered flow within the approximate area of the site.

4.3. The pattern of recharge assigned in the model is representative of the expected post-construction surface cover based on drawings provided by URS (References 4 and 10). The runoff coefficients for these surface materials (References 3 and 16) are the basis for the simulated infiltration/recharge array in the MODFLOW model as described in TXUT-001-PI-09 (Reference 1). It is assumed that infiltration (recharge) is the amount of precipitation that does not exit the site via runoff. All precipitation is assumed to infiltrate into the ground at specified rates based on the runoff coefficients for the general soil type present. For purposes of the numerical MODFLOW model, infiltration was assumed to occur instantaneously and uniformly across each recharge area.

4.4. Squaw Creek Reservoir serves as a major physical boundary along the northern and eastern edges of the site. This model assumes that head along this boundary does not vary with time, with a value of 775.5 ft msl assigned for the reservoir in the model. A model run was completed as part of the sensitivity analysis to assess a more conservative assumption for this boundary.

4.5. Model cells for areas of the reactor buildings for Units 3 and 4 within the power block area are specified as inactive. No groundwater flow will occur through these structures, nor will recharge be contributed to the subsurface through these structures; inactive cells are similarly defined for the Ultimate Heat Sink basins.

4.6. The areas of Units 3 and 4 within the Essential Service Water Pipe Tunnel (ESWPT) is essentially a closed basin which has not been included in the model area. The pipe tunnels enclose this area, with the tops of individual segments of the pipe tunnels ranging from 804 ft msl to 810 ft msl (Reference 10). Because this is a closed area, the water level within this area can theoretically reach a maximum of 804 ft msl; once it has reached this elevation, the water will drain outward across those portions of the pipe tunnel having tops at that elevation.

4.7. The engineered granular fill to be placed around the nuclear reactor building and in site excavations/buildups is unknown at this time. The specifications used in this model are presented in the white paper "Estimation of

Conservative Bounding Fill and Infiltration Cap Properties and Determination of Above Grade Fill Extents" (Reference 3, see Appendix D). The lowest average hydraulic conductivity (K) value of the possible fill materials is used for the granular fill in the flow model since that has the greatest potential to contribute to groundwater mounding.

4.8. Calibration of the flow model is not considered to be appropriate for the limited application of MODFLOW groundwater modeling software for the task of assessing <u>future</u> groundwater flow conditions. MODFLOW is used in this analysis as a tool to simulate anticipated post-construction conditions; post-construction water levels are therefore not available. Because of the significant additional site alteration that will occur during construction, it is considered inappropriate to calibrate the model to pre-construction data. The model is constructed using proposed post-construction design features, known site characteristics, and modeling best practices.

4.9. The transient groundwater model simulates conditions that may potentially be experienced under post-construction conditions assuming an occurrence of a theoretical PMP event. Hourly rainfall measurements generated in the analysis of the PMP event are used to develop model recharge inputs (Reference 2). This theoretical precipitation event assumes a total of 42.53 inches of precipitation for the complete storm event over a 72-hour period.

4.10. All elevations (groundwater and otherwise) are referenced to mean sea level (ft msl).

5.0 DESIGN INPUTS

5.1 Conceptual Site Model

The conceptual model of the site hydrogeology serves as the basis for the structure of the numerical groundwater flow model used to evaluate post-construction groundwater conditions. The conceptual model of the site has been developed based on available hydrogeologic information, hydraulic heads observed in monitoring wells at the site (historical and recent), surface water elevations reported for SCR, and interpretations of the movement of water in the subsurface underlying the site. The numerical model represents a conservative implementation of the conceptual model, taking into account changes in the configuration of the site that will occur under post-construction conditions.

The CPNPP site is situated on a peninsula located on the southwestern bank of SCR (Reference 18). As shown in Figure 5-1, Units 3 and 4 are situated on the north side of this peninsula, bounded to the east and north by SCR. SCR also provides the boundary on the south side of the peninsula, creating a hydraulic low to the south of the site (Figure 5-2).

Figure 5-1.Physical Site Setting with Post-Construction Contours.

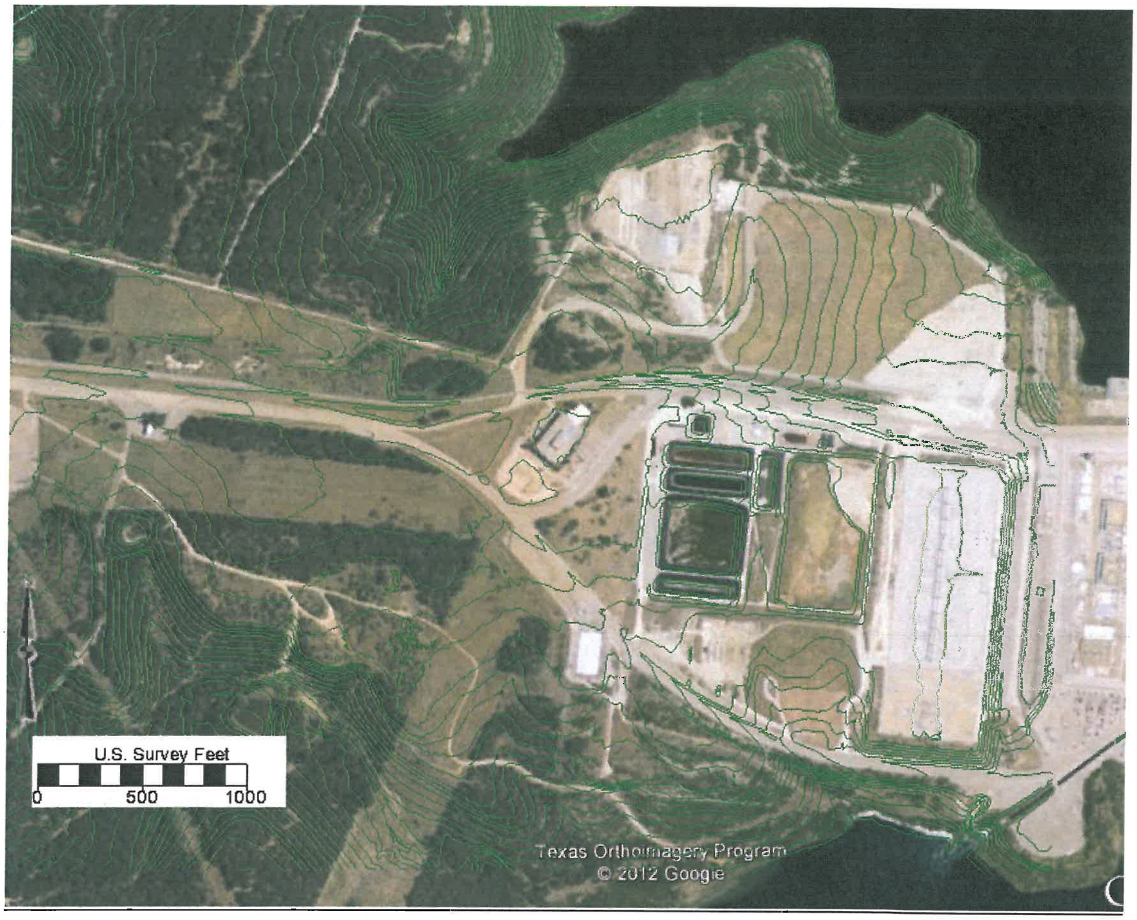


Figure 5-2.Physical Site Setting with Pre-Construction Contours.

Currently at the site, regolith and undifferentiated fill comprise the majority of the shallow geologic materials, with much of the regolith present at elevations greater than the planned site grade of 822 ft msl. The regolith and fill materials have a greater capacity for infiltration of surface water, a greater amount of groundwater storage, and higher matrix permeability as compared to the underlying bedrock. Under post-construction conditions, the regolith and parts of the undifferentiated fill will be removed from across the power block area, and the site will be underlain primarily by low-permeability limestone bedrock of the Glen Rose Formation. Some regolith will remain to the west and south of the main plant construction area, with existing fill remaining where currently present in northern and eastern portions of the site. Thus, the scraping and removal of regolith and fill materials during site construction is expected to influence the post-construction groundwater levels.

The limestone bedrock has a low overall hydraulic conductivity, as determined from packer tests and slug tests completed at the site (details of specific hydraulic properties of these materials are discussed later in this calculation). Regolith and undifferentiated fill overlying the bedrock exhibit higher hydraulic conductivity values than the underlying bedrock (Reference 18), consistent with characteristics of a porous medium. It is also inferred that a portion of the subsurface flow through the bedrock occurs along bedding and joint planes that are subhorizontal in orientation. Thus, groundwater movement through the subsurface is limited by the physical properties of the subsurface materials underlying the regolith and undifferentiated fill.

Hydraulic heads observed in monitoring wells (Figure 5-3) at the site (Reference 17) indicate primarily downward vertical gradients in the subsurface materials underlying the site. Figure 5-4 presents the December 2012 water levels plotted for each well, with the position of each well screen posted on the figure; the general elevations of the engineering units "A" through "F" defined at the site (Reference 18) are also illustrated. Historically, hydraulic gradients have been consistently downward from the regolith into the Engineering "A" bedrock at all but one location (the MW-1216 location is the one anomaly, where hydraulic heads from late 2012 indicate a change to a slight upward gradient from the shallow bedrock into the regolith). Gradients are also downward from the Engineering "A" bedrock unit into the Engineering "B" bedrock unit. Similarly, hydraulic gradients from the shallow bedrock of Engineering "A" and "B" units to the deeper bedrock within the Glen Rose (identified as Engineering "C-F") are consistently downward. This pattern of water levels indicates that water in the subsurface will move downward when given the opportunity. (One exception to this pattern of water levels is the near-shore well pair MW-1209B/1209C; water levels in these wells are essentially at the level of SCR, indicating greater influence from the reservoir at this location.)

The water levels in most of the deep bedrock wells completed in the Engineering "C-F" unit fall within the well screen, at elevations greater than 10 feet below the base of the Engineering "B" unit. Additionally, one well completed across the base of the Engineering "B" unit and the top of the Engineering "C" unit is dry; this well, MW-1205C, has been consistently dry throughout the water level monitoring period (November 2006 through May 2008, and August 2012 through December 2012). This pattern of water levels is consistent with an interpretation that leakage of water from above is slowly recharging the deep bedrock wells; however, there is an insufficient volume of water to uniformly saturate the entire vertical column of geologic materials at the site.

For that reason, the numerical model has been structured as a single-layer model, intended to simulate the potential movement of water through the shallow bedrock encompassing Engineering Units "A" and "B" beneath the site.

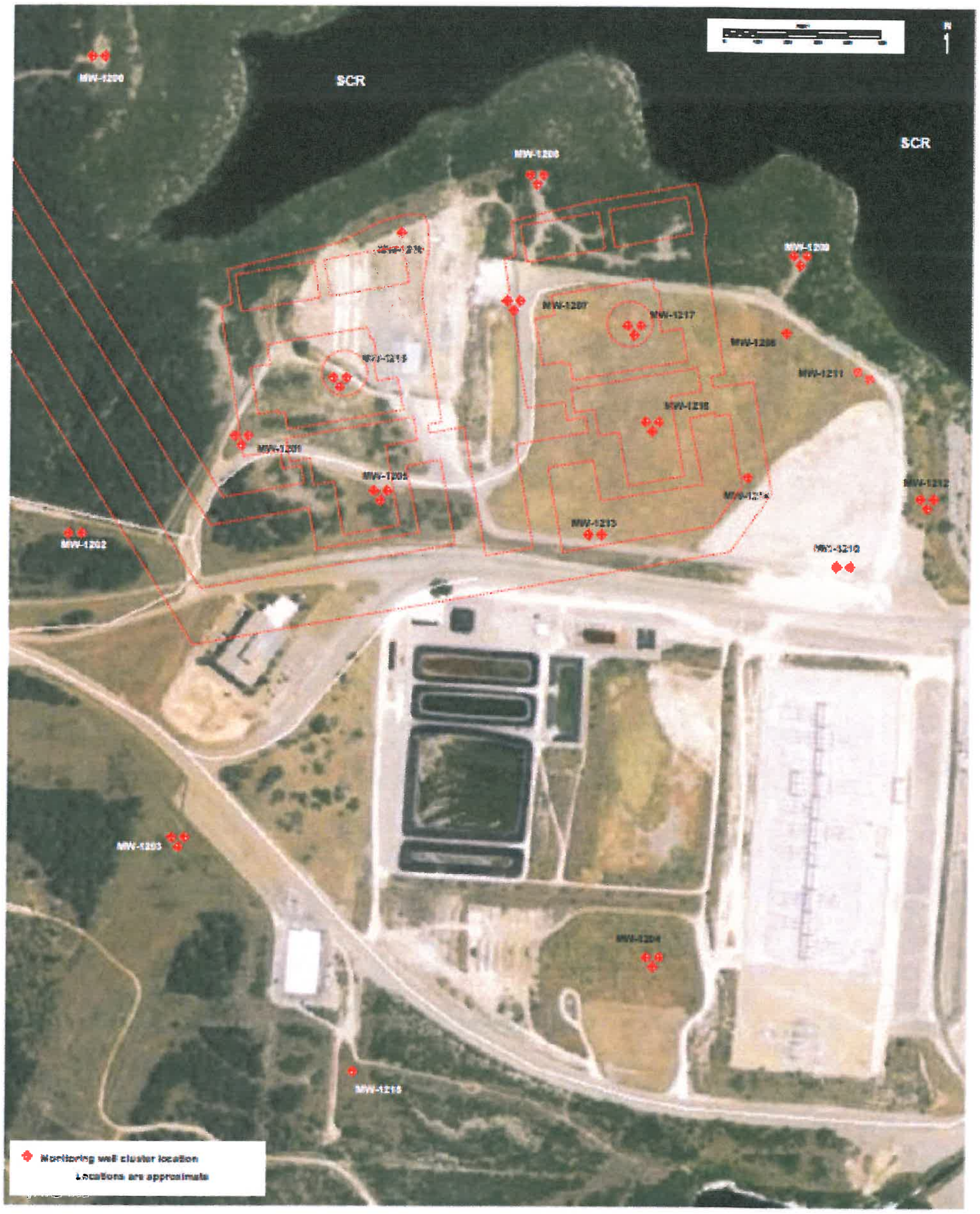


Figure 5-3. Monitoring Well Locations.

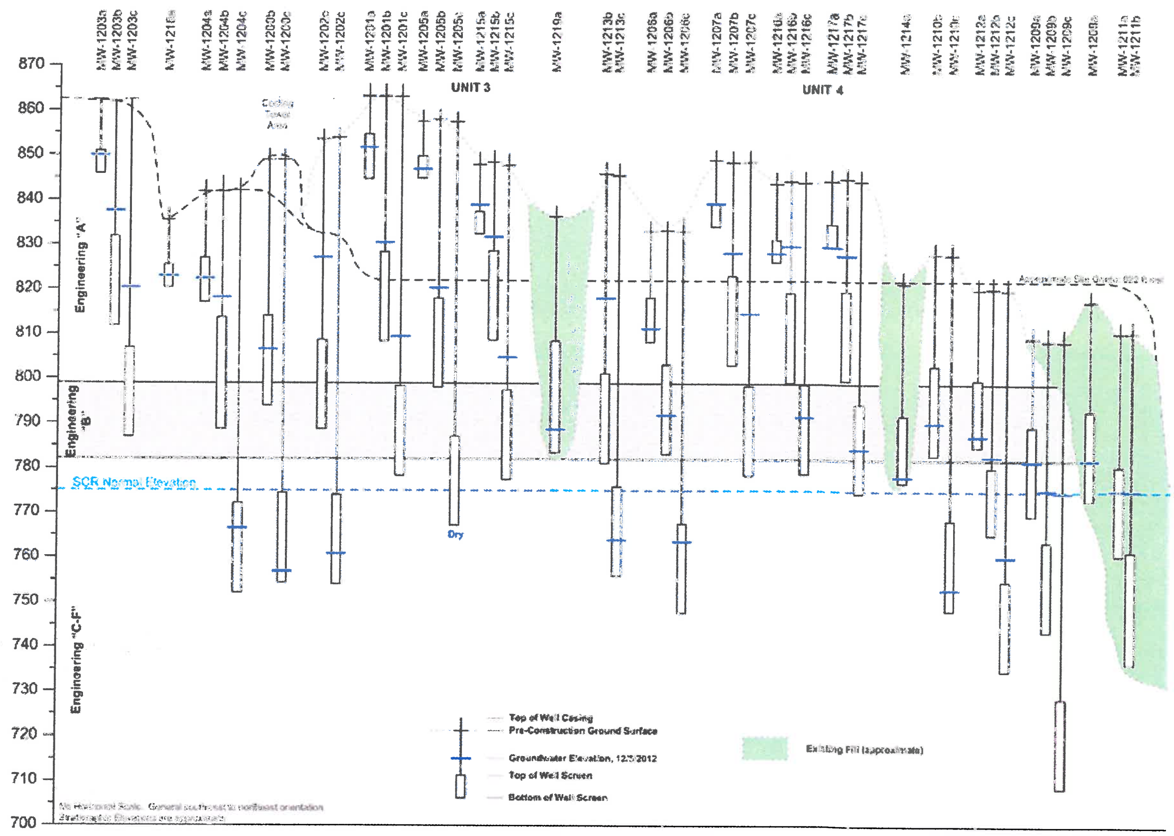


Figure 5-4. Cross Sectional Schematic of Water Levels and Well Screen Positions.

5.2 Flow Model Domain

The flow model covers an area extending approximately 3,318 ft west to east and 2,091 ft south to north (measured parallel to numerical model grid orientation) with the model domain centered on the power block area as shown in Figure 5-5, below. The MODFLOW model files (electronic files) are provided in Appendix A as an electronic attachment (DVD). The model domain is subdivided into rows and columns (Figure 5-5) using a variably-spaced grid necessary for the finite-difference flow equation. The grid spacing ranges in size from less than 5 ft in the immediate vicinity of the power block to a maximum of 150 ft around the perimeter of the model domain. The grid is refined in the power block area to allow more detailed representation of recharge and better lateral resolution of the calculated groundwater surface elevation.

Vertically, the flow model is comprised of one layer representing bedrock, Engineered Fill (where the fill is emplaced in excavations in the bedrock), and existing fill in areas located to the north and east of the nuclear islands. Within the power block area, model cells falling within the reactor buildings for Units 3 and 4 are specified as inactive, since no groundwater flow will occur through these structures, nor will recharge be contributed to the subsurface through these structures; inactive cells are similarly defined for the Ultimate Heat Sink basins.

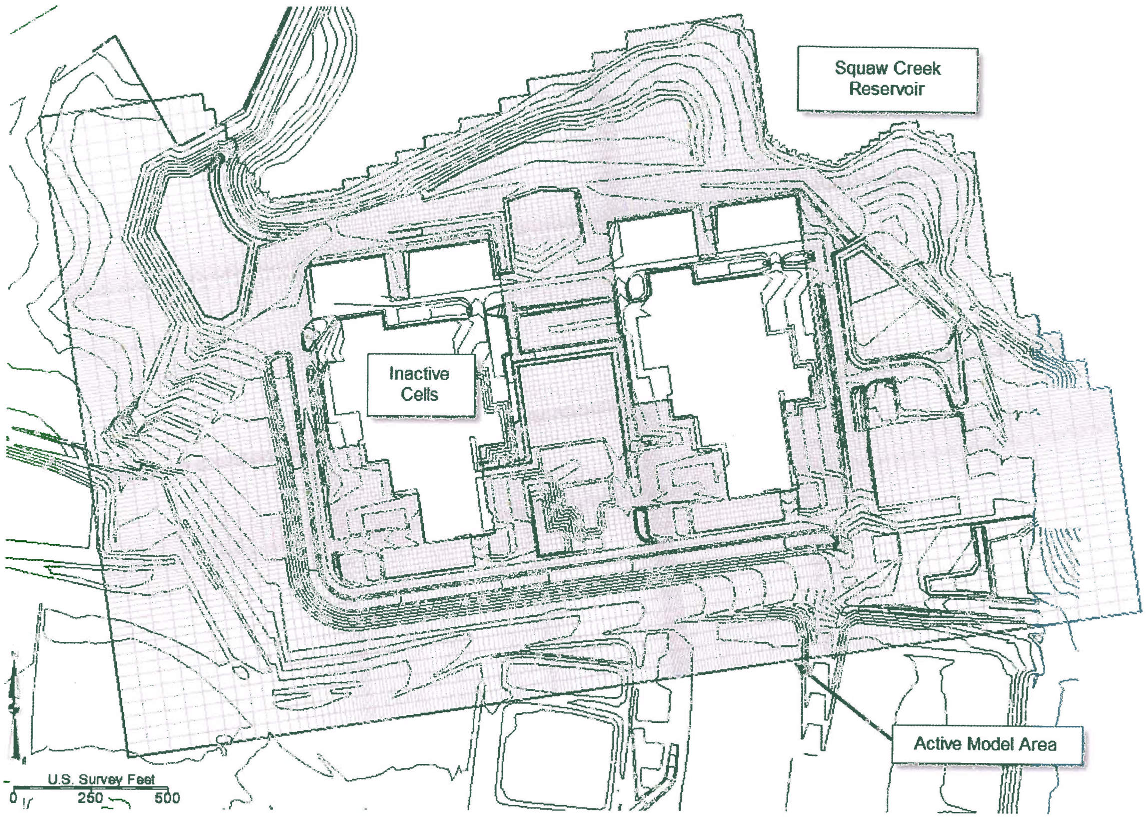


Figure 5-5. Plan View of MODFLOW Model Grid Superimposed on Planned Site Topography.

5.3 Site Topography

The modeled site topography represents the planned post-construction surface grade (References 4 and 10). This surface is defined as the top of the model. The three-dimensional surface was digitized in the GMS software from a shape file of the land surface contours. The electronic data files (ArcGIS shape file and GMS scatter point file) are on DVD; the ArcGIS shape file is provided in Appendix B while the GMS scatter point file is provided in the GMS data files in Appendix A. The contoured surface is shown below (Figure 5-6).

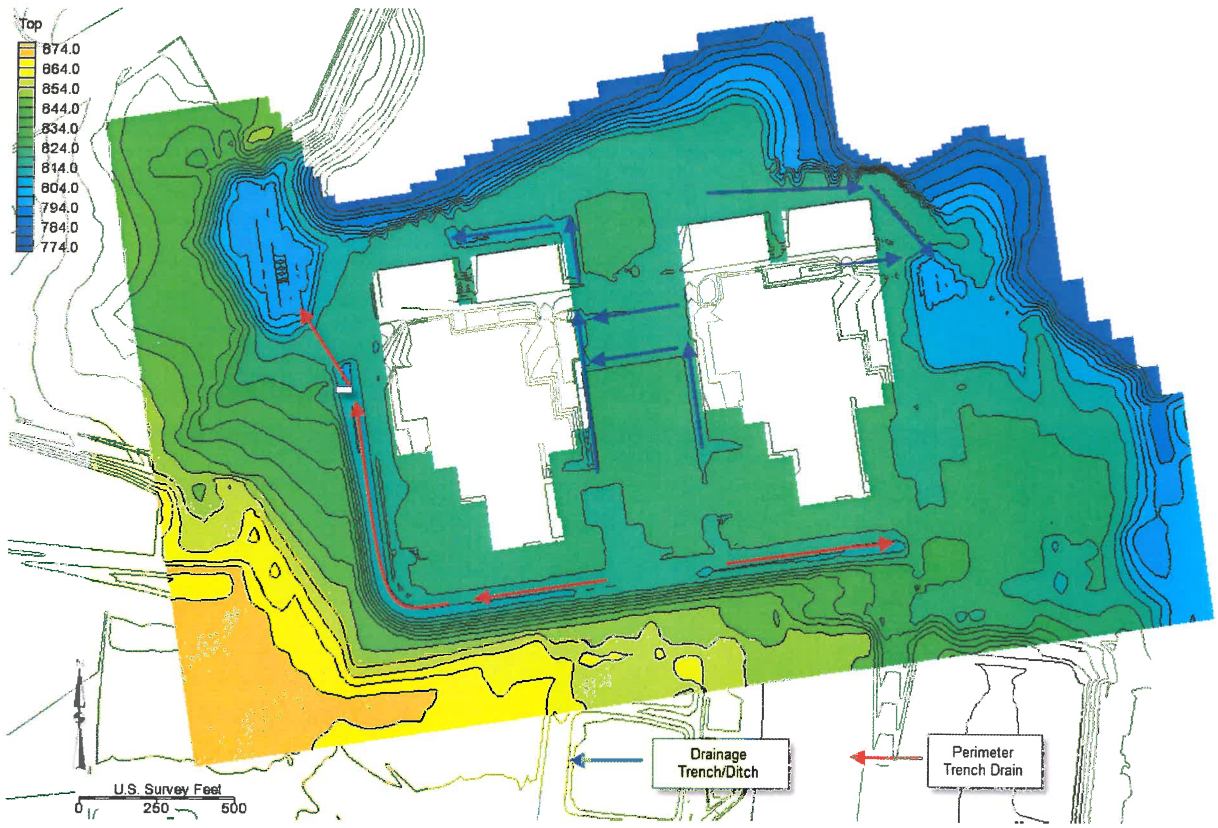


Figure 5-6. Plan View of Post-Construction Surface Topography in the MODFLOW Model (legend shows elevations in ft msl), with Key Surface Drainage Features Indicated by Arrows.

The existing land surface at the site will be extensively modified during plant construction. Current land surface elevations range from approximately 775 ft msl at the edge of SCR on the northern and eastern edges of the site to approximately 870 ft msl in the area southwest of the plant (Figure 5-7). Site surface grade is planned to be approximately 822 ft msl post-construction, with land surface elevations in areas south and west of the site remaining at higher elevations than site grade. Figure 5-8 illustrates that areas of surface cuts (indicated by green shading) will be extensive across the site, while areas of fill placement (indicated by blue shading) are expected to be more limited, such as those near the boundary with SCR. Some of the surface cuts are expected to be relatively deep, with as much as 45 feet of surface materials being removed (Reference 3).

Post-construction surface features at the site include several major drainage ditches designed to drain surface water around the units as well as away from the units (Reference 4) as indicated in Figure 5-6. The planned perimeter trench drain, shown in Figure 5-6, will be a significant surface water drainage feature, intended to direct runoff that enters from the south of the site around each of the units.

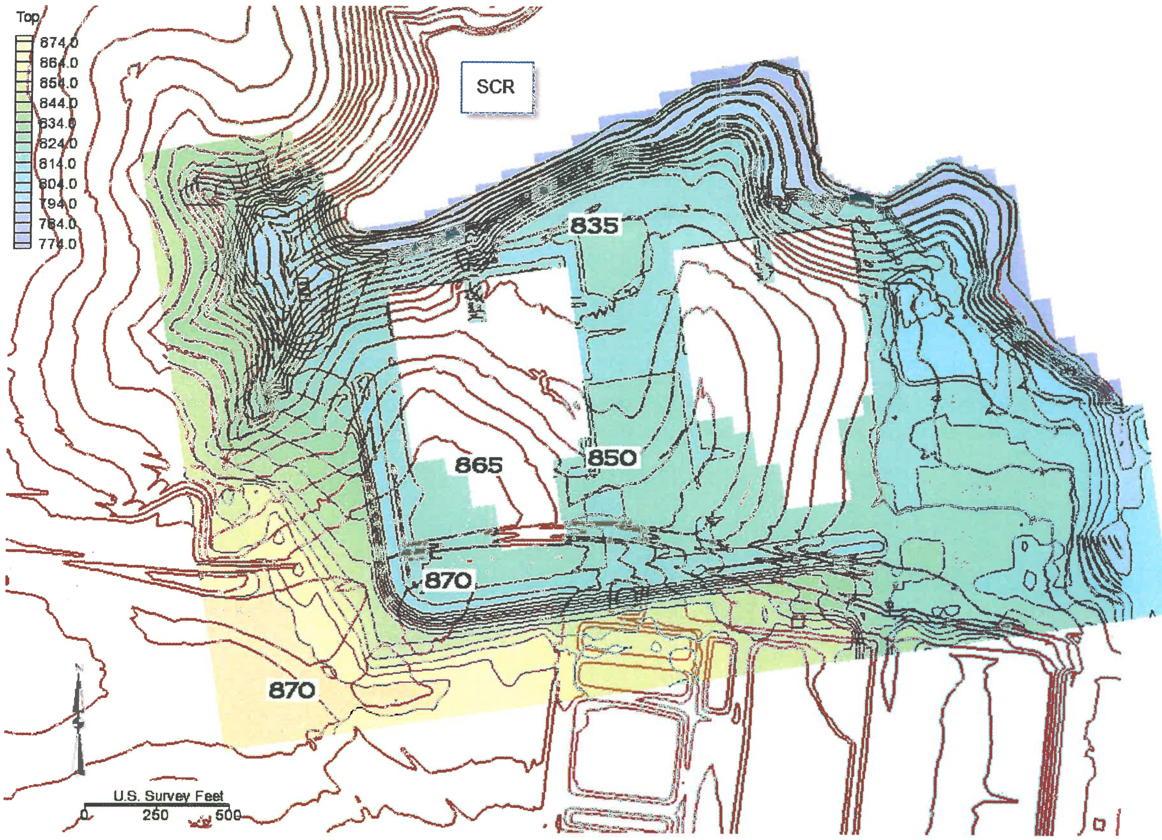


Figure 5-7. Pre-Construction Surface Topography in the Model Area (Brown Contours) Superimposed on Post-construction Surface (Color-Shaded) from Figure 5-4 (legend shows post-construction elevations in ft msl).

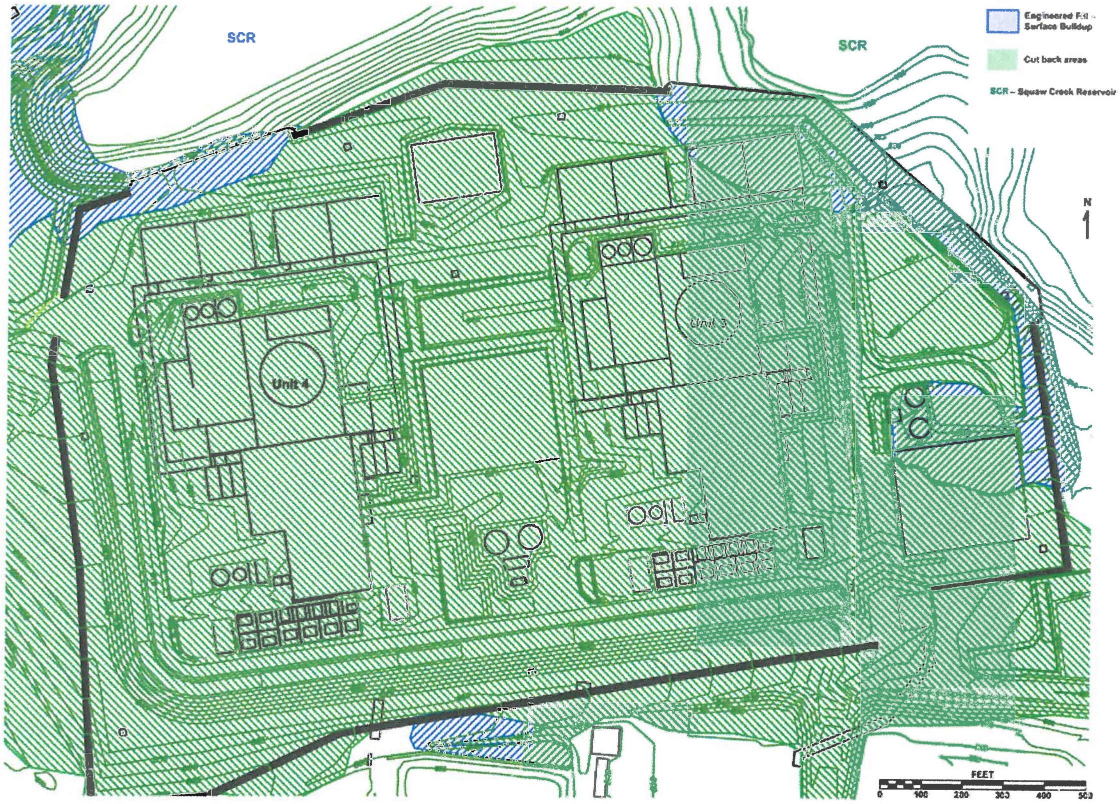


Figure 5-8. Cut and Fill Areas Around Units 3 and 4.

5.4 Model Layers

The model consists of one layer simulating flow through bedrock, Engineered Fill, and Existing Fill at the site. The bottom of the model was defined to take into account the configuration of the excavations into which Engineered Fill is to be placed, as well as the base of the Existing Fill in two areas located on the northern and eastern edges of the site. Excavations into bedrock are planned to range from 779 ft and 782 ft MSL around the power block area of each unit, and grade upward to the west where the excavations extend uphill toward the cooling towers. Areas of the site excavated to 779 ft are beneath the Reactor and Auxiliary Buildings; these areas are inactive in the model. The top of rock surface, incorporating the excavations that will be present post-construction, is shown in Figure 5-9. Elevations of excavations extending up toward the cooling tower area have been inferred based on a uniform slope from the turbine building excavations to the base of the cooling towers.

Figure 5-9. Planned Top of Bedrock Surface Across Site, Color Indicates Elevation as Shown in Legend (ft msl).

To simplify this surface for use in the numerical model, the bedrock surface outside the excavation area was smoothed to an elevation of 782 ft msl over areas upgradient of the nuclear island for representation in the numerical model. Areas outside of the nuclear island were smoothed, including the base of the Existing Fill (eastern and northern area) and the excavations that extend toward the cooling towers. This simplification is conservative in that it reduces the saturated thickness of the existing fill where groundwater exits the nuclear islands, and (in the case of the excavations extending towards the Cooling Towers) allows parts of the model to remain saturated thus avoiding dry cells. Elevations of excavations surrounding the power block areas were assigned a value of 782 ft msl, representing the excavation elevation for plant construction. The resulting surface representing the bottom of Layer 1 in the model is shown in Figure 5-10.

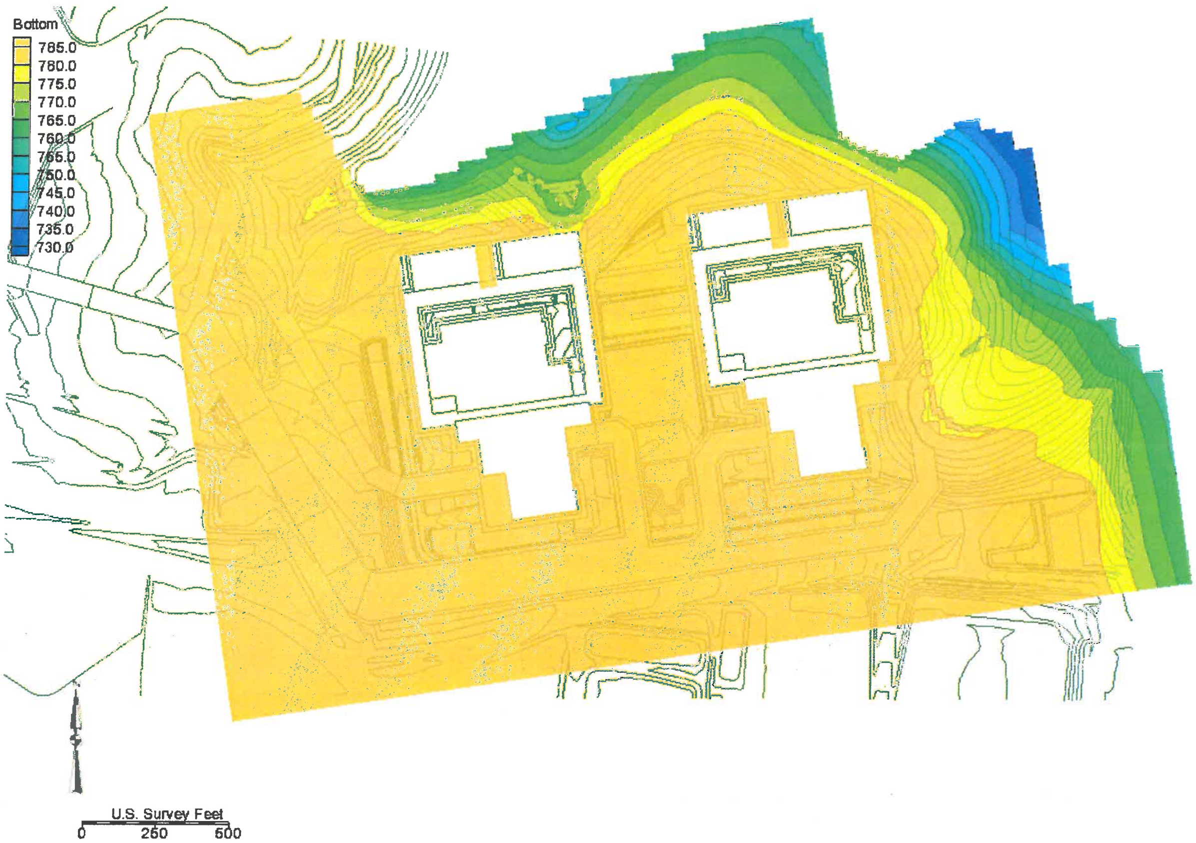


Figure 5-10. Bottom of Model, Derived From Top of Rock Surface, Legend Indicates Elevation (ft msl).

5.5 Aquifer Parameters

The subsurface at the site is represented in the numerical model by three soil materials: bedrock, existing fill, and Engineered Fill, each with different hydraulic properties. The majority of the site is underlain by competent limestone bedrock of the Glen Rose Formation. Two areas of existing fill overlying the bedrock are situated to the north and east of the site. Engineered fill will be placed in excavations made into the competent bedrock across the site. The hydraulic parameters for each of these materials are represented in the model by hydraulic conductivity (K) and specific yield (Sy); note that for unconfined conditions such as this site, the specific yield is equivalent to the effective porosity (n_e).

Site values for these two parameters for the Engineered Fill materials (granular materials) are provided in Estimation of Conservative Bounding Fill and Infiltration Cap Properties & Determination of Above Grade Fill Extents (Reference 3), and listed in Table 6-1 of this calculation. The lowest K (1.789 ft/d or 6.31 x 10-4 cm/sec) and Sy (0.17) values from the range reported in this reference are used in the model calculations.

K of the existing fill is reported to range from a low of 1.42 ft/d (5.0 x 10-4 cm/sec) for the northern fill area to a high of 9.9 ft/d (3.5 x 10-3 cm/sec) for the fill on the eastern side of the site. For purposes of the model, K values for the existing fill were assigned values ranging from 0.1 ft/d (northern fill area immediately adjacent to the Engineered Fill) to 5.0 ft/d (1.8 x 10-3 cm/s), lower than the K values reported for these materials. This adjustment was made to limit the extent of dry cells that develop in the model at the junction between the existing fill and the Engineered Fill in these areas, and is conservative with regard to calculation of water levels. Sy for the existing fill was assigned the same value (0.17) as that for the Engineered Fill.

K values for the bedrock have been derived from multiple packer tests as well as from slug tests. K values developed from the packer tests are very low, ranging from a low of 3.69 x 10-6 ft/d (1.3 x 10-9 cm/sec) to 0.00181 ft/d (6.38 x 10-7 cm/sec) for the Lugeon water test results (Reference 18, Table 2.5.4-206); some packer tests reported values of zero, indicating no water movement through the tested zone. K values reported for the bedrock based on slug tests ranged from 0.0388 ft/d ($1.37x10^{-5}$ cm/s) to 0.0178 ft/d ($6.29x10^{-6}$ cm/s) (Reference 18, FSAR Section 2.4.12.2.5.2). The highest K value derived from the packer tests was assigned for bedrock in this model. Use of this value is more conservative than the use of the slug test results, providing for slower movement of water and greater buildup of heads in the model, while being more realistic in terms of site characteristics than the lowest K values derived from the slug tests.

Sy for the bedrock is assigned a value of 0.119 in the model (Reference 18, FSAR Section 2.4.12.2.5.1). Geotechnical analyses performed at the site indicated an average total porosity of the shallow bedrock (limestone and shale combined) to be 0.256, with an average total porosity of the limestone reported to be 0.119. While it is likely that the shallow bedrock has a higher porosity, the lower value of 0.119 was used in the model as a conservative value. Though these values report total porosity, given the competent nature of the bedrock, the effective porosity is judged to be similar to the total porosity for purposes of the model.

The distribution of K values used in the model is illustrated in Figure 5-11. The distribution of values for Sy is illustrated in Figure 5-12. Areas of existing fill indicated in Figure 5-9 may differ from the area illustrated in Figure 2.5.4-215 of the FSAR (Reference 18). This is related to two factors: the area of saturated fill is slightly smaller than the area of total fill, since the fill extends to land surface above the water table; and the fill area incorporated into the model is slightly smaller than the actual area in an attempt to reduce the number of dry cells resulting in the model calculations. This assumption of fill area is conservative with regard to the model runs for the maximum groundwater level reported in this calculation.

5.6 Model Boundaries

Use of a numerical model requires that characteristics for the boundaries of the model area be defined. Multiple boundaries have been defined in this model as follows:

- Squaw Creek Reservoir (SCR) – SCR is a man-made surface water body created to provide cooling water for CPNPP Units 1 and 2; it serves as a major physical boundary along the northern and eastern edges of the site. This boundary is represented using a General Head Boundary (GHB) in the model. Head along this boundary is set to a value of 775.5, considered appropriate since SCR is at the level approximately 95% of the time (Reference 17). A low conductance value of 1 ft^2/d is assigned along the boundary as a conservative approach to limit flow between the reservoir and the subsurface (this value provides a conservative approach with regard to calculation of the maximum groundwater elevation by limiting groundwater flow into the reservoir). The influence of the water elevation of SCR on the calculated groundwater level is also evaluated in the sensitivity analysis.

- Southwest corner of model – A constant head boundary is assigned along the southwest corner of the site to allow for flow of groundwater from upgradient areas where regolith will remain under post-construction conditions. Heads in the shallow bedrock have been reported as high as approximately 830 ft msl; however, heads near the base of the engineering "B" unit are expected to be at an elevation close to the bottom of the unit. A constant head value of 835 ft msl is assigned in the southwest corner of the model, with the head sloping to 820 ft msl in the center of the southern and western model boundaries.

- Remaining lateral edges of model – GHB cells are assigned along the remaining lateral edges of the model (with the exception of one section in the northwest portion of the model that is a no-flow boundary), to allow limited subsurface movement of water. This type of boundary was assigned in the specified areas since there is no specific source of subsurface water upgradient from these areas.
- Additionally, the vertical movement of groundwater from shallow bedrock to deeper bedrock is an important component of the site conceptual model. Therefore, a GHB is specified at each cell in the model to account for the vertical movement of water out (downward) from the model area. Conductance for these nodes was calculated for a 1 ft^2 unit area based on a head of 782 ft msl estimated to be present at the base of Engineering "B," and a head of 764 ft msl. The head of 764 is based on the average of water levels from December 2012 in wells MW-1204C (766.58 ft msl), MW-1202C (760.82 ft msl), MW-1213C (763.91 ft msl), and MW-1206C (763.55 ft msl). Well MW-1210C was omitted from this calculation since the head in that well is approximately 10 feet lower than the head in the other four wells. Assuming a vertical hydraulic conductivity of 0.000181 ft/d, equivalent to one-tenth of the horizontal K value (0.00181 ft/d), the conductance is calculated to be:

(K x width x thickness)/distance or

(0.000181 x 1 ft x 1 ft)/(782-764) = 1.01 x 10^{-5} ft^2 per unit area

GMS then assigns a specific GHB conductance for each cell based on the cell area.

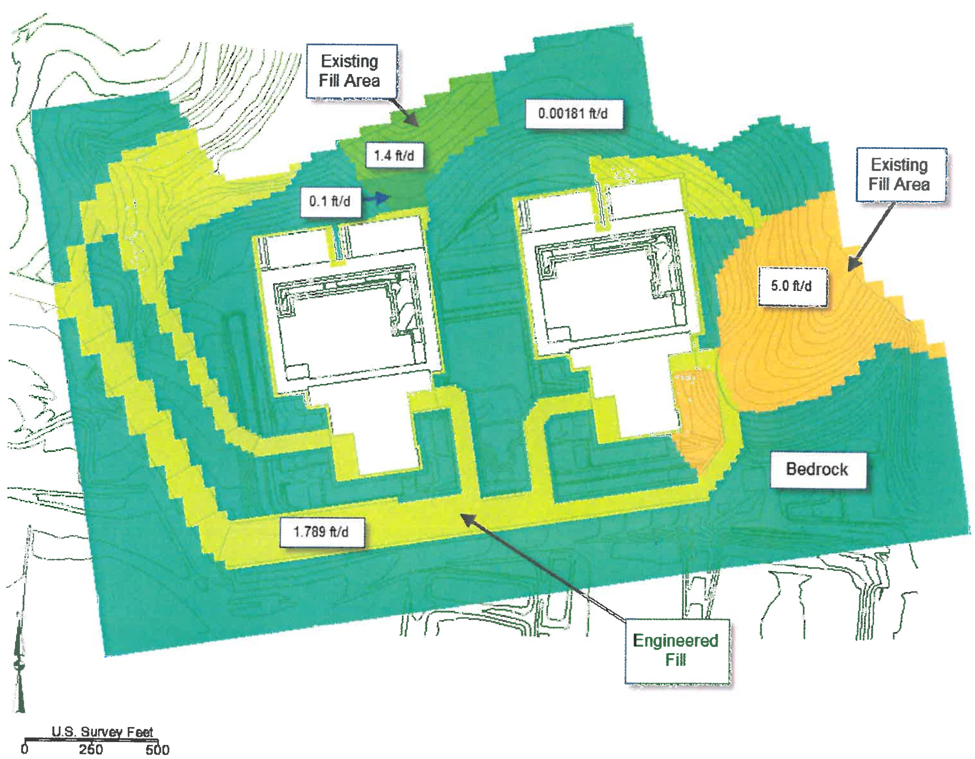


Figure 5-11. Hydraulic Conductivity Distribution.

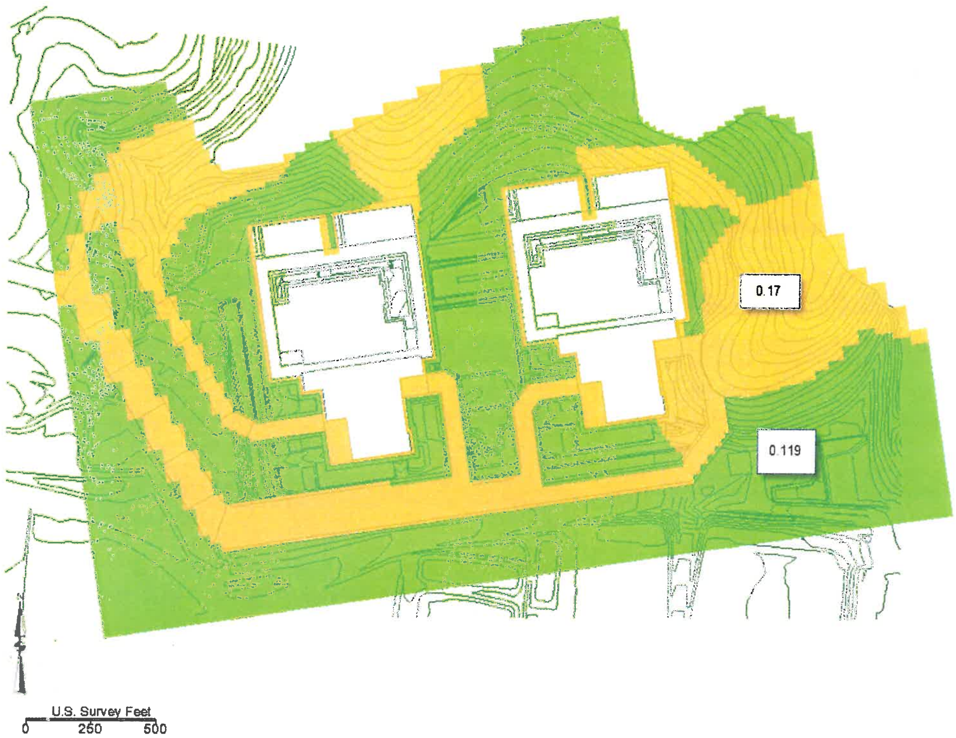


Figure 5-12. Specific Yield (Porosity) Distribution.

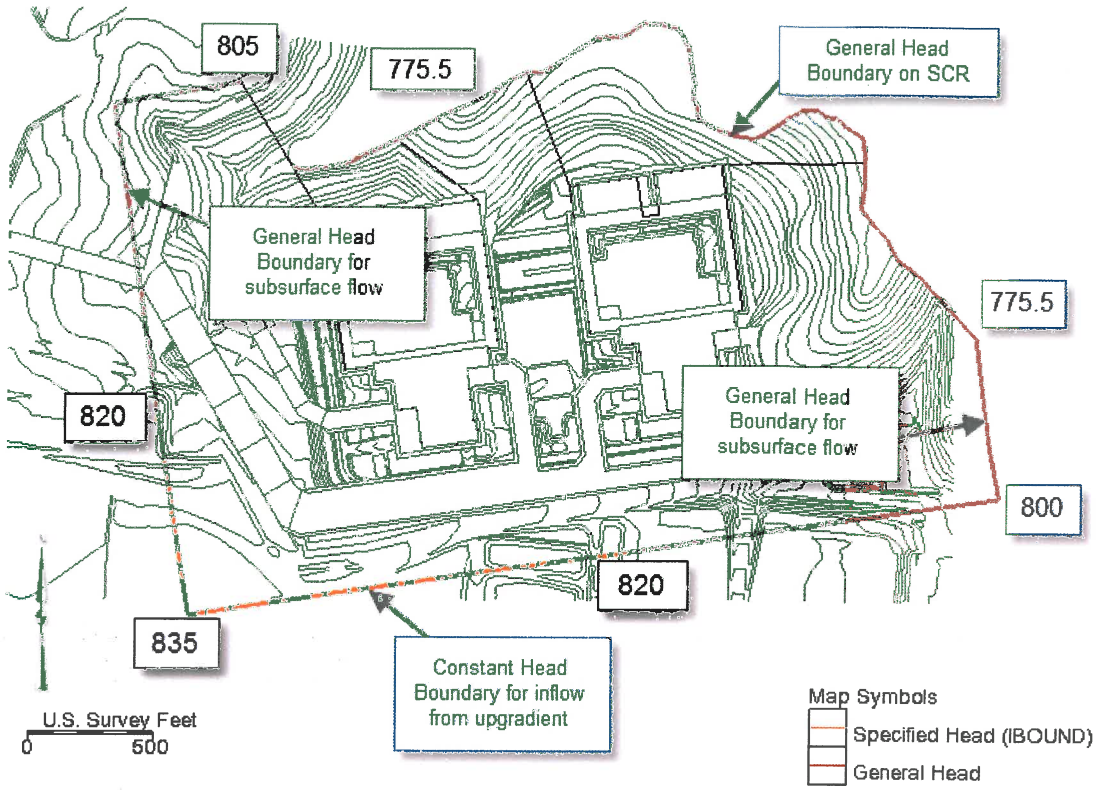


Figure 5-13. Assigned Boundary Conditions, with Assigned Head Values Posted.

5.7 Steady-State Model Run

Since the numerical model simulates post-construction conditions at the site, no projected post-construction groundwater potentiometric surface is available. Thus, each model run begins with an initial steady-state stress period to develop a water level surface for use as starting heads in the subsequent transient stress periods. The steady-state run was completed assuming a uniform average recharge to the aquifer of 0.591 inches per year or 0.000135 ft/d (USGS Reference 15) at all active model cells. The calculated heads for the steady state simulation are shown in Figure 5-14. Calculated heads at many cells downgradient from the power block area are lower than the bottom elevation of the grid cell, resulting in the cell being identified as 'dry' in the model (shown with a red triangle in the figure). These dry cells occur since the hydraulic conductivity of the existing fill materials is higher relative to that of the upgradient bedrock and Engineered Fill (especially for the eastern area of existing fill). Dry cells are shown in this steady-state run to illustrate those areas of the model that tend to go dry as a result of the configuration of the model layer elevations and K distribution. Subsequent runs evaluating the transient recharge conditions discussed later in this text implement a GMS option for assigning the cell bottom elevation at dry cells to limit their occurrence during model runs.

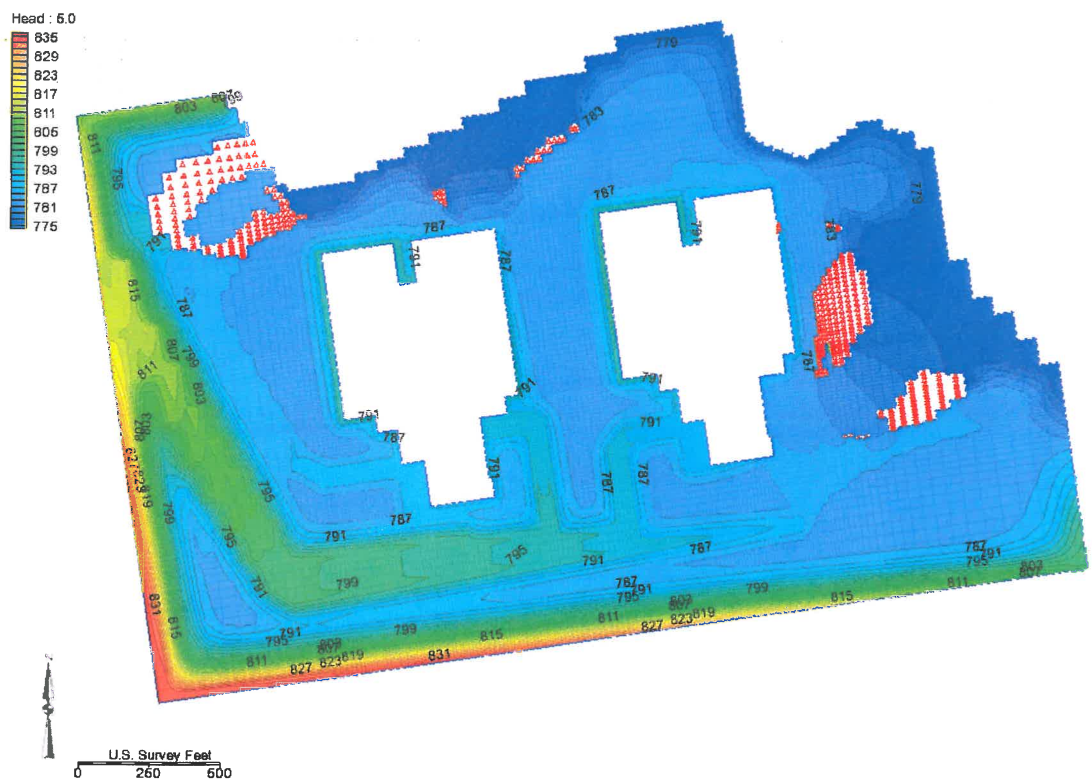


Figure 5-14. Steady-State Groundwater Surface MODFLOW Model Domain (dry cells indicated in red).

5.8 Aquifer Recharge

The average aquifer recharge is assumed to occur uniformly across the site at all active cells under steady-state conditions in the model. Estimating changes in the aquifer recharge that occurs during the major precipitation event involves three steps:

- Identification of the precipitation event – for this calculation, the PMP event is selected as the event, as described in the calculation TXUT-001-FSAR-2.4.3-CALC-011 (Reference 2). This event represents an overall precipitation amount of 42.53 inches occurring over a 72-hour time period.
- Identification of site soil types and land cover based on site-specific information and descriptions presented in the USDA report "Urban Hydrology for Small Watersheds" (Reference 16). These are used to select the curve number used in estimating the runoff for the specific cover type and hydrologic condition, which in turn is used to calculate the runoff coefficient. This reference is considered to outline a conservative method for estimating recharge that may occur during a precipitation event.
- Application of the recharge coefficient (calculated from the runoff coefficient determined from the soil type and land cover) to the precipitation event to calculate the recharge contribution to the model during the major precipitation event

Three recharge zones were identified for the site (Figure 5-15). First, the buildings situated in the power block area (reactor building, turbine building, auxiliary building) were assumed to have zero infiltration/recharge to the subsurface, since these areas will be covered and runoff controls will be implemented for the structures. Similarly, zero recharge values were assigned for the Ultimate Heat Sink basins. All of these areas are inactive in the model, so no recharge or groundwater flow occurs through cells in these zones. These zones are shown with no color in Figure 5-15.

Second, areas of the site where Engineered Fill is to be placed represent areas where a coarse-grained granular fill will be present near the land surface. Thus these areas were considered as having site soils represented by Hydrologic Soils Group (HSG) Type A soils, identified as having a sand, loamy sand, or sandy loam composition (Reference 16). Similarly, areas of Existing Fill are also considered to be Type A soils, given the coarse grained nature of the materials. These areas of Engineered Fill or Existing Fill considered as Type A soils are shown in green, red, or yellow on Figure 5-15.

Third, the remaining areas of the site represent areas where bedrock will be present at or near the land surface. For purposes of this modeling analysis, these areas are considered to have site soils represented by HSG Type D soils, with soil textures of clay loam, silty clay loam, sandy clay, silty clay, or clay. These soil types are consistent with the presence of a fine-grained low-permeability material near the land surface.

The site will have land cover that includes buildings, paved roads and parking lots, and multiple ditches and drainage ways on the land surface. Given this variety of features, an overall land cover of 'Paved/Open ditches' has been selected as representative of the site. The curve number for each HSG was obtained from Table 2-2a of Reference 16 for the 'Paved/Open ditches' cover type and hydrologic condition. The curve number for each soil type was then used to calculate a runoff coefficient. The positions of buildings, paved areas, and other paved or covered surfaces are not explicitly considered in the recharge distribution.

Recharge is then calculated using the following basic equation:

Precipitation (100%) - Runoff Coefficient % = Recharge %.

The recharge rate as a percentage of precipitation is calculated for each recharge area of the model using the precipitation distribution for the PMP event (Table 5-1). Because the flow model dimensions are in feet and the time is expressed in days, the recharge rates are converted to units of feet per day for input to the model (Table 5-1). The volume of water calculated as runoff during the event is considered to be carried across the site surface via the planned drainage system.

For the areas shown in red and yellow around each unit in Figure 5-13, the amount of recharge received by the Essential Service Water Pipe Tunnel (ESWPT) at the unit has been added to the recharge being contributed to the Engineered Fill adjacent to the unit. For all areas of Engineered Fill, the amount of recharge contributed to the adjacent bench area (narrow area where each excavation is benched upward to shallower depths toward surface grade) is added to the recharge being contributed to the area identified as Engineered Fill. The additional recharge is added since the bench area will be filled with Engineered Fill, but the area is anticipated to be dry (and is above the calculated water levels in the model) and therefore is not explicitly represented in the model. The Excel spreadsheet used to calculate recharge for use in the model is provided in electronic form in Appendix B.

This approach to calculating recharge during a maximum precipitation event is extremely conservative in several ways:

- The average recharge rate applied uniformly across the site is considered to be an overly conservative value. The site is located in an arid area, with limited precipitation.
- Recharge during the PMP event is applied across the entire site, minus the buildings in the power block area and the UHS basins. Recharge is allowed even in areas where buildings, tanks, and other physical structures are planned, thus allowing recharge over an area larger than what is expected to occur.
- The PMP event used to calculate recharge values is extremely conservative with regards to the amount of precipitation. Reference 18, Table 2.3-217 presents a statistical analysis of regional precipitation magnitude in inches for given storm durations (5 minutes to 10 days) and storm recurrence intervals (1 to 100 years). It was calculated that for a storm with a 100-year recurrence interval and given durations of 2-days, 4-days, and 10-days, the total rainfall would be 11.0 inches, 12.5 inches, and 15.8 inches.
- The annual average total rainfall is 30.3 inches with a maximum 48-hours rainfall total of 4.5 inches (Reference 18, Subsection 2.3.2.1.5). The PMP event is roughly 10 times this maximum value.

Figure 5-15. Recharge Zones Across the MODFLOW Model Domain

From USDA TR-55

			HSG A (Sand)	HSG D (Clay, Clay loam)
Table 2-2a	CN=		83	93
Eq. 2-4	S=		2.05	0.75
Cumulative		43.191		
Eq. 2-3	Q (runoff)		40.83	42.30
	Infiltration (Precip - Q)		2.36	0.89
	Recharge Coefficient		0.05	0.02

Hour	Cumulative precip (inches)	Incremental precip per hour (inches)	Recharge (inches) HSG A (Sand)	Recharge (inches) HSG D (Clay, Clay loam)	Hour	Cumulative precip (inches)	Incremental precip per hour (inches)	Recharge (inches) HSG A (Sand)	Recharge (inches) HSG D (Clay, Clay loam)	Hour	Cumulative precip (inches)	Incremental precip per hour (inches)	Recharge (inches) HSG A (Sand)	Recharge (inches) HSG D (Clay, Clay loam)
1	0.098	0.098	0.005364	0.00202	25	3.793	0.301	0.016477	0.006204	49	39.372	0.261	0.014287	0.00538
2	0.196	0.098	0.005364	0.00202	26	4.107	0.314	0.017188	0.006472	50	39.633	0.261	0.014287	0.00538
3	0.294	0.098	0.005364	0.00202	27	4.436	0.329	0.018009	0.006782	51	39.894	0.261	0.014287	0.00538
4	0.392	0.098	0.005364	0.00202	28	4.783	0.347	0.018995	0.007153	52	40.155	0.261	0.014287	0.00538
5	0.49	0.098	0.005364	0.00202	29	5.151	0.368	0.020144	0.007586	53	40.416	0.261	0.014287	0.00538
6	0.588	0.098	0.005364	0.00202	30	5.543	0.392	0.021458	0.00808	54	40.677	0.261	0.014287	0.00538
7	0.708	0.12	0.006569	0.002474	31	6.23	0.687	0.037606	0.014161	55	40.854	0.177	0.009689	0.003648
8	0.828	0.12	0.006569	0.002474	32	7.002	0.772	0.042259	0.015913	56	41.031	0.177	0.009689	0.003648
9	0.948	0.12	0.006569	0.002474	33	7.868	0.866	0.047404	0.017851	57	41.208	0.177	0.009689	0.003648
10	1.068	0.12	0.006569	0.002474	34	8.838	0.97	0.053097	0.019994	58	41.385	0.177	0.009689	0.003648
11	1.188	0.12	0.006569	0.002474	35	9.92	1.082	0.059228	0.022303	59	41.562	0.177	0.009689	0.003648
12	1.308	0.12	0.006569	0.002474	36	11.124	1.204	0.065906	0.024818	60	41.739	0.177	0.009689	0.003648
13	1.461	0.153	0.008375	0.003154	37	12.696	1.572	0.08605	0.032403	61	41.873	0.134	0.007335	0.002762
14	1.614	0.153	0.008375	0.003154	38	15.036	2.34	0.12809	0.048234	62	42.007	0.134	0.007335	0.002762
15	1.767	0.153	0.008375	0.003154	39	18.842	3.806	0.208338	0.078452	63	42.141	0.134	0.007335	0.002762
16	1.92	0.153	0.008375	0.003154	40	30.988	12.146	0.664866	0.250364	64	42.275	0.134	0.007335	0.002762
17	2.073	0.153	0.008375	0.003154	41	34.076	3.088	0.169035	0.063652	65	42.409	0.134	0.007335	0.002762
18	2.226	0.153	0.008375	0.003154	42	36.129	2.053	0.11238	0.042318	66	42.543	0.134	0.007335	0.002762
19	2.437	0.211	0.01155	0.004349	43	36.744	0.615	0.033665	0.012677	67	42.651	0.108	0.005912	0.002226
20	2.648	0.211	0.01155	0.004349	44	37.298	0.554	0.030326	0.01142	68	42.759	0.108	0.005912	0.002226
21	2.859	0.211	0.01155	0.004349	45	37.802	0.504	0.027589	0.010389	69	42.867	0.108	0.005912	0.002226
22	3.07	0.211	0.01155	0.004349	46	38.266	0.464	0.025399	0.009564	70	42.975	0.108	0.005912	0.002226
23	3.281	0.211	0.01155	0.004349	47	38.699	0.433	0.023702	0.008925	71	43.083	0.108	0.005912	0.002226
24	3.492	0.211	0.01155	0.004349	48	39.111	0.412	0.022553	0.008492	72	43.191	0.108	0.005912	0.002226
												Total recharge	2.36	0.89

Table 5-1 Hourly Precipitation and Recharge Listing for the PMP Event.

5.9 Groundwater Level Observation Points

Observation points for informational purposes were assigned in the model around each of the two reactor units, as shown in Figure 5-16. Identification labels for each point are identified by the Unit number (3 or 4), and the general directional location of the point (northwest, southeast, etc.). Points situated adjacent to the Ultimate Heat Sink basins are identified with a 'U' in the label. These observation points are used to track calculated groundwater elevations throughout the modeled time period.

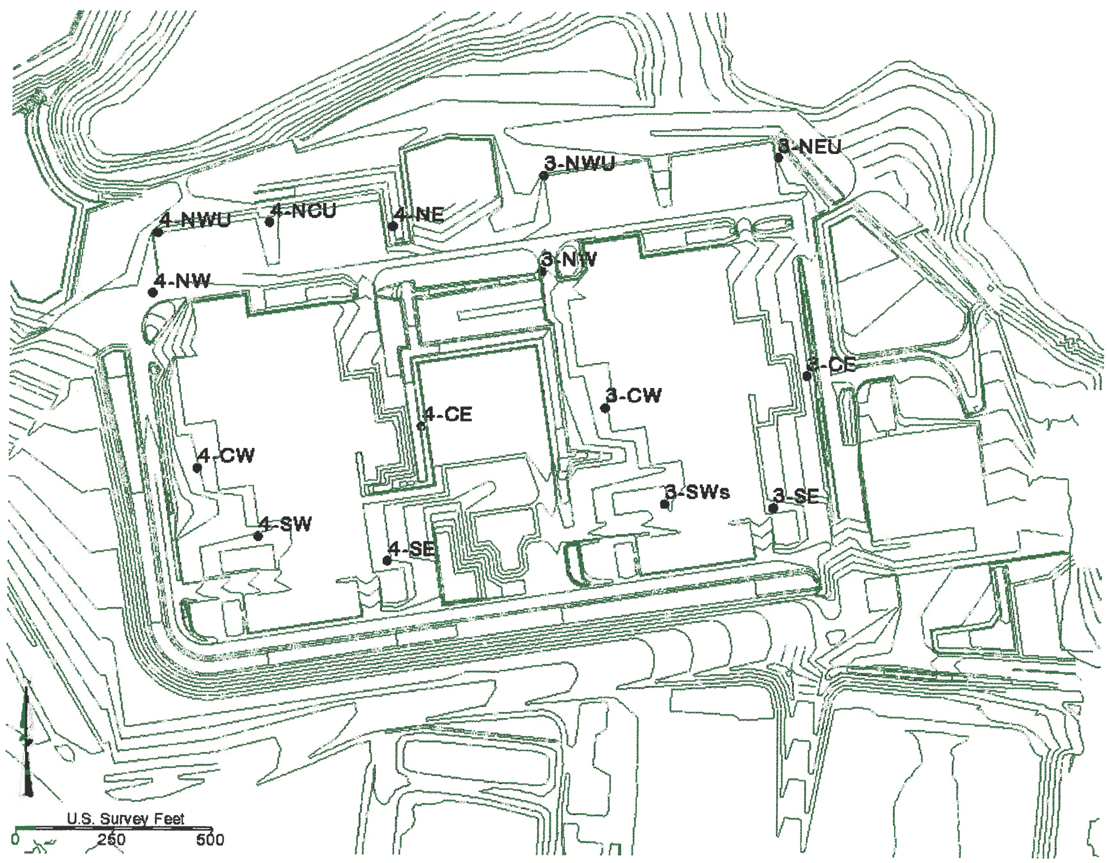


Figure 5-16. Observation Points Specified in the Model.

6.0 METHODOLOGY

MODFLOW is used to solve the three-dimensional finite-difference groundwater flow equation to evaluate post-construction groundwater conditions at the site. MODFLOW-2005 is a computer program developed by the US Geological Survey that simulates three-dimensional groundwater flow through a porous medium using a finite-difference method. The groundwater flow equation and explanation are shown in Figure 1, from the MODFLOW-2005 reference manual (Harbaugh, 2005; Reference 14). An electronic copy of the MODFLOW-2005 manual is provided in electronic format in Appendix C.

The three-dimensional movement of ground water of constant density through porous earth material may be described by the partial-differential equation

(Reference 14)

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)+W=S_s\frac{\partial h}{\partial t} \quad (2\text{–}1)$$

where

K_{xx}, K_{yy}, and K_{zz} are values of hydraulic conductivity along the x, y, and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity (L/T);

h is the potentiometric head (L);

W is a volumetric flux per unit volume representing sources and/or sinks of water, with $W<0.0$ for flow out of the ground-water system, and $W>0.0$ for flow into the system (T^{-1});

S_S is the specific storage of the porous material (L^{-1}); and

t is time (T).

Figure 6-1. Explanation of Groundwater Flow Equation

GMS (Reference 13) is the pre-and post-processing software used to construct, run, and process MODFLOW files for the CPNPP project. MODFLOW is one of several modeling program modules available within GMS. GMS facilitates the input and modification of the model structure and aquifer parameters for the creation of MODFLOW packages which MODFLOW uses to solve the groundwater flow equations. GMS then reads the MODFLOW output files and displays the results.

Because the precipitation data varies over time, MODFLOW 2005 is run with transient stress periods having variable recharge amounts for this water level evaluation. A separate flow model run was created for each set of parameter variations, listed in Table 6-1. The 15 specified observation points (Figure 5-16) are used to record the calculated groundwater levels through each transient model run; only the two points with the highest calculated water levels (points 4-NW and 3-NW) at each unit are used in subsequent text to graphically portray the calculated groundwater elevation over time for each model run.

Each model run is set up with an initial steady-state stress period to establish initial water levels, followed by the transient simulation. Initial water levels were assigned an elevation of 805 ft msl.

MODFLOW MODEL INPUT PARAMETERS

Run #	Description	File Name	Initial Heads	Hydraulic Conductivity (K) in ft/d			Specific Yield (S_y), dimensionless			NI and UHS	Fill Areas	Bedrock	SCR Elevation
				Existing Fill	Engineered Fill	Bedrock	Existing Fill	Engineered Fill	Bedrock	Recharge (Percent of Preciptation)*			
1	Base Run	Feb13_GWLv6a.gpr	805 ft MSL	0.1 to 5	1.79	0.0178	17.0%	17.0%	11.9%	0%	5.5%	2.1%	775.5
2	Sensitivity Run 1 Decrease Sy	Feb13_GWLv6aS1.gpr	805 ft MSL	0.1 to 5	1.79	0.0178	15.0%	15.0%	5.0%	0%	5.5%	2.1%	775.5
3	Sensitivity Run 2 Increase Recharge	Feb13_GWLv6aS2.gpr	805 ft MSL	0.1 to 5	1.79	0.0142	17.0%	17.0%	11.9%	0%	6.0%	2.3%	775.5
4	Sensitivity Run 3 Increase Heads	Feb13_GWLv6aS3.gpr	810 ft MSL	0.1 to5	1.79	0.0178	17.0%	17.0%	11.9%	0%	5.5%	2.1%	775.5
5	Sensitivity Run 4 Increase SCR Level	Feb13_GWLv6aS4.gpr	805 ft MSL	0.1 to 5	1.79	0.0178	174.0%	17.0%	11.9%	0%	5.5%	2.1%	up to 779

NOTES
Sy Specific Yield, the drainable portion of the water table aquifer
* Without additional recharge added from adjacent areas

Table 6-1 Summary of MODFLOW Model Parameter Settings for the Base Model Run (Run 1) and Four Sensitivity Model Runs (Runs 2 – 5).

The Base Run (Run 1) contains site dimensions and aquifer settings that represent the anticipated post-construction site conditions with extremely conservative assumptions. Site dimensions include the finished surface grade elevations, general surface cover materials, Power Block building positions, and engineered fill placement locations and elevations. Attempts to apply the rewetting function of MODFLOW were not successful (the rewetting parameters can be extremely difficult to define); thus, model runs for evaluating the maximum groundwater level were made using a GMS option to limit the drying of model cells by assigning the bottom elevation of the cell as the head in the cell, which allows the model to continue running with saturated cells at locations that would have otherwise been dry. Given the limited number of dry cells generated in the steady-state model run (Figure 5-14), this is considered to be a reasonable approach.

The aquifer settings for the Base Run include the following (Table 6-1):

- K values set to low values;
- Sy values set to low values;
- Initial water levels for transient runs generated from steady-state run completed in initial stress period;
- Recharge determined by runoff coefficients, translated to recharge coefficients, using methods outlined in USDA TR-55 (Reference 16).

After the flow model was constructed and the base run completed, sensitivity analyses were completed to evaluate the impacts on groundwater elevations as a result of even more conservative changes to MODFLOW model parameters. The parameters that were varied are listed in Table 6-1, and include decreasing aquifer specific yield (Run 2), increasing recharge by 10% (Run 3), increasing initial groundwater elevations across the model constant head boundary (Run 4), and increasing the level in SCR over time throughout the major precipitation event (Run 5).

7.0 CALCULATION RESULTS

The results for each simulation include a plan view of the full flow model domain with the groundwater surface contoured via color-fill, and a graph of the calculated water levels over the elapsed time of the PMP event for the two observation points having the highest calculated water levels (points 4-NW and 4-NW).

Run 1. Base Run

Set-up of this simulation includes the following (Table 6-1):

- K values set low values as previously described;
- Sy values were set to low values;
- Initial water levels set to 805 ft msl;
- Surface cover recharge set to those representing the PMP event.

This run is considered the most conservative representation of expected post-construction site conditions within the constraints of the assumptions made relative to site characteristics. Calculated heads for the model run are illustrated in Figure 7-1; a graph of calculated heads versus time for the two observation points with the highest head values is shown in Figure 7-2. Flooded cells are calculated to be present along the edge of SCR; however, this occurs because the elevation of SCR is specified at 775.5 ft msl, 0.5 feet above the land surface elevation of 775.0 specified along the edge of SCR. As such, this is an occurrence related to data specified in the model, not an outcome related to the model results.

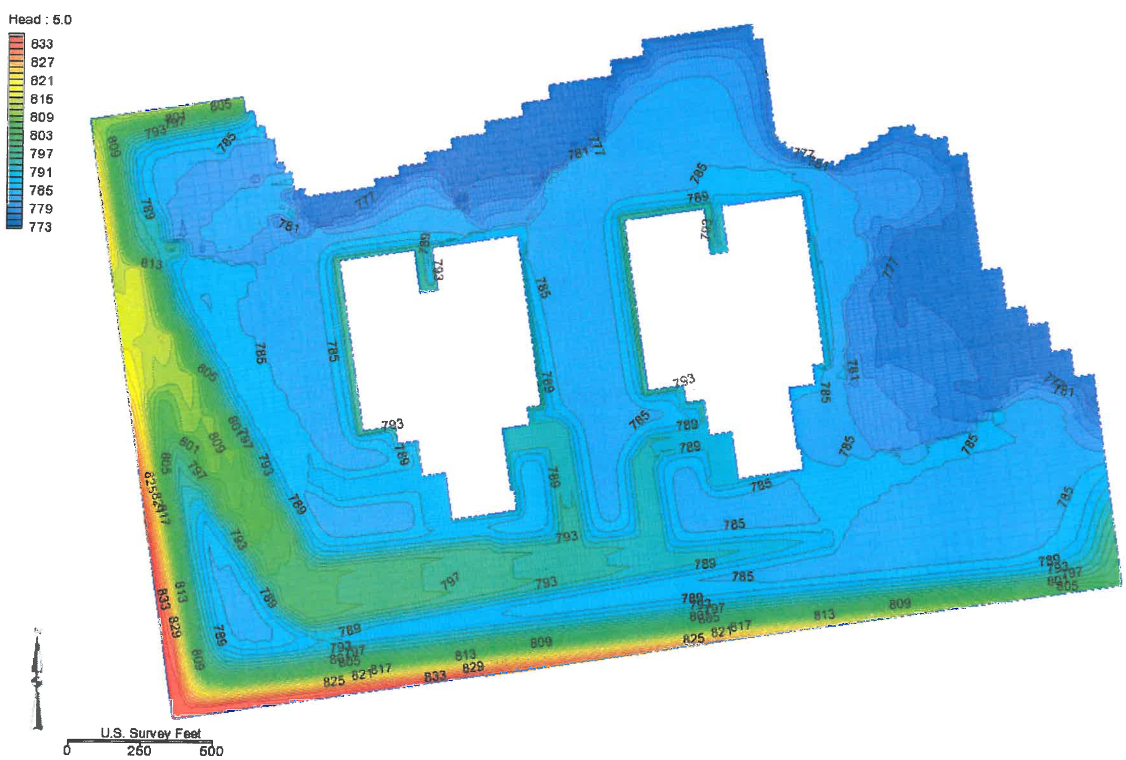


Figure 7-1. Plan View of Groundwater Surface, t = 5.0 days, Base Run (Run 1).

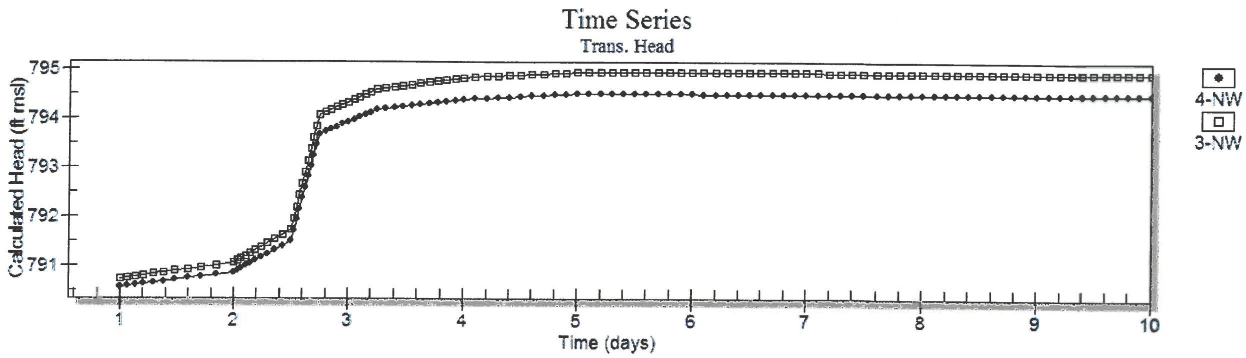


Figure 7-2. Observation Point Hydrographs – Base Run (Run 1).

The highest groundwater elevation recorded at any of the observation points was 794.94 ft msl at observation point 3-NW, at approximately 5.0 days elapsed time. The highest calculated water level in the model was consistently observed at or near to observation point 3-NW. Water levels calculated across the site in the model are below the elevations of the surface drainage ditches and inverts; therefore, no groundwater discharge to surface water drainage features is expected to occur.

Run 2. Sensitivity Analysis Number 1

A sensitivity run was completed using the lowest potentially applicable specific yield values for the subsurface materials.

- Sy for fill reduced to 0.15, Sy for bedrock reduced to 0.05, and other parameters (initial heads, K) remained the same as in the Base Run (Run 1).

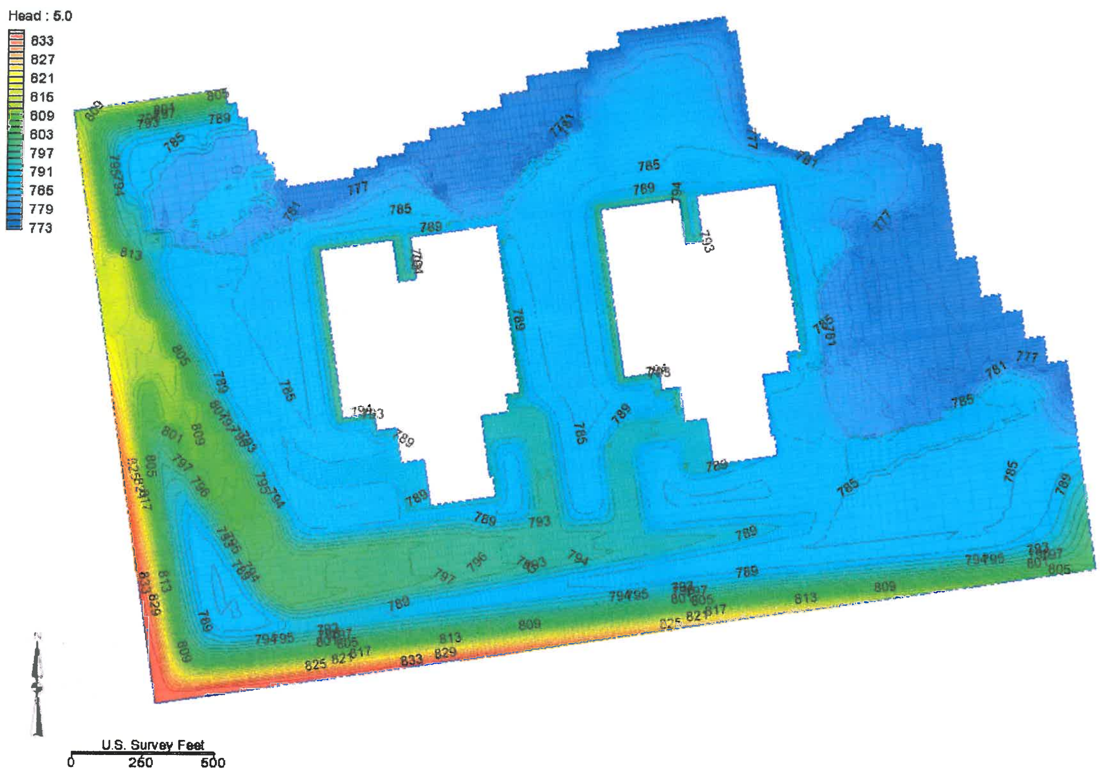


Figure 7-3. Plan View of Groundwater Surface Elevations, t= 5.0 days, Run 2

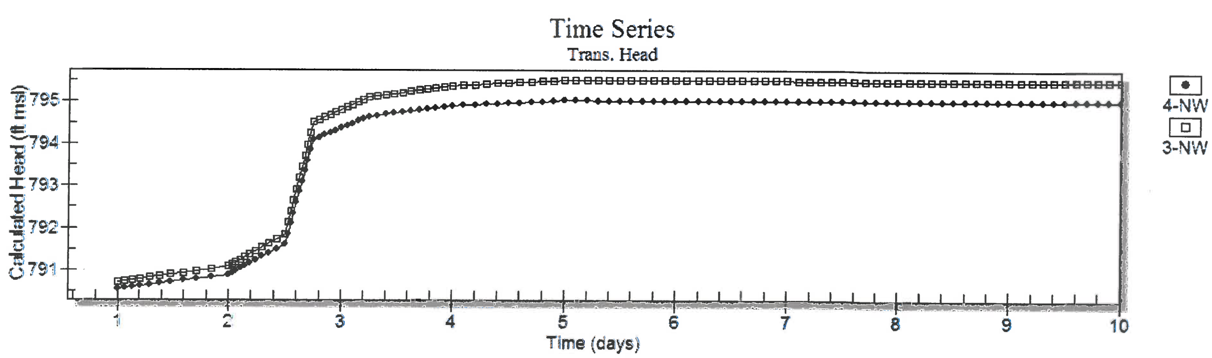


Figure 7-4. Observation Point Hydrographs - Run 2.

The highest groundwater elevation recorded was 795.50 feet at approximately 5 days elapsed time at observation point 3-NW.

Run 3. Sensitivity Analysis Number 2

A sensitivity run was completed using a higher recharge value than that used in Run 1 (Base Run).

- Recharge was increased uniformly by 10% through all stress periods and time steps (including an increase in the average annual recharge amount incorporated into the steady-state period and transient periods subsequent to the major precipitation event).

- All other parameters remained the same as the Base Run (Run 1).

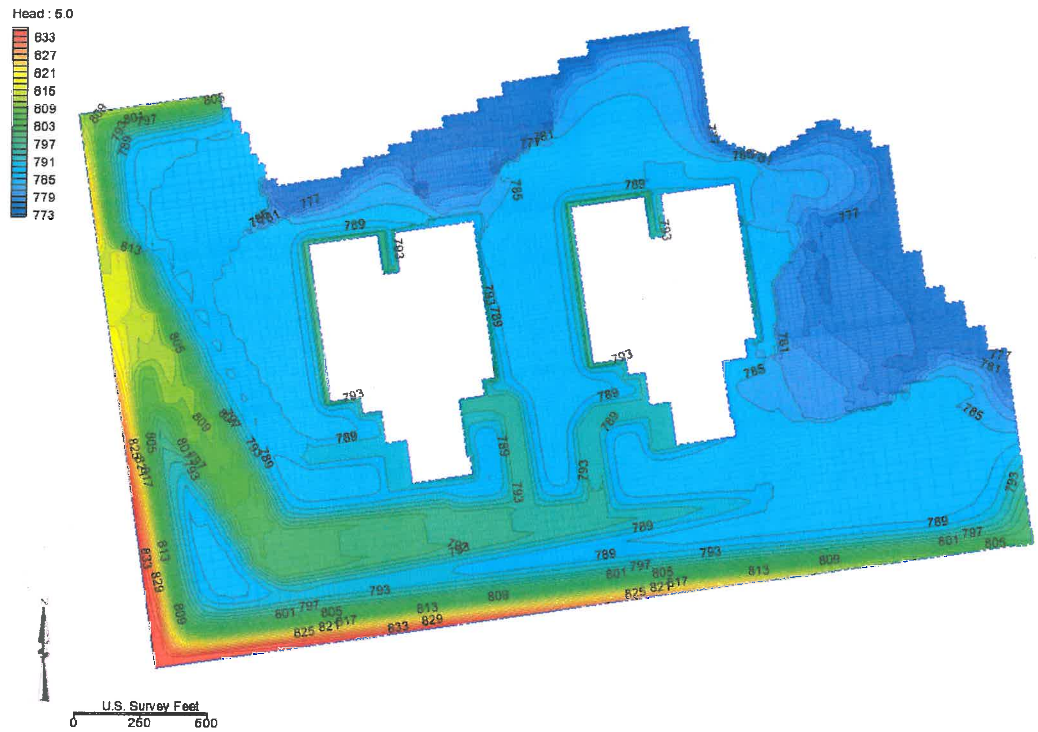


Figure 7-5. Plan View of Groundwater Surface Elevations (Run 3).

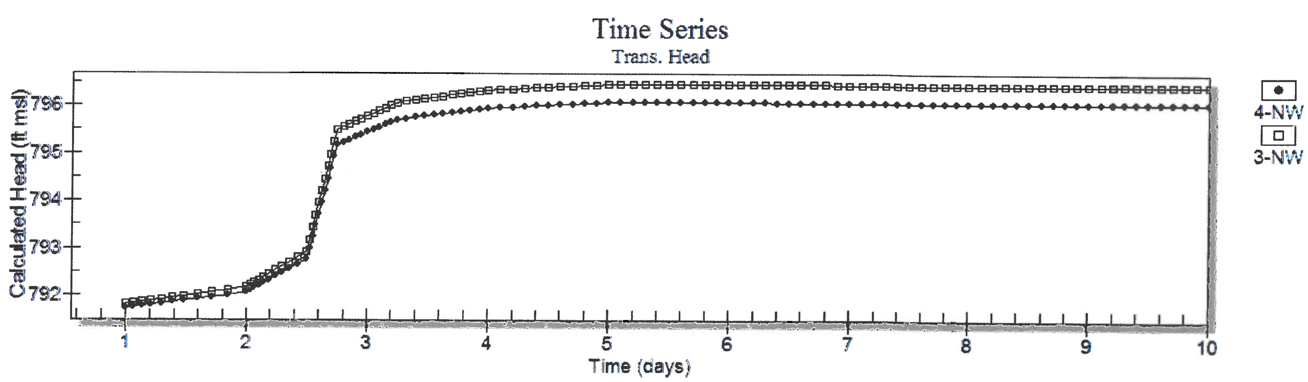


Figure 7-6. Observation Point Hydrographs - Run 3.

The highest groundwater elevation recorded for any of the observation points was 796.45 feet just south of observation point 3-NW, as approximately 5.0 days elapsed time.

Run 4. Sensitivity Analysis Number 3

A sensitivity run was completed using increased head values at the constant head boundary assigned along the southwest corner of the model.

- Increased values assigned to the constant head boundary along southwest corner of model, from 810 ft msl to 815 ft msl; starting heads for the steady-state run were also increased from 805 ft msl to 810 ft msl.
- All other parameters remained the same as the Base Run (Run 1).

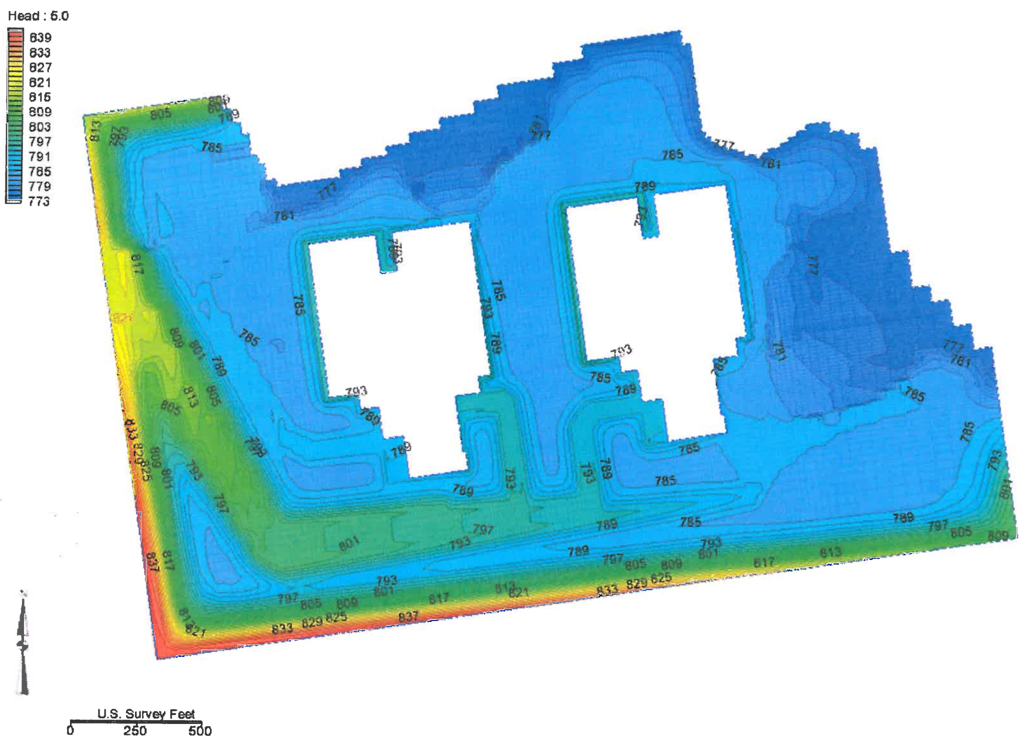


Figure 7-7. Plan View of Groundwater Surface Elevations, t = 5.0 days, Run 4.

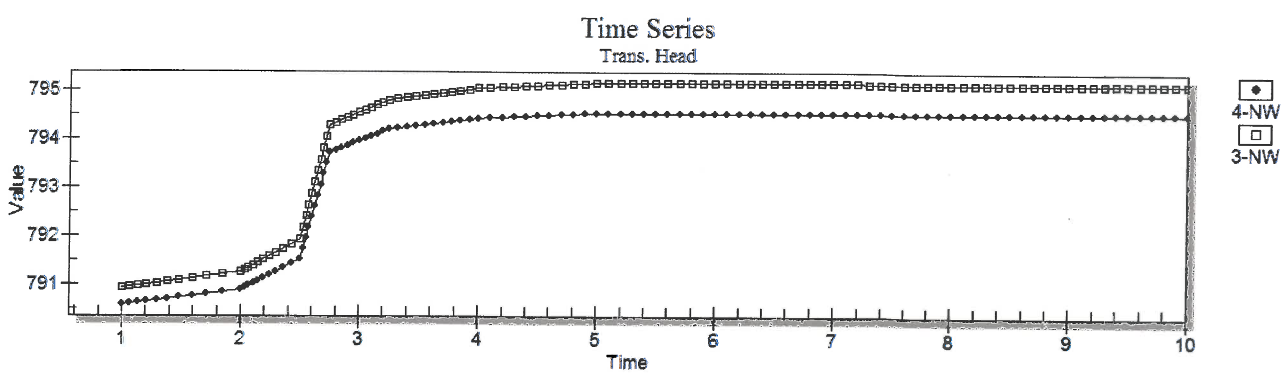


Figure 7-8. Observation Point Hydrographs - Run 4.

The highest groundwater elevation recorded for any of the observation points was 795.16 feet near observation point 3-NW, at an elapsed time of approximately 5.0 days.

Run 5. Sensitivity Analysis Number 4

A sensitivity run was completed using transient surface water levels for SCR relative to the Base Run (Run 1), allowing heads at the SCR boundary to increase as described below.

- The surface water elevation of SCR was assigned transient values through the duration of the precipitation event, starting at an elevation of 775.5 ft msl during the steady-state phase and increasing to a value of 779 ft msl during the height of the event. The level then dropped back down to an elevation of 775.5 at 5 days.
- All other parameters remain the same as the Base Run (Run 1).

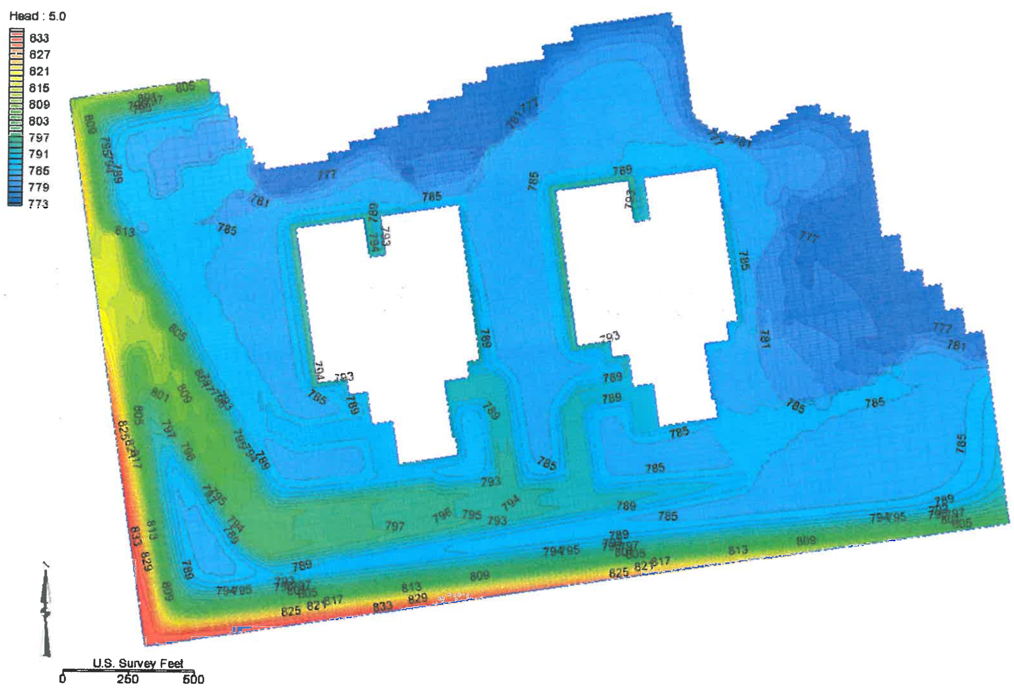


Figure 7-9. Plan View of Groundwater Surface Elevation Contours, t = 5.0 days, Run 5.

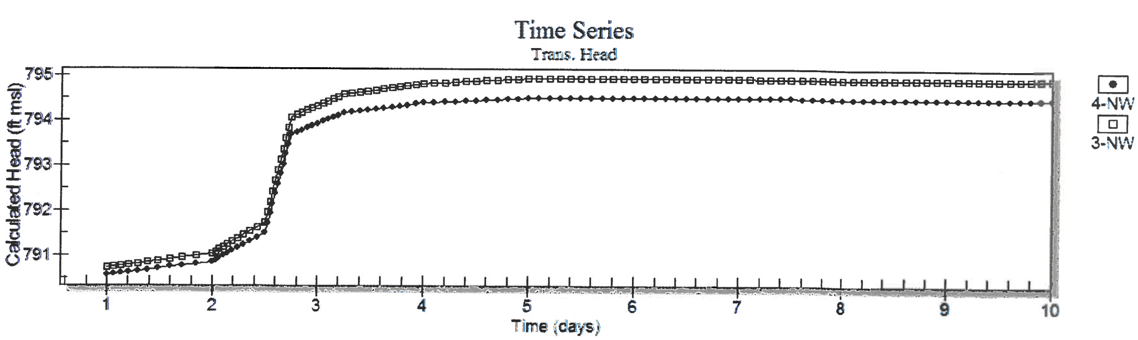


Figure 7-10. Observation Point Hydrographs - Run 5.

The highest groundwater elevation recorded for any of the observation points was 794.94 feet at observation point 3-NW, at approximately 5.0 days elapsed time.

Summary of Sensitivity Analyses

Table 7-1 summarizes the results of the sensitivity analyses relative to the Base Run of the model. Sensitivity analyses indicate that the modeled groundwater level is most sensitive to increases in recharge. A transient increase in the elevation of SCR has no influence on the calculated groundwater level. Sensitivity runs were structured to be more conservative than the original model Base Run, resulting in a higher calculated water level value for each sensitivity analysis run.

Table 7-1

Summary of Model Runs and Sensitivity Analyses

Model Description	Model Run	Maximum Calculated Water Level		Parameter Change
Base Run	Run 1	794.94	ft msl	
Sensitivity Analysis 1	Run 2	795.50	ft msl	Decreased Sy
Sensitivity Analysis 2	Run 3	796.45	ft msl	Increased recharge by 10%
Sensitivity Analysis 3	Run 4	795.16	ft msl	Increased constant head boundary and initial heads
Sensitivity Analysis 4	Run 5	794.94	ft msl	Changed SCR elevation to increase during precipitation event

8.0 CONCLUSIONS

The groundwater flow model Base Run (Run 1) contains site dimensions and aquifer settings that represent anticipated post-construction site conditions using extremely conservative assumptions. Hydraulic conductivity values used in the model are at the lower end of the range anticipated for each material present in the subsurface at the site. The lower hydraulic conductivity values assigned in the model provide for a slower movement of water and greater buildup of heads in the model. Additionally, higher-than-expected recharge rates developed from a theoretical PMP event are applied to the model, resulting in even higher calculated heads than would otherwise be expected. The theoretical PMP event simulated in the numerical model represents a recharge rate that is 10 times the maximum 48-hour rainfall event total for the model area, and recharge is assumed to occur across the entire site (with the exception of power block buildings and UHS basins), thereby allowing for greater infiltration than if the presence of other buildings and site drainage features were taken into account. The combination of factors used in the Base Run result in higher than likely water levels than would normally be expected to occur at the site.

Modeling results from Base Run 1 indicate water levels anticipated to be present at the site under post-construction conditions are lower than the DCD criteria of 821 ft msl. The maximum groundwater level calculated for baseline post-construction conditions given the conservative assumptions outlined in this calculation is 794.94 ft msl. Calculated water levels are below the elevations of surface water conveyances and ditches, therefore groundwater discharge to surface water is not expected to be a major factor in the subsurface flow system.

Four sensitivity analysis model runs, model runs 2 through 5, were completed to evaluate the potential influence of more conservative hydraulic parameter values and boundary conditions on model results. Changes to model parameters included in the sensitivity analyses were: decreased specific yield; increased recharge; increased head at model boundaries; and SCR level increasing during the theoretical major precipitation event. Model parameters in the Base Run were selected to be conservative; thus, the sensitivity analyses represent model parameters that are even more conservative. Results of the sensitivity analyses indicate that increasing the recharge has the greatest impact on modeling results; however, resulting water levels calculated in each sensitivity run did not change substantially and the highest calculated heads are well below the DCD criteria of 821 ft msl.

9.0 APPENDICES

Appendix A – GMS model files, including MODFLOW model files for Base Runs and Sensitivity Analyses (electronic files on DVD)

Appendix B – ArcGIS shape files and Excel Recharge spreadsheet (electronic files on DVD)

Appendix C - The MODFLOW 2005 manual (electronic files on DVD)

Appendix D - Estimation of Conservative Bounding Fill and Infiltration Cap Properties and Determination of Above Grade Fill Extents (electronic files on DVD)