APPENDIX B3

Technical Memorandum

Evaluation of Potential Hydraulic Communication
Between the Production Zone and Underlying Aquifers,
Vicinity of Well 885, Moore Ranch Uranium Project, Wyoming.

Technical Memorandum

To: **Donna Wichers, Ken Milmine, Uranium One**

From: **Errol Lawrence, Petrotek Engineering Corporation**

Date: **8/08/01**

Subject: Evaluation of Potential Hydraulic Communication Between the Production Zone and Underlying Aquifers, Vicinity of Well 885, Moore Ranch Uranium Project, Wyoming

Introduction

Petrotek Engineering Corporation (PEC) has completed an evaluation of possible hydraulic communication between the production zone aquifer (referred to as the 70 Sand) and the underlying aquifer (referred to as the 68 Sand) within a proposed wellfield area of the Moore Ranch Uranium Project, in Campbell County, Wyoming. In 1977, Conoco reported that a pump test conducted at well 885 indicated that hydraulic communication may exist between the two hydrostratigraphic units. The pump test was repeated by PEC and Uranium One in June 2008 at the same well location as the Conoco test, but at higher rates and for longer duration. Results of the recent pump test indicate that there is no hydraulic communication between the 70 and 68 Sands in the vicinity of the previously pumped well. Additional discussion follows.

Conoco Pump Test of Well 885 (1977)

Conoco reported potential hydraulic communication between a proposed production zone aquifer (70 Sand) and the underlying aquifer (68 Sand) in its 1982 Permit to Mine Application for the Moore Ranch Mine and Sand Creek Mine Projects in Campbell County, Wyoming. The reporting was based on the results of a 1977 pump test conducted at well 885. Well 885 is completed in the 70 Sand. In addition to the pumping well, water levels were monitored at two other 70 Sand monitor wells and one underlying 68 Sand monitor well. The 70 Sand monitor wells were identified as 886 and 888 and were reported as being 64 and 50 ft, respectively from the pumping well. However, based on the coordinates provided in the Conoco Permit to Mine Application, the distances are 161 and 12 feet, respectively. The 68 Sand monitor well was reported by Conoco as being 119 feet from the pumping well. Based on the coordinates in the Conoco to Mine Application, the distance to the pumping well appears to be 159 feet. Well data from the wells monitored during the test are provided in Table CR 2-7c(1). The location of the pumping well and observation wells are shown on Figure CR 2-7.c(1).

Well 885 was pumped at a rate of 3.4 gpm for a period of 1 day (for a total of

4,900 gallons). Conoco reported drawdown at the end of the test in the 70 Sand monitor wells 886 and 888 of 0.74 and 1.95 ft, respectively. Drawdown was also reported in the underlying monitoring well (887) of 0.76 feet. Conoco stated in its report that the well seal was suspect and that the pump test did not conclusively demonstrate hydraulic communication between the production zone aquifer and the underlying aquifer.

Uranium One Pump Test of Well 885 (2008)

In an attempt to verify the hydraulic communication reported by Conoco, Uranium One and PEC conducted a pump test at well 885 on June 4, 2008. Well 885 is located in the southern half of proposed wellfield one of the Moore Ranch Uranium Project. As in the 1977 Conoco test, water levels were monitored during the test in wells 886 and 888 (70 Sand) and well 887 (68 Sand). However, for this pump test, the wells were instrumented with transducers to allow more frequent water level measurements. Figure CR 2-7.c(1) is a map indicating the location of the pumping well and observation wells.

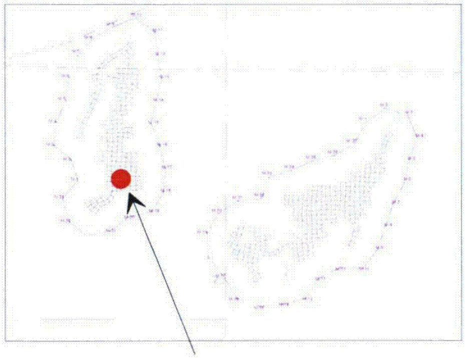
Well 885 was initially pumped at a rate of approximately 10 gpm for 1 hour. The rate was increased to 12.5 gpm for another hour and then increased to rate of slightly over 16.1 gpm for 18 hours. The average pumping rate for the 20 hours pumping period was 15.6 gpm. A total of 18,600 gallons were extracted during the test, providing a significantly larger hydraulic stress to the 70 Sand than the Conoco test.

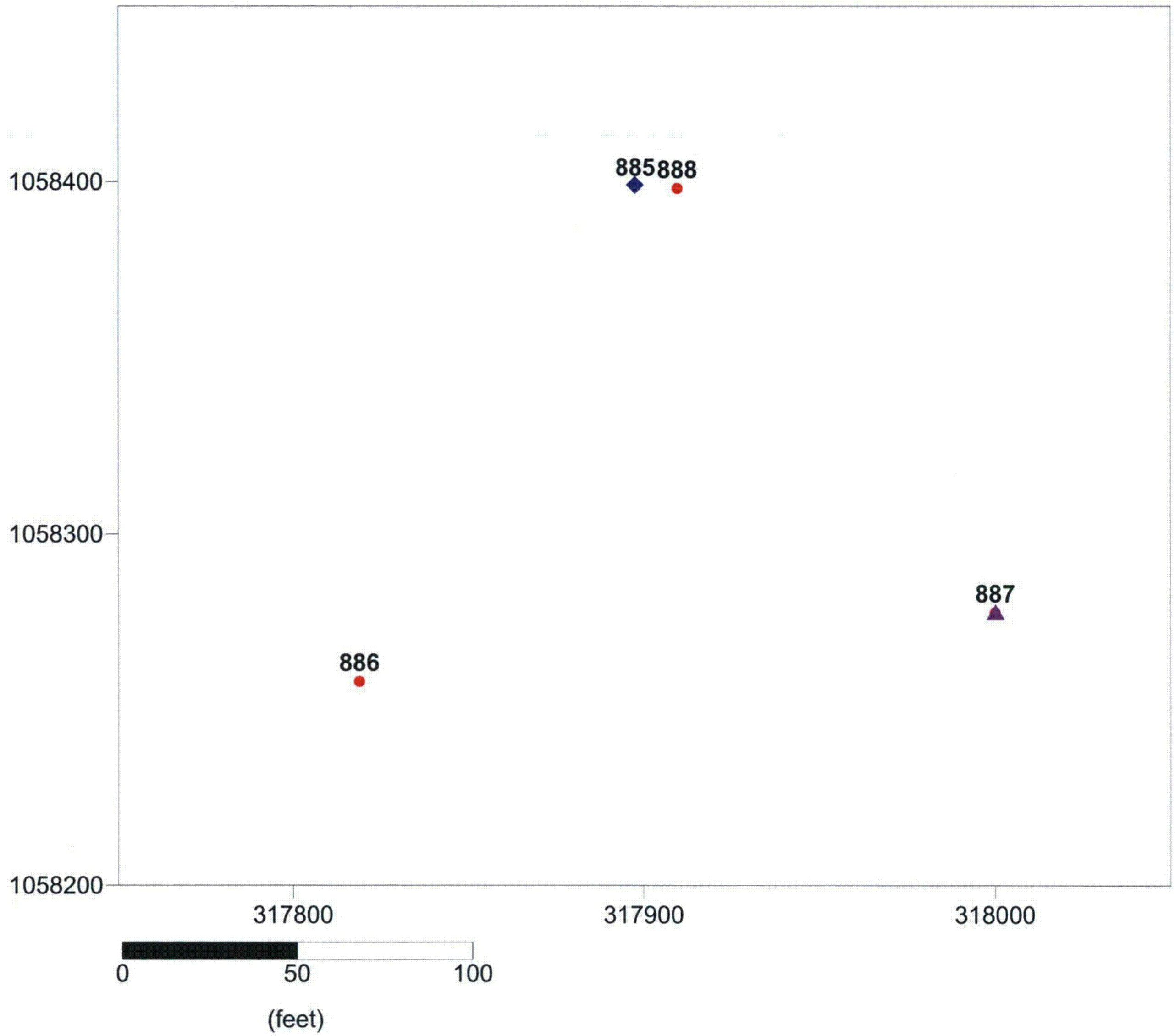
Drawdown in the pumping well (885) was 17.4 feet at the end of the test [Figure CR 2-7.c(2)]. The observed drawdown at the end of the test at 70 Sand monitor well 888 was 2.6 ft [Figure CR 2-7.c(3)]. Note that well 886 showed did not show drawdown during the test and actually showed a slight rise during the test [Figure CR 2-7.c(4)]. At the start of the test, the depth to water at this well was approximately 20 to 25 feet shallower than the depth to water in wells 885 and 888. Well construction data reported by Conoco (1982) indicates this well should be completed in the same interval as the pumping well. However, based on the test results and the depth to water prior to the start of the test, well 886 does not appear to be completed within the same hydrostratigraphic unit as well 885.

The underlying monitor well (887) showed no response due to pumping of the production zone well (885). There was an unexplained and abrupt increase in the water level at well 887 halfway into the test [Figure CR 2-7.c(5)]. However, the shift does not appear to be related to the pumping test because it was a sharp instantaneous rise in water level of 0.1 feet approximately 11 hours into the test. No drawdown was observed during the duration of the pump test.

Summary

Uranium One and PEC conducted a pump test at well 885 within the Moore Ranch Uranium Project in order to evaluate if hydraulic communication exists between the production zone aquifer (70 Sand) and the underlying aquifer (68 Sand). The results of the test clearly demonstrate there is no communication between the 70 Sand and 68 Sand in the vicinity of the 885 monitor well. Extensive additional hydrologic testing will be performed to further evaluate the hydraulic relationship between the production zone and overlying and underlying aquifers prior to commencing production as required under Wyoming Department of Environmental Quality regulations.





885 Pumping Well

Observation Well - 70 Sand

Observation Well - 68 Sand

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URANIUM ONE

Figure CR2-7.c(1). MW 885 Pump Test, Monitoring Locations
Moore Ranch Uranium Project, Wyoming

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Table CR 2-7.c(1) Pumping Well and Observation Well Data, 2008 Pumping Test, Moore Ranch Uranium Project, Wyoming.

Well	Easting (feet)	Northing (feet)	Completion Zone	Collar Elevation (ft amsl)	Total Depth (ft bgs)	Casing Depth (ft bgs)	Screen Top (ft bgs)	Screen Top Elevation (ft amsl)	Screen Bottom (ft bgs)	Screen Bottom Elevation (ft amsl)	Screen Interval (feet)
885	317898	1058399	70 SS	5350	240	240	180	5170	240	5110	60
886	317819	1058258	70 SS	5349	240	240	180	5169	240	5109	60
887	318000	1058278	68 SS	5347	320	320	290	5057	320	5027	30
888	317910	1058398	70 SS	5352	250	250	180	5172	240	5112	60

ft amsl - feet above mean sea level
ft bgs - feet below ground surface
TOC - top of casing

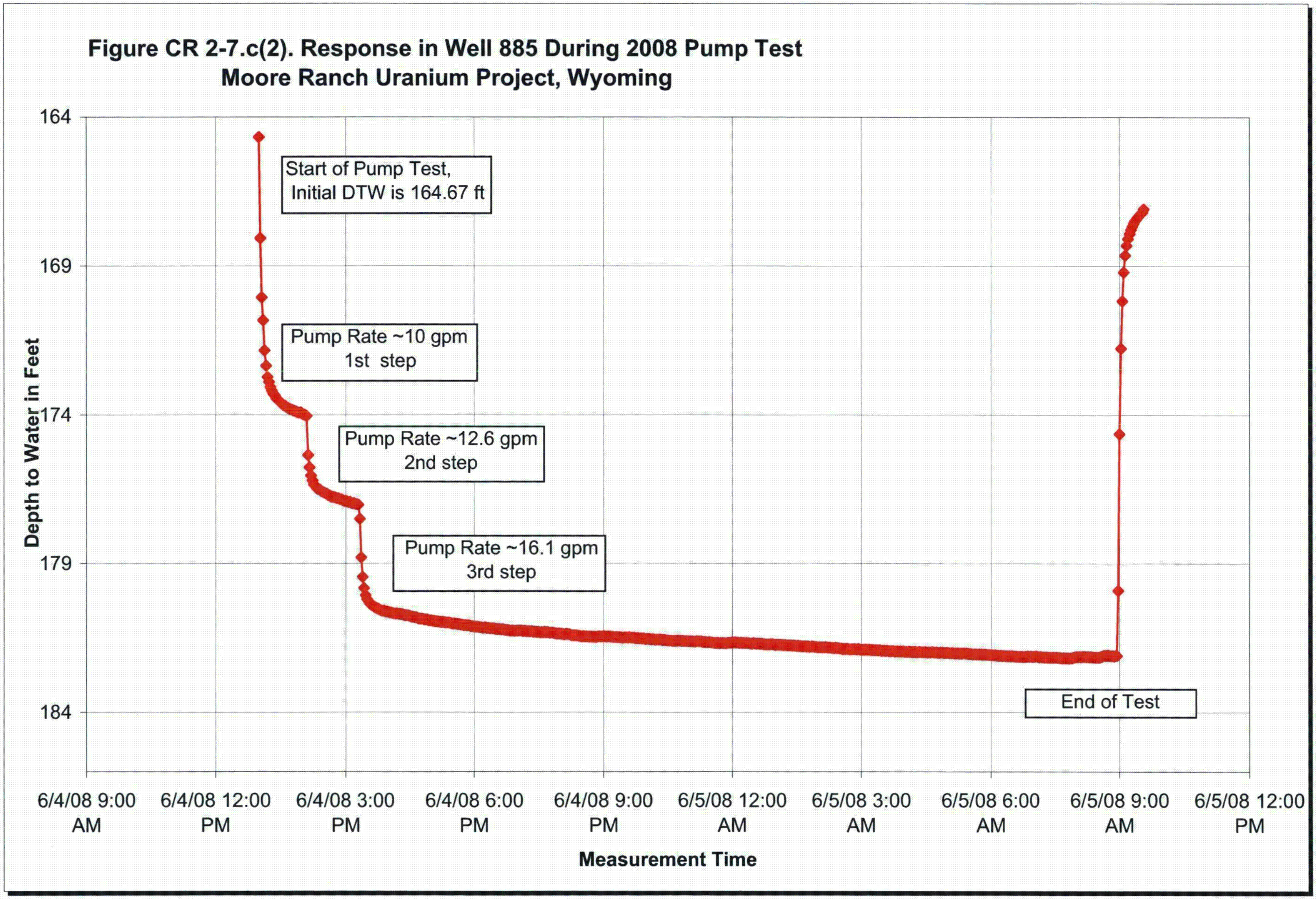
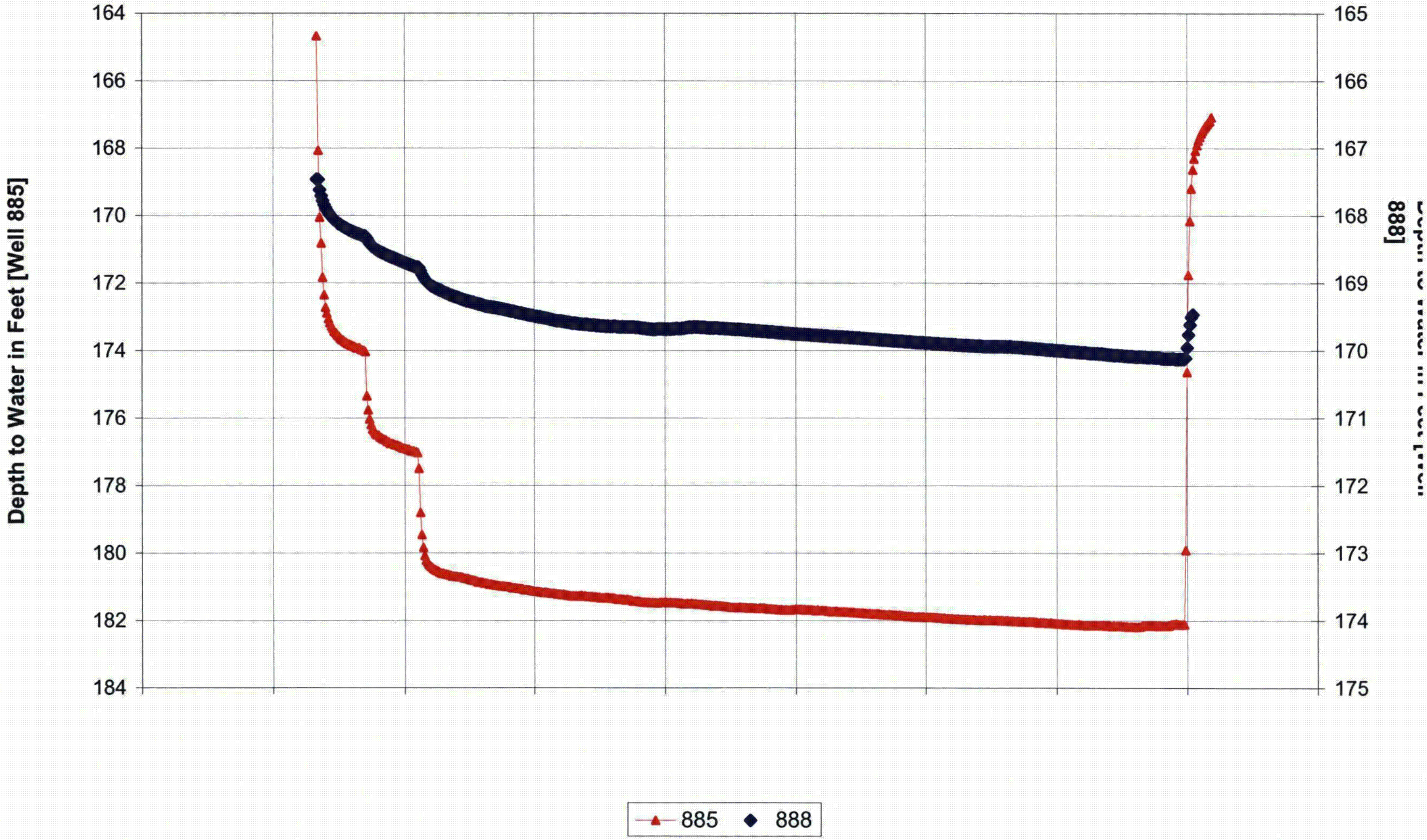


Figure CR 2-7.c(2). Response in Well 885 During 2008 Pump Test
Moore Ranch Uranium Project, Wyoming
164
169
174
179
184
Depth to Water in Feet
Start of Pump Test,
Initial DTW is 164.67 ft
Pump Rate ~10 gpm
1st step
Pump Rate ~12.6 gpm
2nd step
Pump Rate ~16.1 gpm
3rd step
End of Test
6/4/08 9:00 AM
6/4/08 12:00 PM
6/4/08 3:00 PM
6/4/08 6:00 PM
6/4/08 9:00 PM
6/5/08 12:00 AM
6/5/08 3:00 AM
6/5/08 6:00 AM
6/5/08 9:00 AM
6/5/08 12:00 PM
Measurement Time

Figure CR 2-7.c(3). Response in Well 885 and 888 During 2008 Pump Test
Moore Ranch Uranium Project, Wyoming



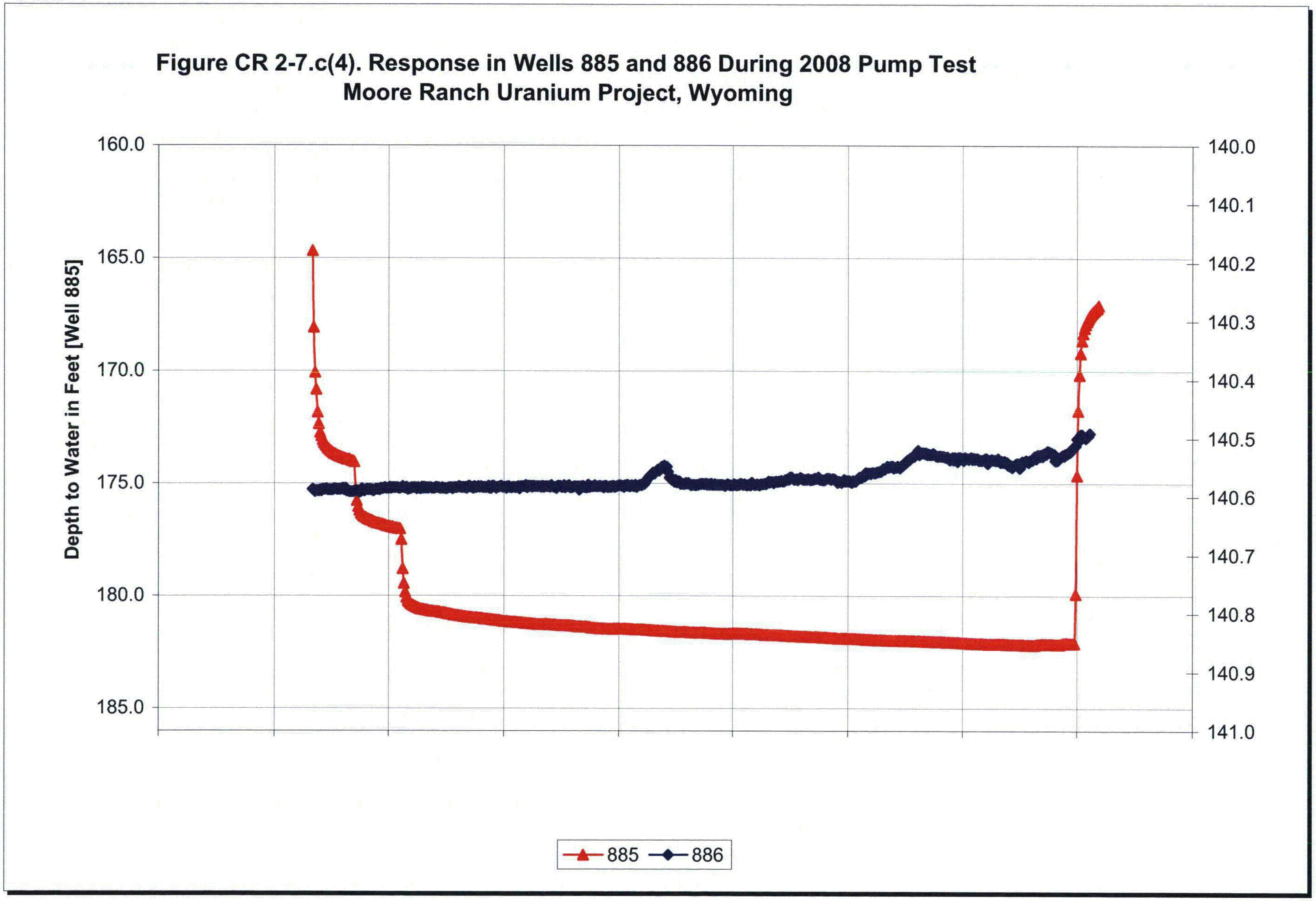
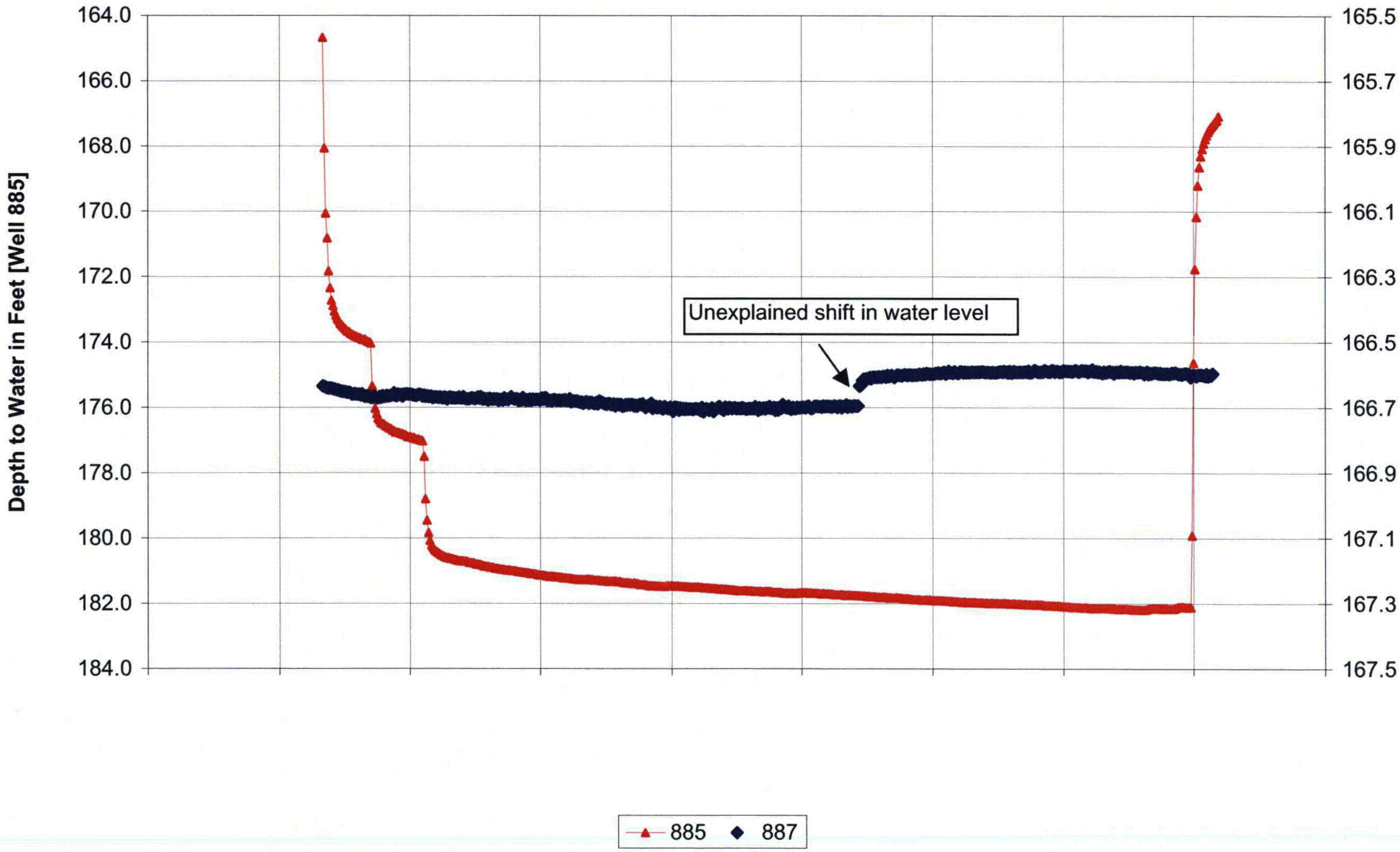


Figure CR 2-7.c(4). Response in Wells 885 and 886 During 2008 Pump Test
Moore Ranch Uranium Project, Wyoming
Depth to Water in Feet [Well 885]
160.0
165.0
170.0
175.0
180.0
185.0
140.0
140.1
140.2
140.3
140.4
140.5
140.6
140.7
140.8
140.9
141.0
885
886

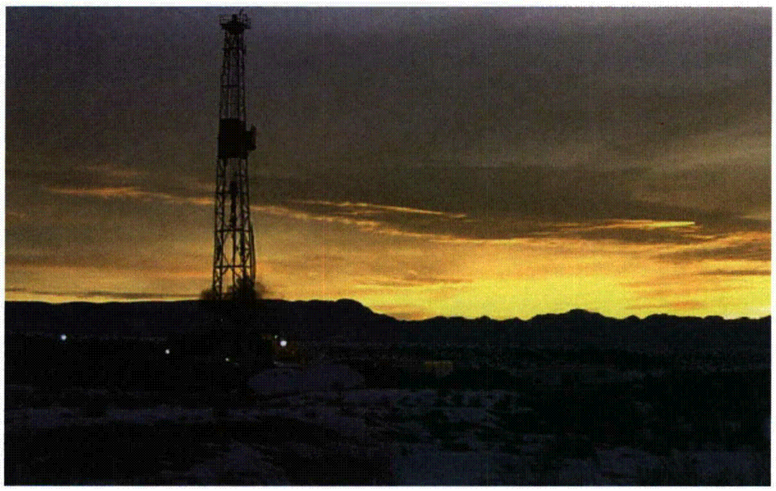
Figure CR 2-7.c(5). Response in Well 885and 887 During 2008 Pump Test
Moore Ranch Uranium Project, Wyoming



APPENDIX B4

Moore Ranch 5 Spot Hydrologic Testing Report Volume II
Model Development and Simulations

MOORE RANCH
5-SPOT HYDROLOGIC TEST REPORT
VOLUME II
MODEL DEVELOPMENT AND SIMULATIONS



MOORE RANCH PROJECT

CAMPBELL COUNTY, WY

August 2008

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Moore Ranch 5-Spot Hydrologic Test Report
Volume II –Groundwater Model Development and Simulations

Introduction

Uranium One has submitted an application to the U.S. Nuclear Regulatory Commission (NRC) for a Source Materials License (SML) to conduct in-situ recovery (ISR) of uranium from the Moore Ranch Project in Wyoming (Energy Metals, Inc., 2007). The target ore zone is designated as the 70 Sand. Aquifer conditions within the 70 Sand are unconfined across the southern portion of the site. A groundwater model was developed to evaluate potential impacts that unconfined conditions will have on production and restoration phases of the ISR project. The model was developed using data collected from a 5-Spot Hydrologic Test conducted at the site. The hydrogeologic test design, results and analysis were described in detail in Volume I of this report. This volume of the report describes the development of the numerical model and summarizes the results of numerical simulations used to address NRC concerns regarding ISR operations in an unconfined aquifer. Additional modeling will be being performed to address wellfield scale issues related to production and aquifer restoration. Description and results of the larger scale modeling will be covered under a separate report.

Purpose and Objectives

The numerical groundwater flow model was developed to support Uranium One in planning and operation of the ISR project. The numerical model is also used to address NRC comments regarding operational issues specific to ISR of uranium within an unconfined aquifer system.

Data derived from the 5-Spot Hydrologic Test were used to develop a numerical model that is representative of site-specific conditions (including the unconfined nature of the production zone aquifer) on a well pattern scale. The numerical model was calibrated and verified to measured field data from the Test. The calibrated model was then used to demonstrate impacts of an unconfined system on mine design. The results of this modeling will be extrapolated to a wellfield and permit area scale model to evaluate wellfield bleed, operational flare, excursion control, water disposal requirements and restoration operations. The permit area model is described under a separate report titled "Numerical Modeling of Groundwater Conditions Related to Insitu Recovery at the Moore Ranch Uranium Project, Wyoming" (Petrotek Engineering, Inc., 2008).

Conceptual Model

Detailed description of the geology and hydrogeology of the Permit area can be found in the SML application (Energy Metals, Inc 2007). Geohydrologic conditions specific to the 5-Spot Hydrologic Test area were described in Volume I of this report. The 5-Spot Hydrologic Test area is located within the central portion of proposed Wellfield 2 [Figure 5ST(1) Volume I]. A conceptual hydrologic model for the Moore Ranch Project area is summarized below.

The aquifer being simulated is the 70 Sand, which is the uranium production zone for the Moore Ranch Project. The 70 Sand ranges from 85 to 95 feet thick within the area of the 5 Spot Hydrologic Test and dips north-northwesterly at 0.5 to 1 degree. The 70 Sand aquifer is unconfined within the area of the Test. The potentiometric surface prior to the beginning of the 5-Spot Hydrologic Test is shown on Figure 5ST (7) in Volume I. The potentiometric surface has a hydraulic gradient of 0.0026 to 0.0036 ft/ft toward the north. In the area of the Test, the water level within the 70 Sand is approximately 20 feet below the top of the stratigraphic unit. The saturated thickness of the 70 Sand in the wells ranges from 67 to 75 feet. Transmissivity of the 70 Sand, calculated from the 5-Spot Hydrologic Test, ranges from 180 to 680 ft^2/d (1,350 to 5,080 gpd/ft). However, as described in Volume I, the Neuman analytical method, designed for unconfined aquifer evaluation, provides the best visual fit to the observed drawdown curves and is considered most representative of site conditions. The range of transmissivity using the Neuman analytical solution is from 272 to 395 ft^2/d (2,035 to 2,955 gpd/ft). The hydraulic conductivity calculated from the 5-Spot Hydrologic Test using the Neuman analysis ranges from 3.8 to 5.5 ft/d.

Total porosity of the 70 Sand is estimated at 26 percent. Specific yield estimated from the 5-Spot Hydrologic Test, ranges from 0.011 to 0.039. Accurate assessment of the storativity was not possible from the 5-Spot Hydrologic Test because of the unconfined condition of the aquifer. Storativity estimated from other hydrologic testing conducted within the 70 Sand in the vicinity of the Moore Ranch indicates a range of 2.4×10^{-4} to 4.4×10^{-3} for the aquifer.

Within the vicinity of the 5-Spot Hydrologic Test, the 70 Sand is bounded above and below by low permeability clays and silts that act as confining units. The 70 Sand is overlain by a 30 to 40 foot thick confining unit. Water level differences between the 70 Sand and overlying aquifer (72 Sand) range from 50 to 60 feet with the higher levels within the 72 Sand. The unsaturated upper portion of the 70 Sand and the large head difference between the 70 and 72 Sands conclusively demonstrate that the overlying aquifer is not in communication with the production zone aquifer. Water levels between the underlying aquifer (68 Sand) and the production zone aquifer are similar. There is evidence of discontinuity in the confining unit between the 68 and 70 Sands in portions of Wellfield 2. However, as described in Volume I, a 68 Sand monitor well (UMW5) indicated no response attributable to pumping of the 70 Sand for the duration of the Extraction Test. The focus of this model is on operational issues specific to ISR of uranium within an unconfined aquifer system. Therefore, for purposes of this modeling exercise, the 68 Sand is not considered or included in the model.

Recharge occurs to the 70 Sand within a few miles to the south where this hydrostratigraphic unit crops out. There are no known discharge areas from the 70 Sand within the Permit Area.

Model Code

The model code used to simulate the 5-Spot Hydrogeologic Test was MODFLOW-SURFACT, Version 2.2 (SURFACT), developed by HydroGeologic, Inc. (1996). SURFACT is a proprietary version of the widely used and public domain MODFLOW code developed by the U.S. Geological Survey (McDonald, 1988, 1996). MODFLOW simulates groundwater flow using a block-centered, finite-difference approach that is capable of a wide array of boundary conditions. The code can simulate aquifer conditions as unconfined, confined, or a combination of the two. MODFLOW also supports variable thickness layers (i.e. variable aquifer bottoms and tops. Documentation of all aspects of the MODFLOW code is provided in the users manuals (McDonald, 1988 and 1996).

SURFACT was designed to enhance the groundwater flow modeling capabilities of MODFLOW. SURFACT provides significant improvements over the original MODFLOW code with respect to unconfined and unsaturated flow, dewatering and rewetting of cells within the model, and simulation of wells. Similar to the MODFLOW code, SURFACT is modular by design so that specific modules can be incorporated into the model simulation to address characteristics and physical processes of the site being modeled. These modules, or packages, work in conjunction with the original MODFLOW code. Only modules that address specifics of the site need be included in the simulation. Full description of the SURFACT packages, including verification examples, is provided in the MODFLOW-SURFACT Software (Version 2.2) Documentation (HydroGeologic, Inc, 1996). Specific modules of SURFACT employed in the 5-Spot Hydrologic Test Model include the following:

- BCF4 – The block center flow package available in SURFACT provides rigorous treatment of unconfined flow using a variably saturated formulation with psuedo-soil functions. The BCF4 package is superior to earlier versions of block centered flow packages in handling dewatering and rewetting of cells within the model simulation. The formulation has been designed to provide accurate delineation of the water table and capture the delayed yield response of an unconfined system to pumping and recharge

- FWL4 – The SURFACT fracture well package provides rigorous treatment of well withdrawal ((or injection) conditions using one-dimensional fracture tube elements to emulate a well. This package allows accurate representation of wells screened across multi-layers, apportioning flow based on transmissivity and available head in each layer. The package also automatically adjusts flow rate when overpumpage of an unconfined aquifer occurs to prevent dewatering of the aquifer and can also simulate well bore storage. This package couples with the BCF4 package previously described to define unsaturated flow behavior in well cells such that the water table condition within a well cell is accurately represented.

- ATO4-This adaptive time stepping package provided with SURFACT automatically controls time step size and simulation output. This package allows a simulation to be performed more efficiently and outputs to be reported at specific desired times of the simulation.

- PCG4–SURFACT includes the option of using this Preconditioned Conjuguate Gradient solver. Earlier versions of PCG solvers are available with MODFLOW, however the PCG4 solver is more efficient and robust (HydroGeologic, 1996).

A particle-tracking code was utilized to that could readily incorporate information collected from the MODFLOW/SURFACT groundwater flow model. The code chosen was MODPATH, Version 3 (Pollock, 1994), which was designed to use the output head files from MODFLOW (or SURFACT) to calculate particle velocity changes over time in three dimensions. MODPATH was used to provide computations of groundwater seepage velocities and groundwater flow directions at the site. MODPATH is also a public domain code that is well accepted in the scientific community. Full documentation of the MODPATH code is provided in the MODPATH users guide (Pollock, 1994).

The pre/post-processor Groundwater Vistas (Environmental Simulations, Version 4, 2004) was used to assist with input of model parameters and output of model results. Groundwater Vistas serves as a direct interface with MODFLOW, SURFACT and MODPATH. Groundwater Vistas provides an extensive set of tools for developing, modifying and calibrating numerical models and allows for ease of transition between the groundwater flow and particle tracking codes. Full description of the Groundwater Vistas program is provided in the Users Guide to Groundwater Vistas, Version 4.0 (Environmental Simulations, Inc. 2004).

Model Domain and Grid

The model domain encompasses an area with north-south and east-west dimensions of 1,980 ft. The model grid is centered over the 5 Spot Hydrologic Test. The entire model domain is within an area where the modeled aquifer (70 Sand) is unconfined. The extent of the model domain is illustrated in Figure 5ST(25).

Drawdown results from the 5-Spot Hydrologic Test indicated the development of a steep drawdown cone around the pumped well. The model grid was designed to provide adequate spatial resolution in the area of the 5-Spot Hydrologic Test in order to simulate response of a pumped well in an unconfined aquifer. Cell dimensions within the area of the 5-Spot well pattern were 1 foot by 1 foot. Cell dimensions are gradually increased to a maximum size of 5 feet by 5 feet near the edges of the model. The model consists of 629 rows and 629 columns and contains 421,201 active cells.

Because of the presence of overlying and underlying confining units, only the 70 Sand was simulated. The model contains a single layer representing the 70 Sand. The base of the model and the top of the model are no flow boundaries that simulate the overlying and underlying confining units. The top and bottom elevation of the 70 Sand correspond the top and base of the model, respectively.

Boundary Conditions

Boundary conditions imposed on a numerical model define the external geometry of the groundwater flow system being studied as well as internal sources and sinks. Boundary conditions assigned in the model were determined from observed conditions. Descriptions of the types of boundary conditions that can be implemented with the MODFLOW and SURFACT code are found in McDonald and Harbaugh (1988) and HydroGeologic Inc., (1996). Boundary conditions used to represent hydrologic conditions at the 5-Spot Hydrologic Test site included general-head (GHB) and wells. The locations of boundary conditions within the model are illustrated in Figure 5ST(25). Discussion of the placement and values for these boundary conditions is provided below.

The GHB was used in the 5-Spot Hydrologic Test model to account for inflow and outflow from the model domain. GHBs were assigned along the edges of the model domain where available water-level data suggest the aquifer is being recharged from, or discharging to, a source external to the model domain. GHBs were used because the groundwater elevation at those boundaries can change in response to simulated stresses. In the 5-Spot model, GHBs were assigned to the south and north boundaries of the model. The values of head assigned to the GHBs ranged from 5,188.75 ft along the south edge of the model 5,195.15 ft, along the north edge. This configuration represents a hydraulic gradient of 0.0032 ft/ft to the north, consistent with water levels measured in the 70 Sand monitor wells.

The model domain was extended a suitable distance from the location of the 5 Spot Hydrologic Test to minimize perimeter boundary effects on the interior of the model where the hydraulic stresses were applied.

The SURFACT well package (FWL4) was used to simulate extraction and injection wells of the 5 Spot Hydrologic Test. The well configuration includes a 5-Spot pattern with an extraction well located in the center, surrounded by four injection wells. The distance between injectors is 100 feet along the sides of the pattern and 141.4 ft diagonally across the pattern. The distance from each injection well to the extraction well is 70.7 feet. Additionally, four monitor wells were placed throughout the 5-Spot well pattern at distances of 10, 20, 40 and 70 feet from the extraction well. Figure 5ST(26) shows the distribution of injection and extraction wells within the model domain. Extraction and injection rates applied to the wells are described under the calibration and simulation discussions of this report.

Aquifer Properties

Input parameters used in the model to simulate aquifer properties are consistent with site-derived data including; top and bottom elevations of the 70 Sand, saturated thickness, hydraulic gradient, hydraulic conductivity, specific yield, specific storage and porosity.

The top and bottom elevations of the 70 Sand were determined from boring and electric logs from each of the 5-Spot Hydrologic Test wells [Figures 5ST(3) and (4) of Volume I]. Gridded contour maps were generated using the contouring program Surfer, Version 8.0 (Golden Software, 2002). The maps were imported into Groundwater Vistas to represent the top and bottom elevations of the 70 Sand. The initial saturated thickness and potentiometric surface of the 70 Sand were determined from depth to water measurements in each of the wells prior to the beginning of the hydrologic testing [Figure 5ST(7) of Volume I]. A contour map of that surface was also generated in Surfer and used as initial conditions in the model simulations.

Hydraulic conductivity determined from the 5 Spot Hydrologic Test ranged from 2.5 to 9.5 ft/d using several analytical methods. As described in Volume I of this report, the Neuman analytical method for unconfined aquifer systems provided the best fit to the observed drawdown curves. The range of hydraulic conductivity using the Neuman method was 3.8 to 5.5 ft/d [Table 5ST(5)]. Hydraulic conductivity was used as a variable in calibrating the groundwater flow model, as described in the calibration section of this report.

Specific yield and specific storage are also aquifer properties of interest with respect to the response of an aquifer to extraction or injection. Specific yield is the storage term used for unconfined aquifers. Specific yield accounts for the physical draining of the aquifer that occurs in response to lowering of the water table and subsequent dewatering of pore space in the aquifer matrix. Specific yield is equivalent to the drainable porosity within an aquifer and typically ranges from 0.01 to 0.30 (Freeze, 1979). Specific yield calculated from the 5-Spot Hydrologic test ranged from 0.011 to 0.039.

Specific storage is a measure of the water released from storage due to compaction of the aquifer and expansion of water in response to a decline in head. Specific storage is the storage term used for confined aquifers, where lowering of the potentiometric surface in response to pumping does not result in physical dewatering of the aquifer. Specific storage multiplied by the saturated thickness of an aquifer is referred to as storativity or storage coefficient. Storativity of a confined aquifer system is typically in the range of 5×10^{-3} to 10^{-6} or less. Comparison of the magnitude of the values for specific yield and specific storage indicates that in an unconfined aquifer, the bulk of the water produced is the result of physical dewatering of the aquifer.

Porosity of the aquifer is used in the model to estimate groundwater velocity. Groundwater velocity is calculated from the Darcy equation as follows:

$$v = ki/n$$

where

- v = average interstitial groundwater velocity
- k = hydraulic conductivity
- i – hydraulic gradient
- n = porosity (effective)

The porosity for the 70 Sand in the 5-Spot Test area is estimated from site data as 26 percent. However, for purposes of groundwater velocity calculations, the parameter required is effective (essentially interconnected) porosity. For the 5-Spot Test Model, the effective porosity is estimated as ranging from 15 to 20 percent.

Model Simulations

A numerical groundwater flow model was developed to evaluate, in detail, the site-specific hydraulics associated with unconfined flow during typical ISR operations. The 5-Spot Hydrologic Test provided a rare opportunity to compare model simulations to a tightly controlled and intensely monitored hydrologic test in an unconfined aquifer system. The scale of the Test and the model were designed such that detailed evaluation of hydraulic response within a single 5 spot well pattern was possible.

The 5-Spot Extraction Test was described in detail in Volume I. Simulation of that Test was used to calibrate the model to field measured results. The calibrated model was then used to simulate the 5-Spot Extraction/Injection Test in order to verify the model. The calibrated and verified model was then used to demonstrate impacts of an unconfined system on well pattern design and hydrologic testing of the monitor well ring. The 5-Spot Hydrologic Test Model has been extrapolated to a larger scale model that will be used to evaluate wellfield and permit area effects of ISR uranium mining in an unconfined aquifer system. Discussion of the larger scale model and simulations is provided in a separate report titled "Numerical Modeling of Groundwater Conditions Related to Insitu Recovery at the Moore Ranch Uranium Project, Wyoming" (Petrotek Engineering, Inc., 2008).

Calibration Simulation

Groundwater flow model calibration is an integral component of groundwater modeling applications. Calibration of a numerical groundwater flow model is the process of adjusting model parameters to obtain a reasonable match between field measured values and model predicted values of heads and fluxes (Woessner and Anderson, 1992). The calibration procedure is generally performed by varying estimates of model parameters (hydraulic properties) and/or boundary condition values from a set of initial estimates until an acceptable match of simulated and observed water levels and/or flux is achieved. Calibration can be accomplished using trial and error methods or automated techniques (often referred to as inverse modeling). Because of the tight control within the 5-Spot Hydrogeologic Test, in terms of the aquifer geometry and hydraulic stresses applied to the aquifer, only two parameters were varied during the calibration process, hydraulic conductivity and specific yield. Because only two parameters were varied and the fact that detailed analysis of the Extraction Test provided a relatively narrow range of likely values for those parameters, the trial and error method was considered a reasonable approach to calibration.

The adequacy of model calibration is judged by examining model residuals. A residual, as defined for use in this modeling report, is the difference between the observed change in groundwater elevation and the change in groundwater elevation predicted by the model. The objective of model calibration should be the minimization of the residual mean, residual standard deviation, and residual sum of squares (RSS) (Duffield, et al, 1990). The mean residual is the arithmetic average of all the differences between observed and computed water levels. A positive sign indicates that the model has under-predicted the observed water level and a negative sign indicates over-prediction. The residual standard deviation quantifies the spread of the differences between observed and predicted water levels around the mean residual. The ratio of residual standard deviation to the total head change across the model domain should be small, indicating the residual errors are only a small part of the overall model response (Anderson and Woessner, 1992). The RSS is computed by adding the square of each residual and is another measure of overall variability. Minimization of the RSS is typically used as the objective function during model calibration. In other words, as model input parameters are varied during calibration, a decrease in the value of the RSS is usually an indication that the "goodness of fit" is improving. For a statistically accurate model calibration, the residuals and the statistics based on the residual should approach zero.

Calibration was achieved by comparing field-measured (observed) drawdown in the 5-Spot well pattern with drawdown predicted by MODFLOW for the same wells under simulated pumping conditions of the 5-Spot Extraction Test. The Extraction test was described in detail in Volume I but is summarized here. A single well (PMW-1) was pumped at an average rate of 22.32 gpm for a period of four days. The drawdown measured in each of the four injection wells, four observation wells and the extraction well at 1, 2, 3 and 4 days into the test were used as calibration targets to determine how well the model replicated the field results. Table 5ST (6) lists the values used for calibration targets. Note that all drawdown values have been corrected for barometric pressure changes monitored during the Extraction Test.

As previously stated, hydraulic conductivity and specific yield were varied during the calibration process to determine the best fit to the data. Table 5ST(7) summarizes the results of the calibration simulations. Table 5ST8 is a matrix showing the RSS value for each calibration. Results of model simulations indicate that the best fit to the data (lowest RSS) occurred in the simulation of hydraulic conductivity of 4.0 ft/d and specific yield of 0.025. These values are within the ranges calculated from analysis of the field data and therefore present reasonable estimates of those aquifer properties. Figures 5ST(27) and (28) graph the RSS of the calibration simulations versus the specific yield and hydraulic conductivity, respectively. The range of specific yield and hydraulic conductivity that were determined using the Neuman analysis are also shown on the figures. The potentiometric surface at the end of that simulation is shown in Figure 5ST (29). Figure 5ST(30) indicates the model residuals at the end of the Extraction Test.

The top and bottom elevations and initial saturated thickness, initial potentiometric surface and hydraulic gradient were all field measured values that were imported directly into the model. Therefore no evaluation of these parameters was included in the calibration process. Result of the actual 5-Spot Extraction Test did not indicate any significant hydraulic boundaries (either barrier or recharge) encountered during the period of the test. Therefore, extrapolation of the top and bottom elevations and initial potentiometric surface is considered justified for purposes of this model simulation and no additional calibration of those terms was attempted.

A summary of input parameters used in the final calibration simulation is presented in Table 5ST(9).

Verification Simulation

The numerical groundwater flow model was calibrated to the 5-Spot Extraction Test data. Verification that the model can reproduce hydraulic heads or drawdown under simulated hydraulic stresses in the aquifer other than those simulated for the calibration data set provides additional confidence in the predictive capabilities of the model. The calibrated model was then used to simulate the 5-Spot Extraction/Injection Test as a verification of the model.

As described in Volume I, the 5-Spot Extraction/Injection Test included extraction from a single well (PMW-1) and distribution of the recovered water into four injection wells. The test included three stages. The first stage included pumping from the extraction well for 2.06 days at a rate of 20 gpm. The recovered water was equally distributed to the four injection wells (5 gpm each). The second stage involved continued extraction at 20 gpm from PMW1, with injection into only two of the injection wells (IMW3 and IMW4 at 10 gpm each) for a period of 1.0 days. The final stage included extraction from PMW1 at 20.5 gpm for a period of 0.92 days and injection of all recovered water into injection well IMW3. Validation targets included the change in water levels in each of the four monitor wells, four injection wells and the extraction well at the end of each stage of the Extraction/Injection Test. The validation targets are included in Table 5ST(9).

The model simulation reproduced the field results reasonably well, with the following exceptions (Table 5ST(10). As described in Volume I, complications encountered during development of well IMW2 resulted in that well not being adequately developed. As a result, the water level rise was significantly larger in that well compared to the other three injection wells during the first stage of the Extraction/Injection Test. Analysis of the data from the Extraction Test indicate that the transmissivity and hydraulic conductivity at this location are similar to the value of those parameters at the other three injection wells. The discrepancy between the simulated and observed values at IMW2 is largely attributed to well inefficiency or incomplete well development. The simulated water level rise in wells IMW3 and IMW4 during the second stage of the Test, and in well IMW3 during the final stage of the Test, were also much less than observed. Again, the discrepancy between the simulated and observed values at IMW3 and IMW4 is largely attributed to well inefficiency or incomplete well development. By comparison, wells that were not used for extraction of injection showed good comparison between simulated and observed data. Figure 5ST(31) shows the simulated potentiometric surface at the end of the 5-Spot Extraction/Injection Test. Residuals from the verification simulation are shown on figure 5ST(32).

Based on the results of the calibration and verification simulations, the 5-Spot Hydrologic Test model adequately simulates hydraulic stresses applied to the production zone aquifer under unconfined conditions. The numerical model is suitable for additional evaluation of site-specific conditions related to ISR uranium mining in an unconfined aquifer.

Additional Simulations

Simulations were performed using the numerical model to address requests for additional information posed by the NRC in response to the SML license application. The additional simulations described in this report include:

- A hydrologic test design to demonstrate hydraulic communication between a pumping well within the wellfield and the monitor well ring at a proposed distance of 500 feet from the wellfield;

- Simulation of the degree of dewatering that could occur and how pulsing wells (alternating between injection and extraction) can minimize or negate the impacts.

A hydrologic testing program is required to demonstrate that the monitor well ring that circumscribes the wellfield is hydraulically connected to the production zone before ISR operations can commence. The unconfined conditions present in portions of the production zone aquifer may limit the horizontal extent of measurable hydraulic response to pumping. The calibrated model was set up to evaluate the amount of drawdown that could be expected at distances of 500 feet or greater using pumping rates that can be sustained from a single extraction location. Observation wells were placed at a distance of 500 feet, 600 feet and 700 feet from the extraction well. The well configuration for simulation of a wellfield hydrologic test design is presented in Figure 5ST(33). Pumping rates of 20, 30 and 40 gpm were simulated. The hydraulic responses of the different simulations are shown on Figure 5ST (34). Results of the simulations for various times, distances and pumping rates are tabulated in Table 5ST(11). The results indicate that it will take numerous pumping tests to demonstrate hydraulic communication with all of the wells in the monitor well ring. Additional modeling will be performed with the wellfield scale model to determine the number of tests that will be required.

The NRC has expressed concerns regarding potential dewatering of the 70 Sand during production operations and how that may effect restoration of the aquifer. As described in Volume I, the drawdown cones associated with extraction wells tend to be steeply sided and of generally small area even without the benefit of reinjection. Injection tends to further decrease the area that may be dewatered during production. However, to ensure that areas that may become temporarily dewatered during a production sequence, pulsing of the production zone (switching extraction wells to injection wells and injection wells to extraction wells) can be used to effectively resaturate essentially all areas within the wellfield that may have been dewatered. The 5 Spot Hydrologic test model that was simulated in the previous discussions was expanded to demonstrate this point. A small-scale wellfield is simulated with a total of 9 extraction wells and 16 16 injection wells, initially. The well configuration is shown in Figure 5ST(35). The simulation includes two stages. The first stage of the simulation is run for a period of 30 days with each of the extraction wells pumping at a rate of 20 gpm for a total of 180 gpm. The total injection rate of the 16 injection wells was also 18 gpm. The net change in water levels at the end of this stage is shown in Figure 5ST(36). The valleys represent net drawdown and the peaks represent net rise in water levels in the aquifer. For the second stage of production, the wells are switched so that the extractors become injectors and the injectors become extractors. The extraction and injection rates are the same as in the previous phase but reversed. This stage is also run for 30 days. The change in water levels at the end of this stage is shown in Figure 5ST (37). Note that the peaks and valleys are reversed. Wherever drawdown had occurred there is now a peak, or high indicating that all of the area that was dewatered has resaturated. Similar pulsing during restoration will ensure that any areas dewatering during a pumping stage can be sufficiently resaturated.

Discussion and Summary

A numerical model was developed to evaluate the response of an unconfined aquifer to hydraulic stresses imposed by operation of an ISR uranium project. The model was developed using site-specific data regarding top and bottom aquifer elevations, saturated thickness, potentiometric surface and hydraulic gradient, hydraulic conductivity, specific yield, and porosity of the modeled aquifer. The model was calibrated to water level data collected during the 5-Spot Extraction Test within an unconfined portion of the production zone aquifer (70 Sand). The 5-Spot Extraction Test included a centrally located recovery well and 8 observation wells located within 72 feet of the recovery well. The simulated hydraulic conductivity and specific yield values that provided the best calibration results were 4.0 ft/d and 0.025, respectively. These simulated values are within the range of values estimated from analysis of the Extraction Test data.

The calibrated model was then used to simulate the 5-Spot Extraction/Injection Test. The 5-Spot Extraction/Injection Test was conducted in three stages. The first stage included injection into each of the four injection wells at 5 gpm per well for 2 days. The second stage involved injection into two of the wells at 10 gpm per well for 1 day and the third stage included injection of 20.5 gpm into a single well for 1 day. A single extraction well was used for all three stages of the test. Results of the simulation agreed well with the field data with some exceptions at the injection wells. Discrepancies between the simulated and observed water levels are largely attributed to incomplete well development and or well efficiency issues. Simulated water level changes at non-injection observation wells correlated well with the observed data. Simulation of the 5-Spot Extraction/Injection Test provided verification that the calibrated model was adequate for additional simulations of hydraulic stresses to the unconfined production zone aquifer at the Moore Ranch project.

Additional simulations were run to evaluate the maximum lateral extent that hydraulic responses resulting from pumping at a single extraction well can be observed. The results indicate that hydrologic testing to demonstrate hydraulic communication between the production zone in the wellfield and the monitor well ring will require several separate pumping tests.

A pulsing simulation was run in which extraction and injection wells were switched after 30 days of operation. The results of the simulation indicate that any portions of the aquifer that are dewatered during ISR production operations can be readily resaturated by pulsing wells.

The 5-Spot Hydrologic Test Model has been calibrated and verified to site-specific data and hydraulic stress tests. The model provides representative simulation of the unconfined 70 Sand aquifer during production and restoration operations. The numerical model is a useful tool for assessment of the aquifer response to ISR uranium mining at the Moore Ranch Project. This model is expanded to simulate wellfield scale production and restoration operations. Results of those simulations are included in a separate report titled "Numerical Modeling of Groundwater Conditions Related to Insitu Recovery at the Moore Ranch Uranium Project, Wyoming" (Petrotek Engineering, Inc., 2008).

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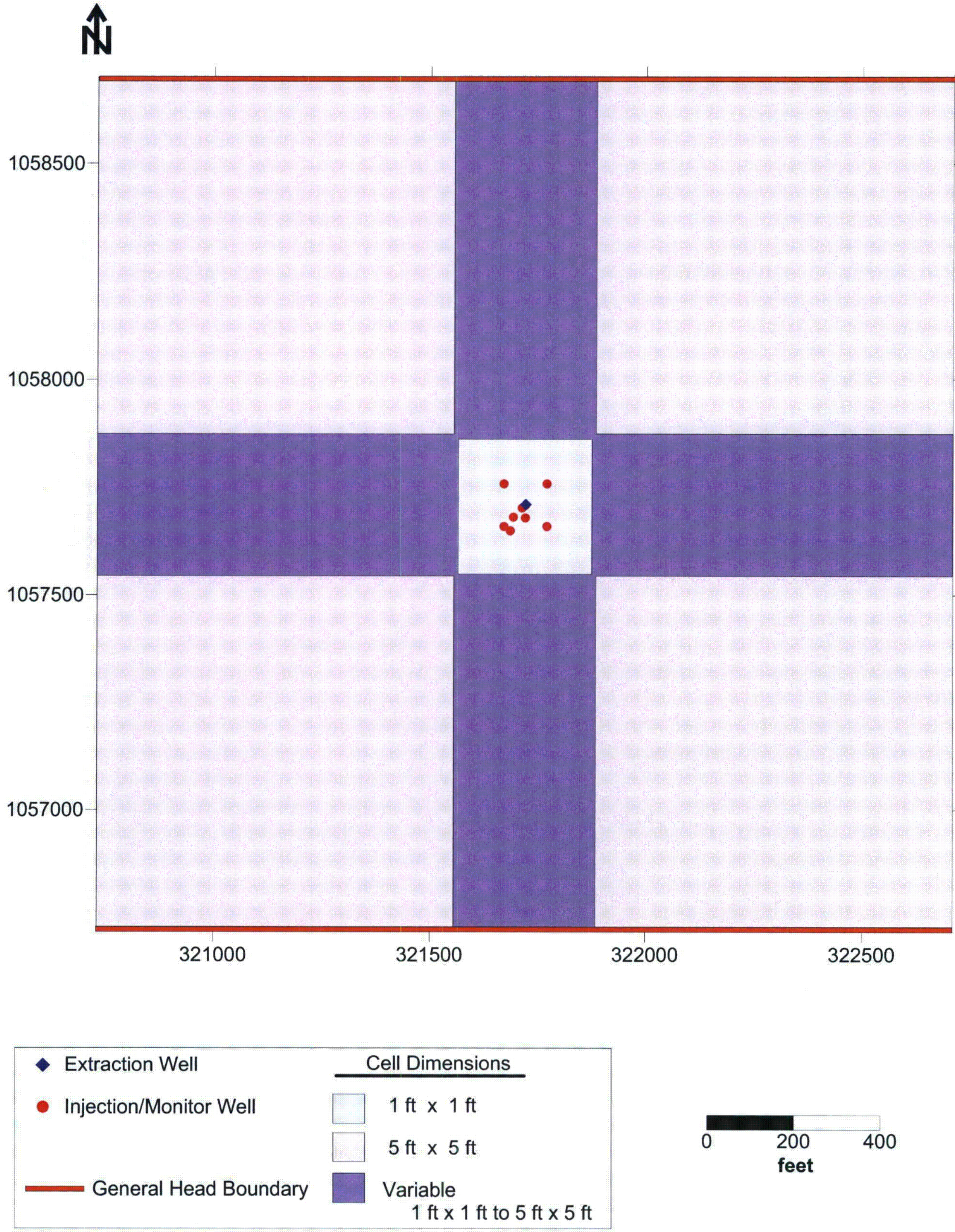

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Figure 5ST(25). Model Domain
Moore Ranch Uranium Project, Wyoming

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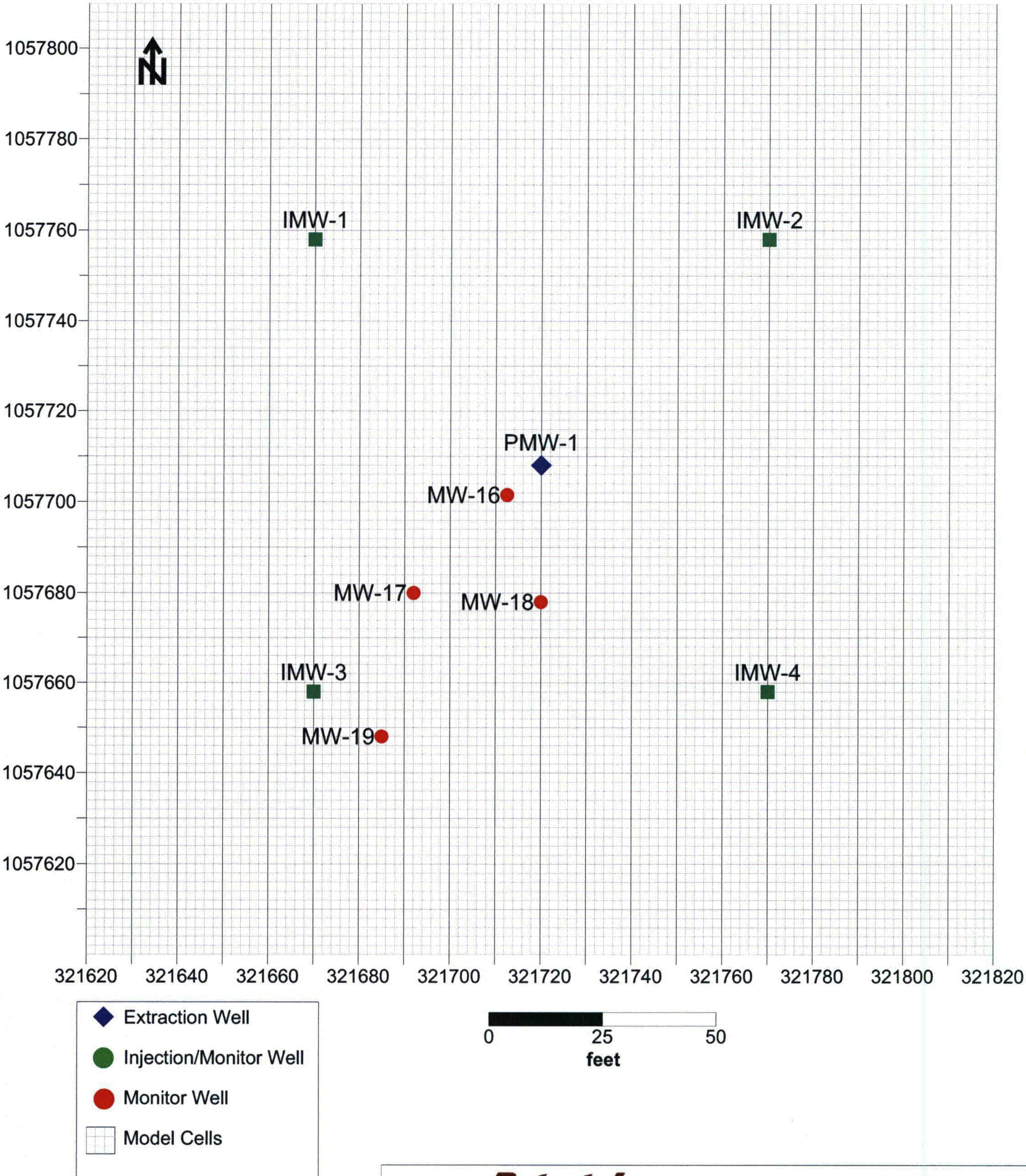

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Figure 5ST(26). Well Configuration, 5-Spot Hydrologic Test Simulations Moore Ranch Uranium Project, Wyoming

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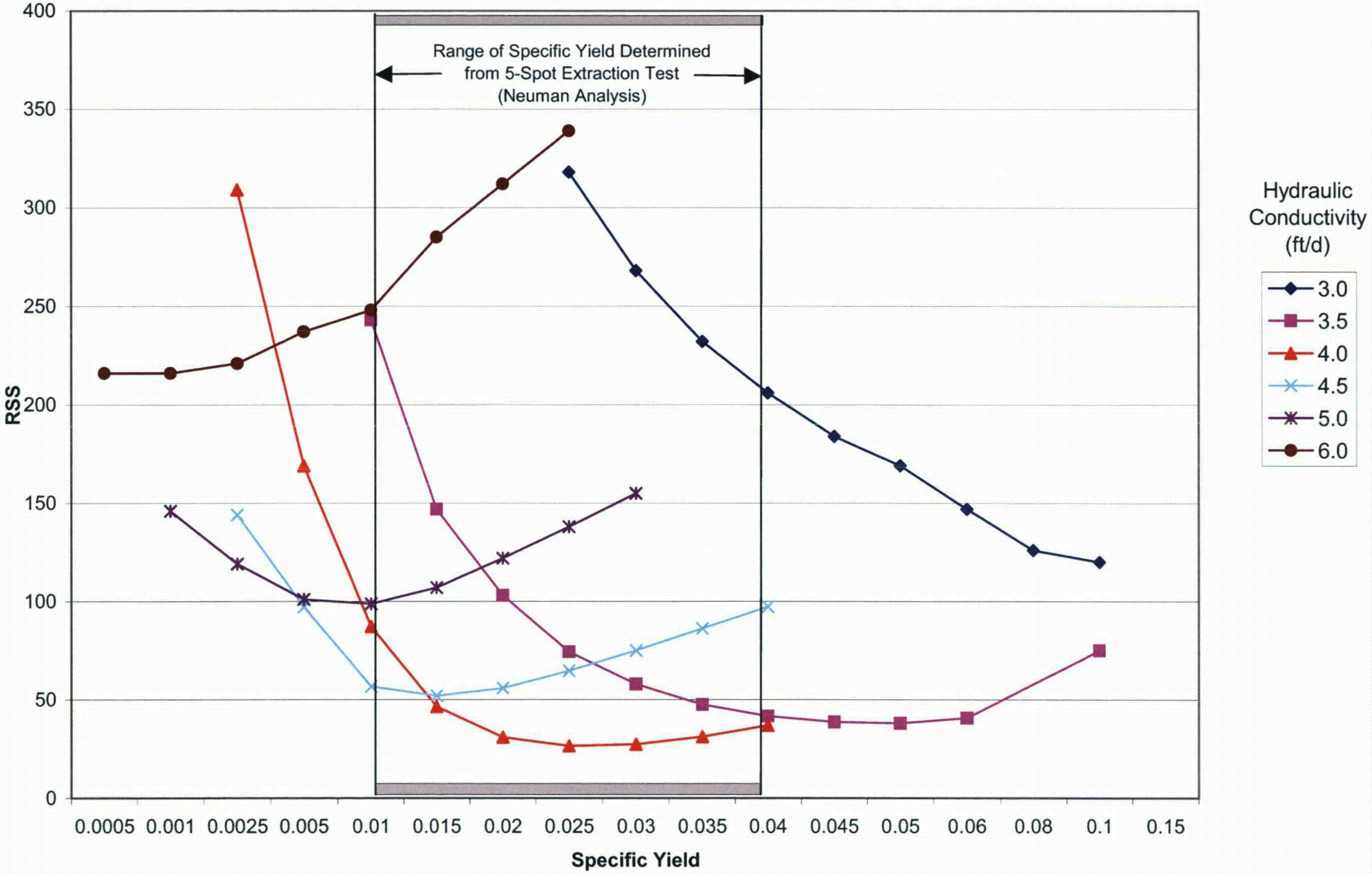

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Figure 5ST(27). Residual Sum of Squares vs Specific Yield Calibration Simulations Moore Ranch Uranium Project, Wyoming

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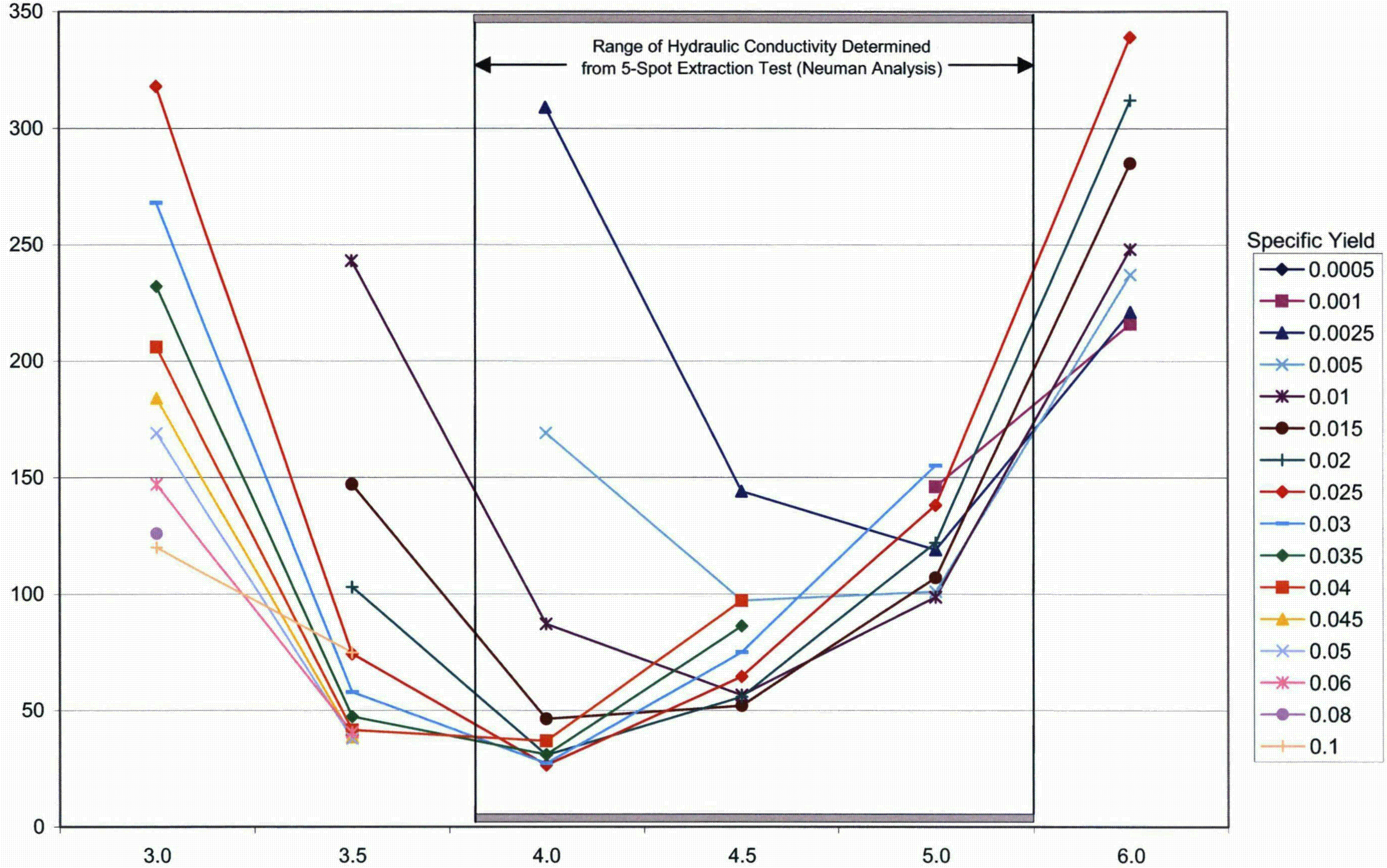

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Figure 5ST(28). Residual Sum of Squares Hydraulic Conductivity Calibration Simulations
Moore Ranch Uranium Project, Wyoming

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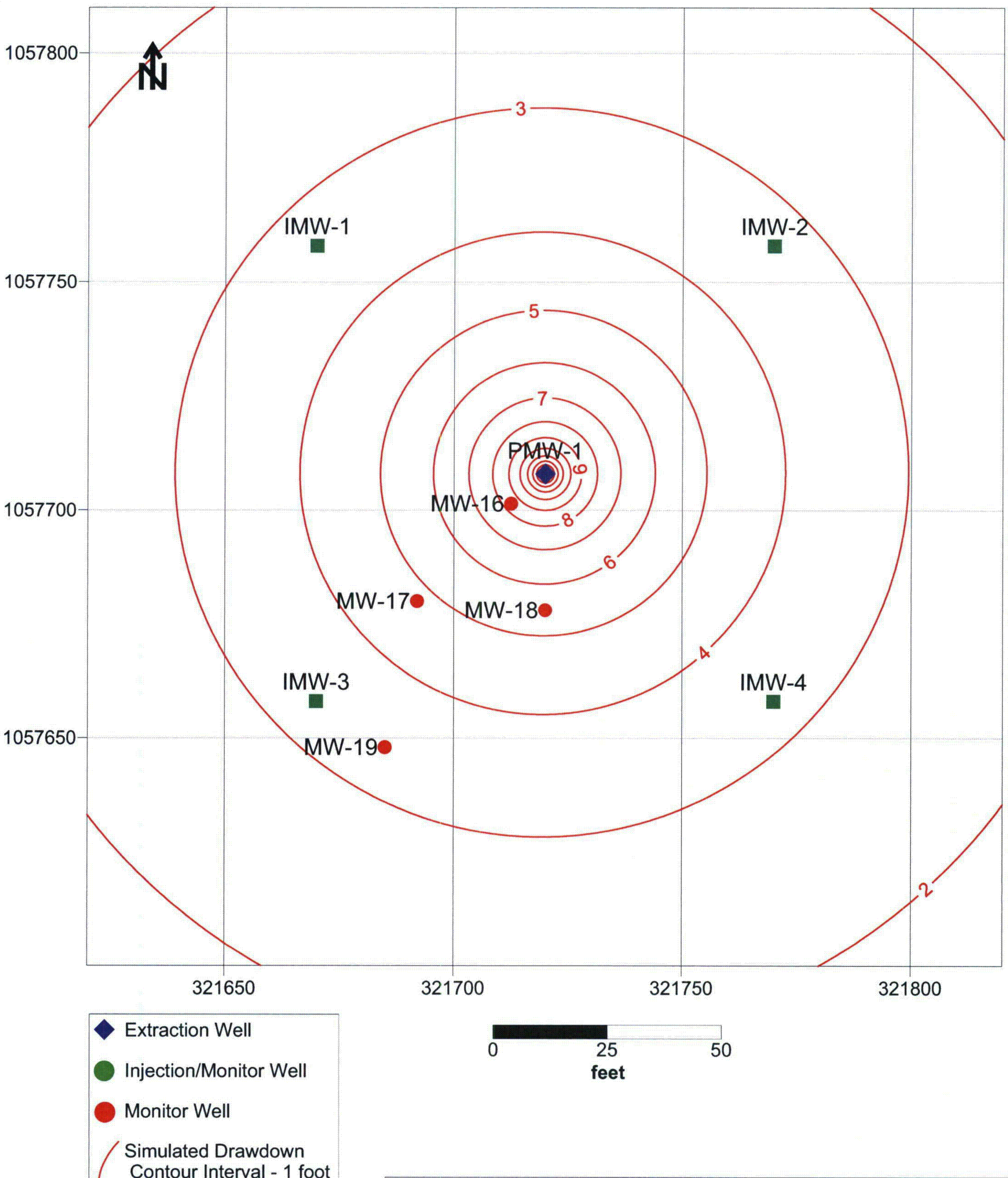

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Figure 5ST(29). Drawdown - End of 5-Spot Extraction Test Calibration Simulation Moore Ranch Uranium Project, Wyoming

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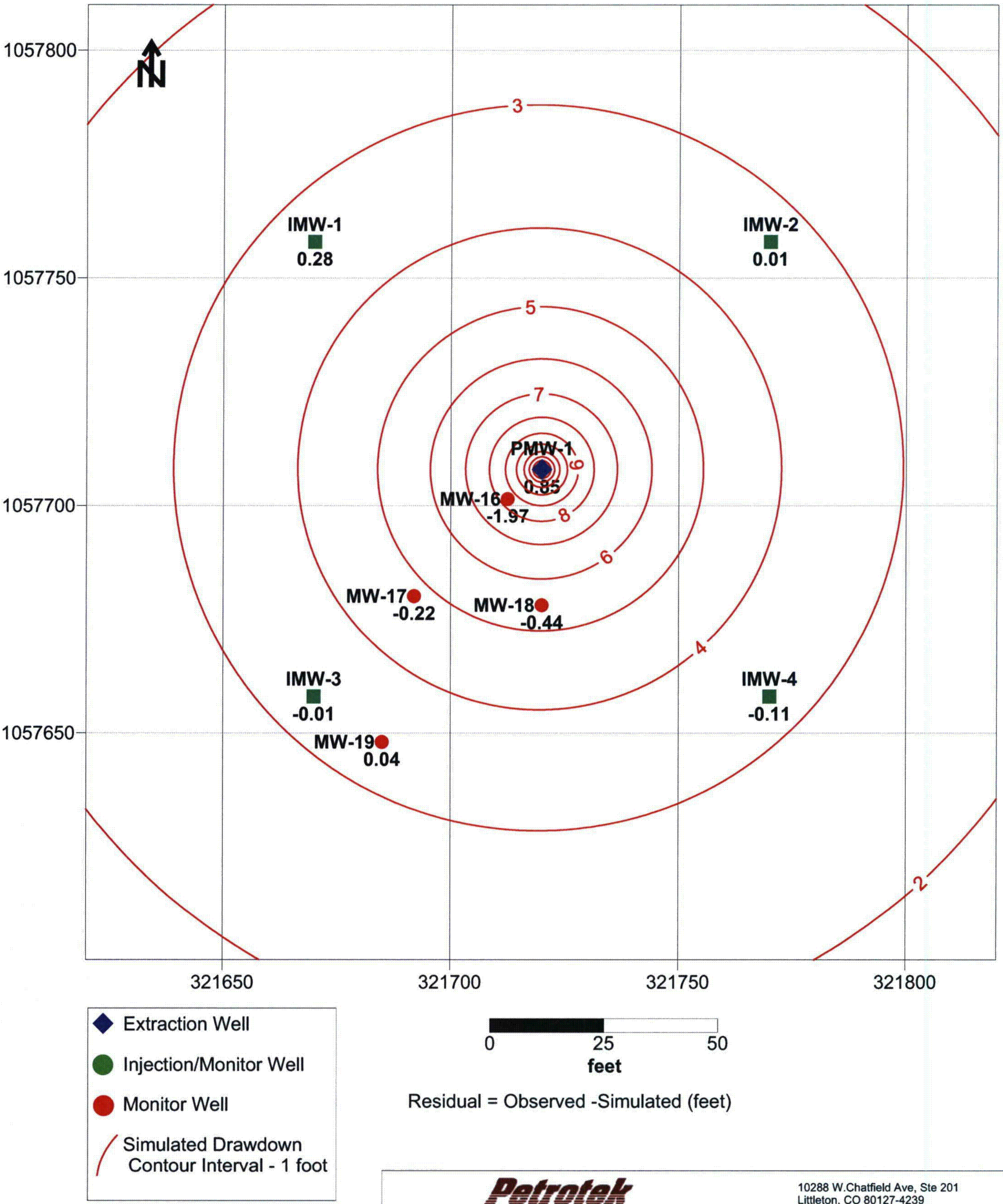

Residual = Observed -Simulated (feet)

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Figure 5ST(30). Residuals - End of 5-Spot Extraction Test Calibration Simulation Moore Ranch Uranium Project, Wyoming

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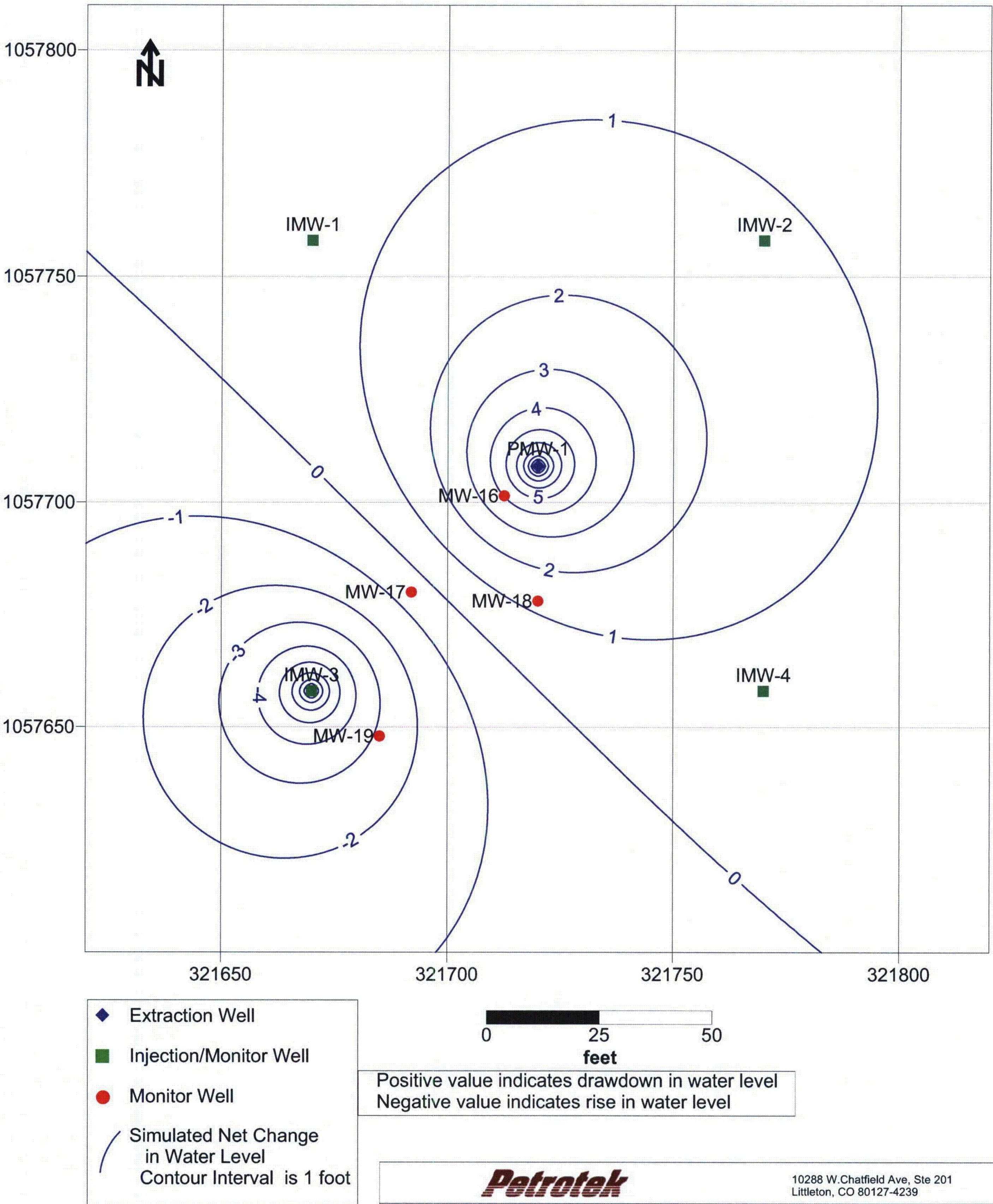

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Figure 5ST(31). Net Change in Water Level
End of 5-Spot Extraction/Injection Test Verification Simulation
Moore Ranch Uranium Project, Wyoming

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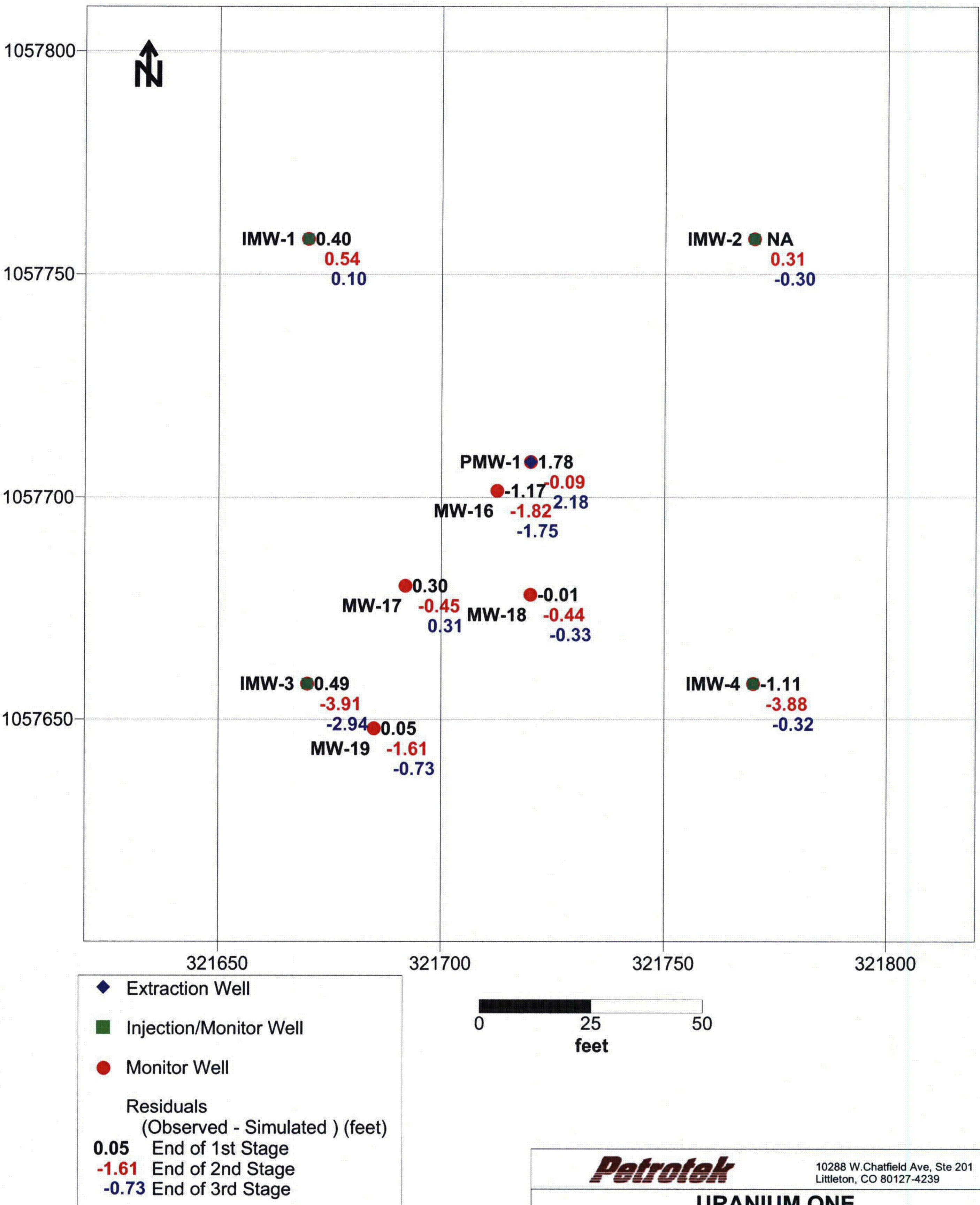

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Figure 5ST(32). Residuals-Extraction/Injection Test Verification Simulation Moore Ranch Uranium Project, Wyoming

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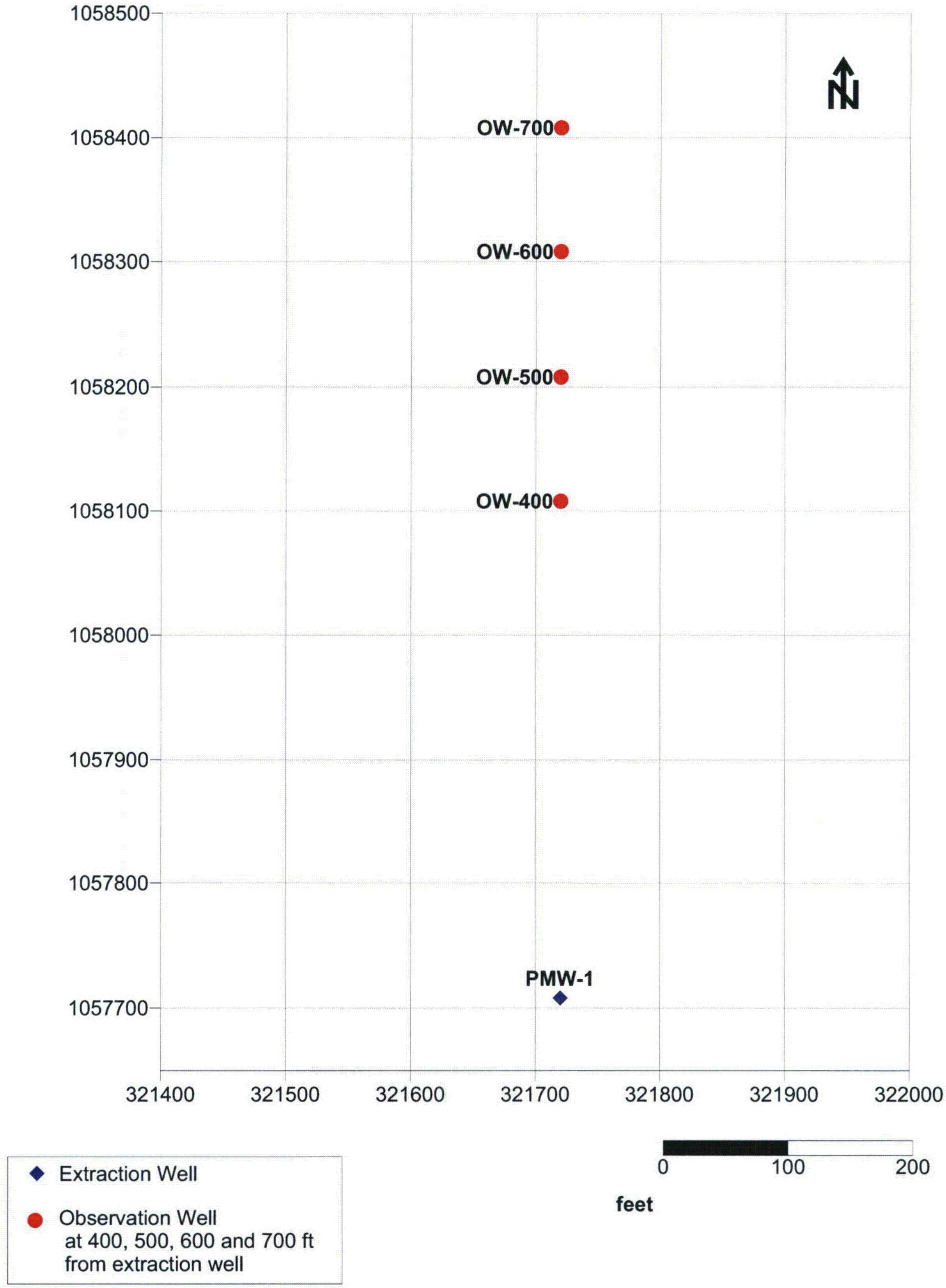

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Figure 5ST(33). Well Configuration, Hydrologic Test Simulations
Moore Ranch Uranium Project, Wyoming

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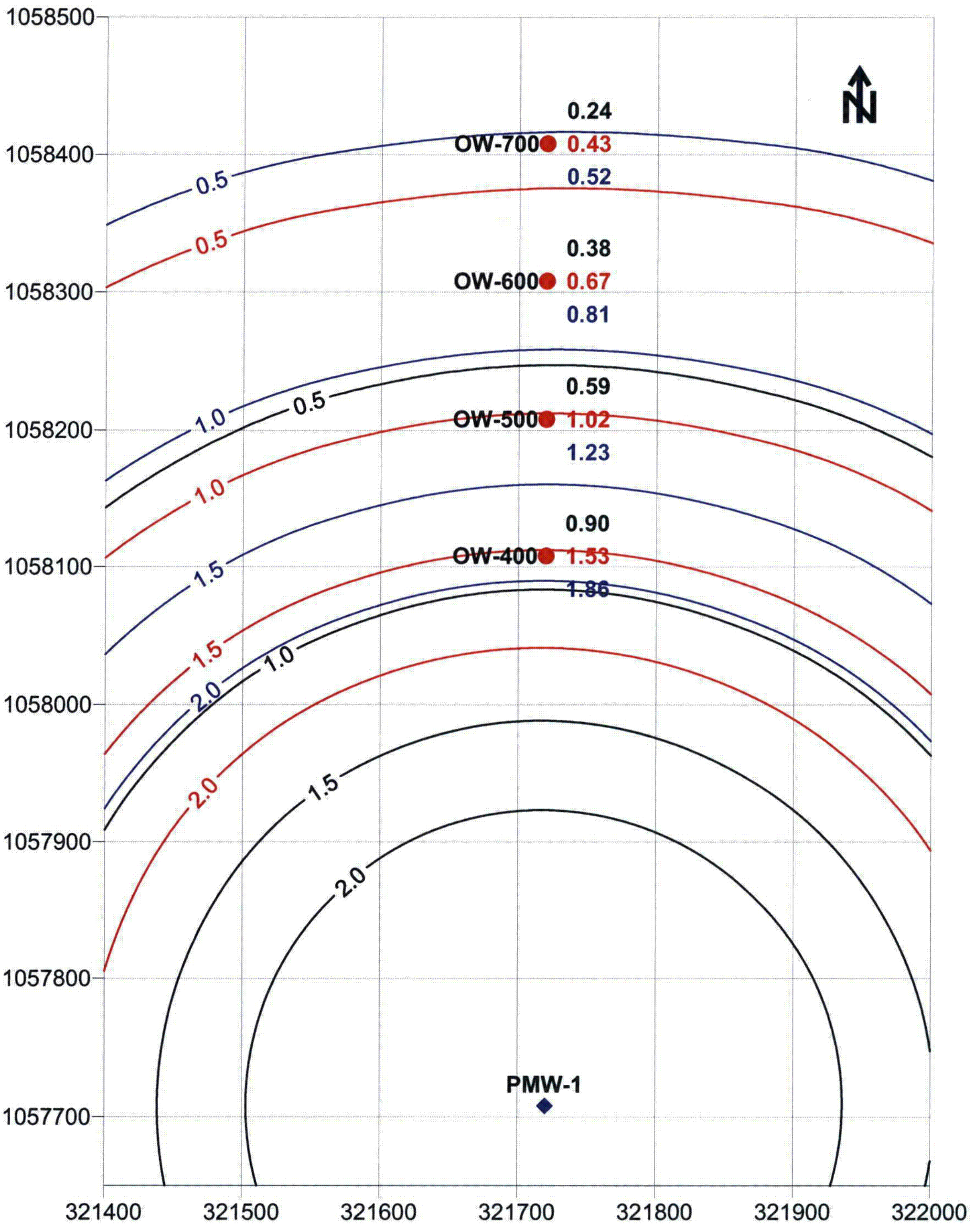

◆ Extraction Well

● Observation Well at 400, 500, 600 and 700 ft from extraction well

Simulated Drawdown After 8 Days of Pumping

0.38 - 20 gpm Simulation
0.67 - 30 gpm Simulation
0.81 - 40 gpm Simulation

0 50 100
feet

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Figure 5ST(34). Drawdown Response, Hydrologic Test Simulations Moore Ranch Uranium Project, Wyoming

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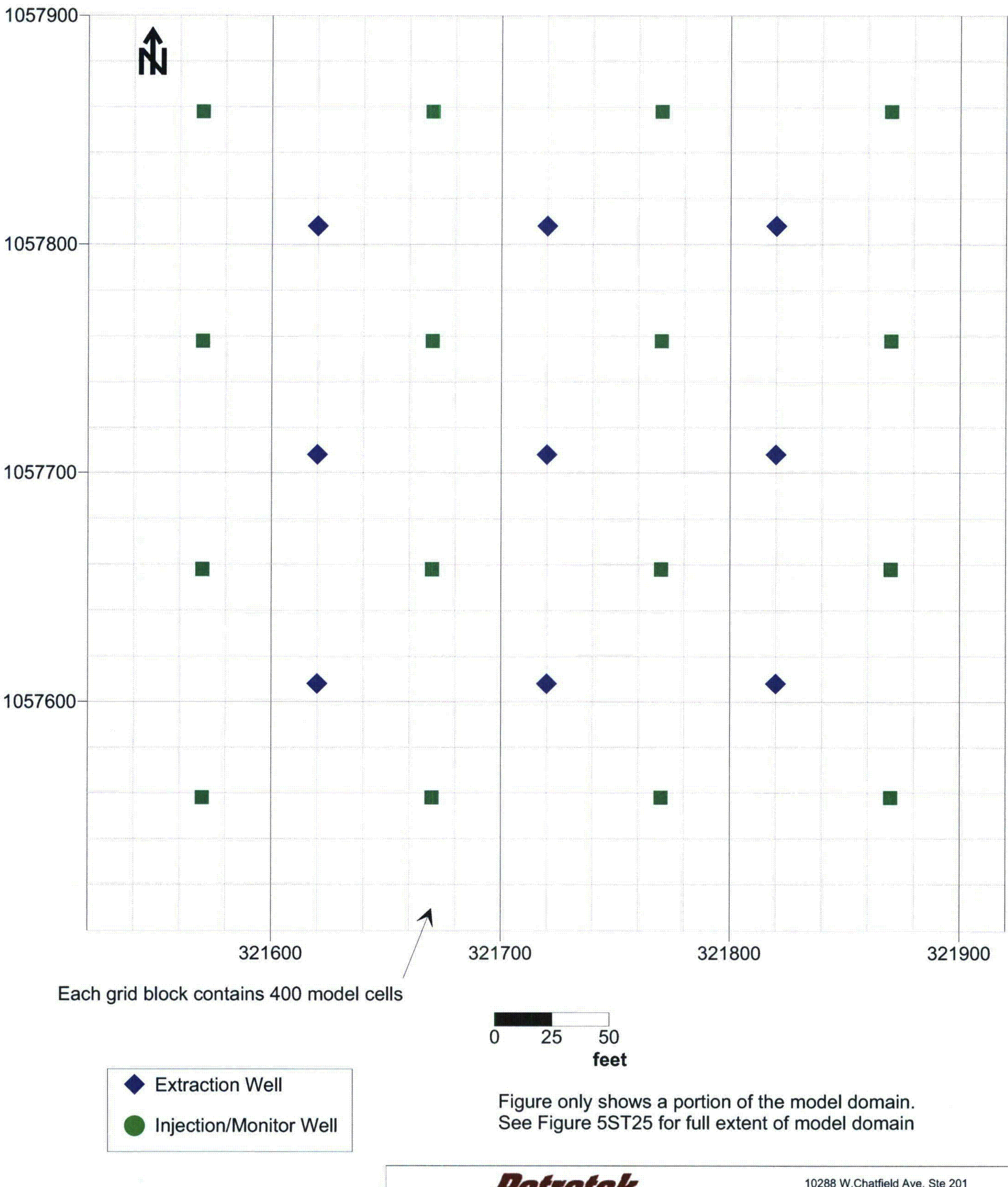

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Figure 5ST(35). Well Configuration, Wellfield Pulsing Simulations Moore Ranch Uranium Project, Wyoming

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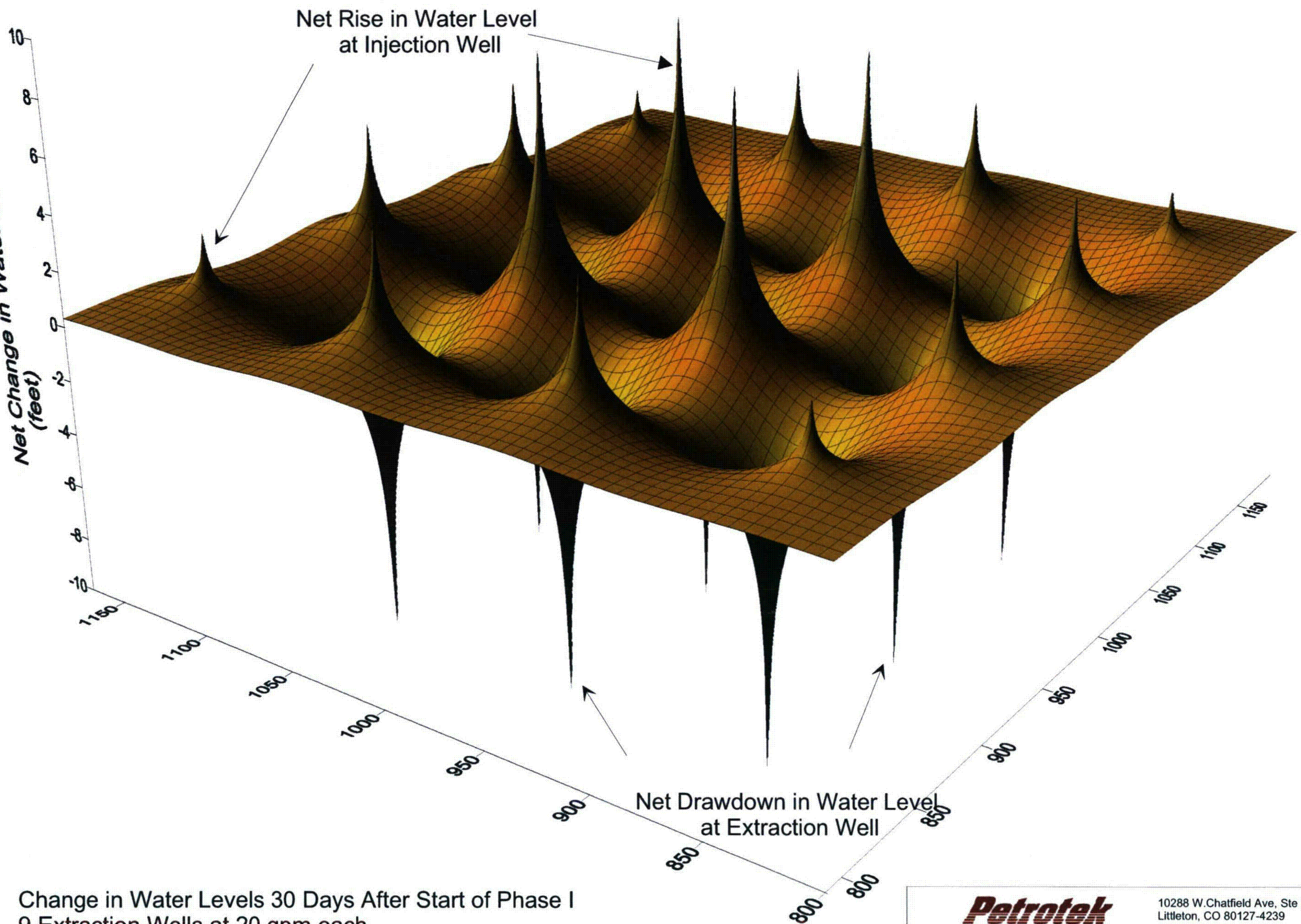

Change in Water Levels 30 Days After Start of Phase I
9 Extraction Wells at 20 gpm each
16 Injection Wells at a total of 180 gpm

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Figure 5ST(36). Net Water Level Change, Phase I Wellfield Pulsing Simulation
Moore Ranch Uranium Project, Wyoming

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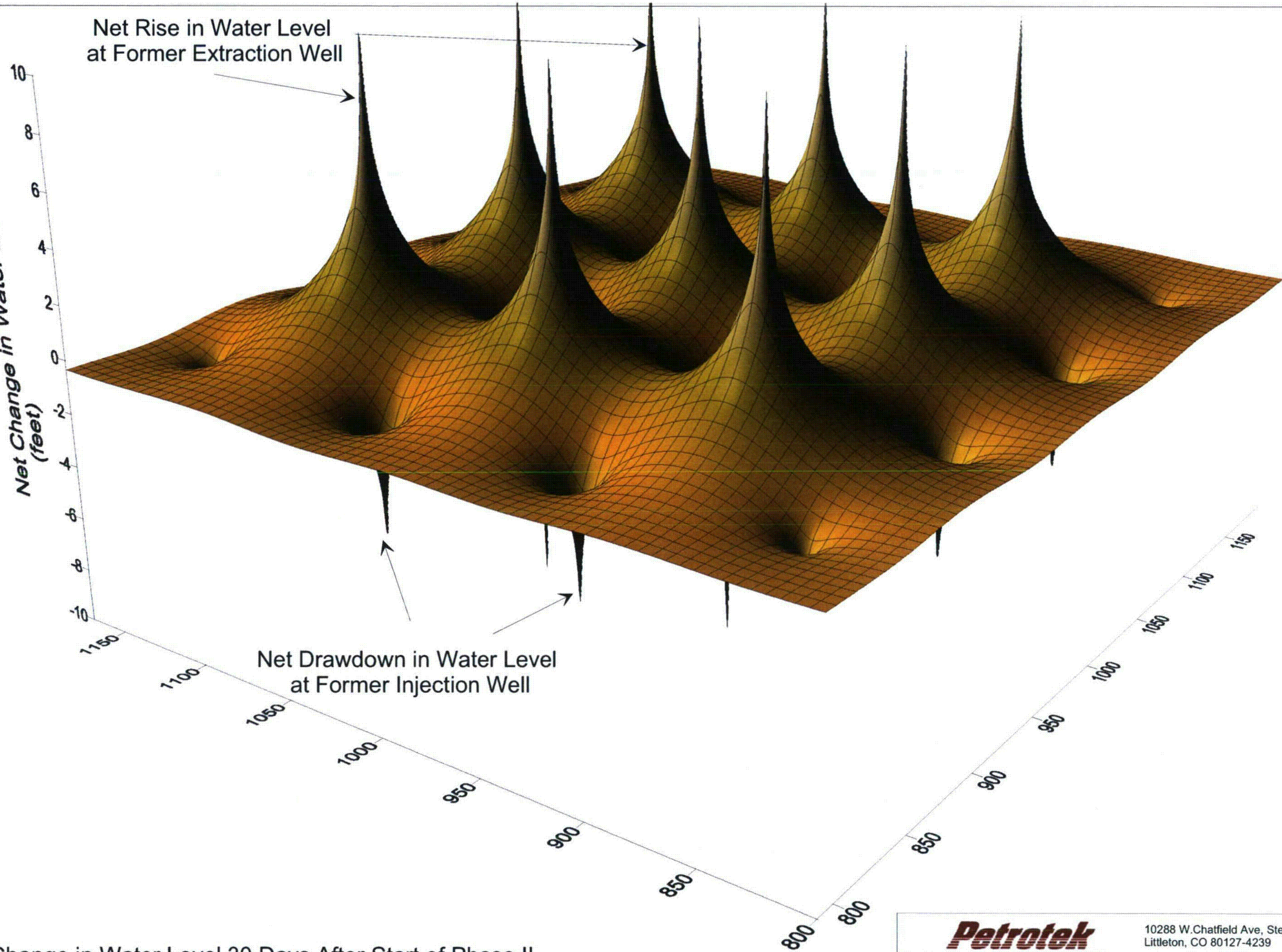

Change in Water Level 30 Days After Start of Phase II Extraction and Injection Wells are Reversed.

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Figure 5ST(37). Net Water Level Change, Phase II Wellfield Pulsing Simulation Moore Ranch Uranium Project, Wyoming

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Table 5ST (6) Calibration Targets, Residuals and Statistics, 5-Spot Extraction Test Simulation

Well ID	Simulation Time (days	Observed Drawdown (ft)	Computed Drawdown (ft)	Residual (ft)
IMW-1	0.5	2.04	1.33	0.71
	1	2.53	2.04	0.49
	2	3.05	2.82	0.23
	3	3.37	3.30	0.07
	4	3.60	3.32	0.28
IMW-2	0.5	1.81	1.31	0.50
	1	2.27	2.01	0.26
	2	2.75	2.78	-0.03
	3	3.06	3.26	-0.20
	4	3.29	3.28	0.01
IMW-3	0.5	1.70	1.32	0.38
	1	2.19	2.03	0.16
	2	2.71	2.81	-0.10
	3	3.04	3.29	-0.25
	4	3.30	3.31	-0.01
IMW-4	0.5	1.55	1.31	0.24
	1	2.04	2.01	0.03
	2	2.59	2.78	-0.19
	3	2.92	3.25	-0.33
	4	3.16	3.27	-0.11
MW-16	0.5	4.82	6.03	-1.21
	1	5.30	6.93	-1.63
	2	5.86	7.83	-1.97
	3	6.19	8.37	-2.18
	4	6.43	8.40	-1.97
MW-17	0.5	2.92	2.57	0.35
	1	3.43	3.38	0.05
	2	3.98	4.22	-0.24
	3	4.28	4.73	-0.45
	4	4.53	4.75	-0.22
MW-18	0.5	3.44	3.22	0.22
	1	3.93	4.06	-0.13
	2	4.44	4.91	-0.47
	3	4.78	5.42	-0.64
	4	5.00	5.44	-0.44
MW-19	0.5	1.76	1.35	0.41
	1	2.24	2.07	0.17
	2	2.78	2.84	-0.06
	3	3.12	3.32	-0.20
	4	3.38	3.34	0.04
PMW-1	0.5	18.90	17.08	1.82
	1	19.46	18.16	1.30
	2	20.00	19.25	0.75
	3	20.47	19.91	0.56
	4	20.79	19.94	0.85

Residual = Observed - Simulated

A positive residual indicates the model underpredicted drawdown

A negative residual indicates the model overpredicted drawdown

Calibration Statistics	
Residual Mean	-0.07
Res. Std. Dev.	0.76
Sum of Squares	26.49
Abs. Res. Mean	0.51
Min. Residual	-2.18
Max. Residual	1.82
Range	19.24
Std/Range	0.040

5ST (7) Comparison of Calibration Statistics, 5 Spot Extraction Test Simulations

Simulation ID	k	Sy	RSS Total	RM Total	ARM Total	RSD Total	RSS End	RM End	ARM End	RSD End
	(ft/d)		(ft2)	(ft)	(ft)	(ft)	(ft2)	(ft)	(ft)	(ft)
MR5STMs082408_K3S0025	3.0	0.0025	1650.0	-5.44	5.44	2.67	375.0	-5.85	5.86	2.71
MR5STMs082408_K3S025	3.0	0.025	318.0	-1.67	1.76	2.07	93.5	-2.40	2.40	2.15
MR5STMs082408_K3S03	3.0	0.03	268.0	-1.38	1.56	2.01	80.2	-2.11	2.11	2.11
MR5STMs082408_K3S035	3.0	0.035	232.0	-1.14	1.42	1.96	70.1	-1.87	1.87	2.07
MR5STMs082408_K3S04	3.0	0.04	206.0	-0.94	1.33	1.92	62.3	-1.66	1.66	2.04
MR5STMs082408_K3S045	3.0	0.045	184.0	-0.75	1.27	1.88	54.9	-1.44	1.46	2.00
MR5STMs082408_K3S05	3.0	0.05	169.0	-0.59	1.24	1.84	49.9	-1.28	1.33	1.98
MR5STMs082408_K3S06	3.0	0.06	147.0	-0.32	1.27	1.78	42.2	-0.99	1.27	1.93
MR5STMs082408_K3S08	3.0	0.08	126.0	0.10	1.34	1.67	33.1	-0.51	1.27	1.85
MR5STMs082408_K3S10	3.0	0.1	120.0	0.40	1.42	1.58	28.8	-0.15	1.34	1.78
MR5STMs082408_K35S01	3.5	0.01	243.0	-2.02	2.02	1.15	58.3	-2.28	2.28	1.12
MR5STMs082408_K35S015	3.5	0.015	147.0	-1.44	1.45	1.09	36.6	-1.71	1.71	1.07
MR5STMs082408_K35S02	3.5	0.02	103.0	-1.08	1.12	1.06	29.5	-1.48	1.48	1.04
MR5STMs082408_K35S025	3.5	0.025	74.3	-0.77	0.89	1.03	21.8	-1.18	1.18	1.01
MR5STMs082408_K35S03	3.5	0.03	57.9	-0.54	0.77	1.00	17.6	-0.98	0.98	0.99
MR5STMs082408_K35S035	3.5	0.035	47.4	-0.33	0.70	0.97	13.9	-0.77	0.80	0.97
MR5STMs082408_K35S04	3.5	0.04	41.6	-0.15	0.68	0.95	11.4	-0.59	0.68	0.96
MR5STMs082408_K35S045	3.5	0.045	38.6	0.01	0.71	0.93	9.5	-0.42	0.66	0.92
MR5STMs082408_K35S05	3.5	0.05	38.0	0.14	0.75	0.91	8.6	-0.30	0.67	0.93
MR5STMs082408_K35S06	3.5	0.06	40.6	0.44	0.86	0.84	7.6	0.30	0.83	0.87
MR5STMs082408_K35S1	3.5	0.1	74.9	1.06	1.21	0.74	14.4	0.99	1.20	0.79
MR5STMs082408_K4S0025	4.0	0.0025	309.0	-2.52	2.52	0.73	49.8	-2.24	2.24	0.70
MR5STMs082408_K4S005	4.0	0.005	169.0	-1.79	1.79	0.73	27.0	-1.58	1.58	0.70
MR5STMs082408_K4S01	4.0	0.01	87.1	-1.17	1.19	0.76	18.4	-1.25	1.25	0.70
MR5STMs082408_K4S015	4.0	0.015	46.4	-0.67	0.76	0.76	9.8	-0.76	0.78	0.71
MR5STMs082408_K4S02	4.0	0.02	30.9	-0.33	0.56	0.76	6.2	-0.43	0.55	0.71
MR5STMs082408_K4S025	**4.0**	**0.025**	**26.5**	**-0.07**	**0.51**	**0.76**	**4.9**	**-0.17**	**0.44**	**0.72**
MR5STMs082408_K4S03	**4.0**	**0.03**	**27.3**	**0.14**	**0.55**	**0.77**	**4.7**	**0.04**	**0.48**	**0.72**
MR5STMs082408_K4S035	4.0	0.035	31.1	0.32	0.70	0.77	5.2	0.22	0.57	0.73
MR5STMs082408_K4S04	4.0	0.04	36.9	0.48	0.74	0.77	6.3	0.40	0.70	0.73
MR5STMs082408_K45S0025	4.5	0.0025	144.0	-1.47	1.67	1.02	17.6	-0.98	1.31	1.00
MR5STMs082408_K45S005	4.5	0.005	97.1	-1.06	1.38	1.01	14.8	-0.79	1.17	1.01
MR5STMs082408_K45S01	4.5	0.01	56.6	-0.38	0.88	1.06	10.1	-0.15	0.71	1.05
MR5STMs082408_K45S015	4.5	0.015	52.0	0.08	0.69	1.07	10.1	-0.04	0.65	1.06
MR5STMs082408_K45S02	4.5	0.02	55.9	0.23	0.62	1.09	11.0	0.26	0.58	1.08
MR5STMs082408_K45S025	4.5	0.025	64.6	0.46	0.69	1.11	12.9	0.49	0.73	1.09
MR5STMs082408_K45S03	4.5	0.03	75.0	0.64	0.83	1.12	15.1	0.68	0.87	1.10
MR5STMs082408_K45S035	4.5	0.035	86.2	0.80	0.95	1.13	17.3	0.83	0.98	1.11
MR5STMs082408_K45S04	4.5	0.04	97.2	0.93	1.04	1.14	19.4	0.95	1.07	1.12
MR5STMs082408_K5S001	5.0	0.001	146.0	-1.03	1.64	1.48	19.4	-0.34	1.14	1.43
MR5STMs082408_K5S0025	5.0	0.0025	119.0	-0.72	1.42	1.46	18.8	-0.14	0.99	1.44
'MR5STMs082408_K5S005	5.0	0.005	101.0	-0.44	1.21	1.41	18.8	0.07	0.94	1.45
'MR5STMs082408_K5S010	5.0	0.01	98.7	0.17	0.80	1.47	21.9	0.48	0.69	1.48
'MR5STMs082408_K5S015	5.0	0.015	107.0	0.42	0.71	1.48	22.8	0.57	0.74	1.49
'MR5STMs082408_K5S02	5.0	0.02	122.0	0.68	0.82	1.50	26.4	0.82	0.94	1.50
MR5STMs082408_K5S025	5.0	0.025	138.0	0.89	0.98	1.51	30.0	1.02	1.09	1.52
MR5STMs082408_K5S03	5.0	0.03	155.0	1.05	1.10	1.53	33.5	1.18	1.21	1.53
MR5STMs082408_K6S0005	6.0	0.0005	216.0	0.28	1.21	2.17	50.3	1.00	1.01	2.15
MR5STMs082408_K6S001	6.0	0.001	216.0	0.27	1.21	2.17	50.2	0.99	1.00	2.15
MR5STMs082408_K6S0025	6.0	0.0025	221.0	0.46	1.15	2.17	53.2	1.13	1.13	2.15
MR5STMs082408_K6S005	6.0	0.005	237.0	0.75	1.13	2.17	59.2	1.37	1.37	2.17
MR5STMs082408_K6S01	6.0	0.01	248.0	0.95	1.03	2.15	59.1	1.37	1.37	2.17
MR5STMs082408_K6S015	6.0	0.015	285.0	1.28	1.28	2.17	69.0	1.70	1.70	2.19
MR5STMs082408_K6S02	6.0	0.02	312.0	1.48	1.48	2.18	75.3	1.88	1.88	2.20
MR5STMs082408_K6S025	6.0	0.025	339.0	1.65	1.65	2.19	82.3	2.07	2.07	2.21

k - hydraulic conductivity **Values in bold indicate simulations with calibration statistics that "best fit" observed data**

Sy - specific yield

RSS Total- residual sum of squares for all calibration targets

RM-Total - residual mean of calibration targets for all calibration targets

ARM-Total - absolute residual mean of calibration targets for all calibration targets

RSD Total - Standard deviation of the residuals for all calibration targets

RSS End- residual sum of squares for calibration targets at end of simulation

RM-End - residual mean of calibration targets at end of simulation

ARM-end - absolute residual mean of calibration targets at end of simulation

RSD End - Standard deviation of the residuals for calibration targets at end of simulation

Table MR5ST (8) Calibration Simulation Results-Hydraulic Conductivity vs Specific Yield

Residual Sum of Squares for Calibration Simulations, All Simulation Targets

		Hydraulic Conductivity (ft/d)					
		3.0	3.5	4.0	4.5	5.0	6.0
Specific Yield	0.0005						216.0
	0.001					146	**216**
	0.0025			309	144	119	221
	0.005			169	97.1	101	237
	0.01		243	87.1	56.6	**98.7**	248
	0.015		147	46.4	**52**	107	285
	0.02		103	30.9	55.9	122	312
	0.025	318	74.3	**26.5**	64.6	138	339
	0.03	268	57.9	27.3	75	155	
	0.035	232	47.4	31.1	86.2		
	0.04	206	41.6	36.9	97.2		
	0.045	184	38.6				
	0.05	169	**38**				
	0.06	147	40.6				
	0.08	126					
	0.1	**120**	74.9				

Residual Sum of Squares for Calibration Simulations, End of Simulation Targets

		Hydraulic Conductivity (ft/d)					
		3.0	3.5	4.0	4.5	5.0	6.0
Specific Yield	0.0005						50.3
	0.001					19.4	**50.2**
	0.0025			49.8	17.6	**18.8**	53.2
	0.005			27.0	14.8	**18.8**	59.2
	0.01		58.3	18.4	**10.1**	21.9	59.1
	0.015		36.6	9.8	**10.1**	22.8	69.0
	0.02		29.5	6.2	11.0	26.4	75.3
	0.025	93.5	21.8	4.9	12.9	30.0	82.3
	0.03	80.2	17.6	**4.7**	15.1	33.5	
	0.035	70.1	13.9	5.2	17.3		
	0.04	62.3	11.4	6.3	19.4		
	0.045	54.9	9.5				
	0.05	49.9	8.6				
	0.06	42.2	**7.6**				
	0.08	33.1					
	0.1	**28.2**	14.4				

Values in Bold indicate lowest RSS ("best fit") for that simulated hydraulic conductivity

Table 5ST(9) Summary of Input Parameters for the Calibration Simulation

Model Input	Number or Value	Units
Dimensions		
South to North	1980	feet
West to East	1980	feet
Model Origin (from bottom LH corner)		
Easting	320,730.00	feet
Northing	1,056,718.00	feet
Layers		
Number	1	-
Cells		
Number	421,201	-
Minimum size	1' x 1'	feet
Maximum size	5' x 5'	feet
Elevation		
Top Elevation (south end)	5218	feet; AMSL
Bottom Elevation (south end)	5130	feet; AMSL
Top Elevation (north end)	5196	feet; AMSL
Bottom Elevation (north end)	5093	feet; AMSL
Boundaries		
General Head - South Side	5195.15	feet; AMSL
General Head - North Side	5188.75	feet; AMSL
No Flow - East and West Sides	-	-
Recharge		
Rate	0.0	ft/d
Wells		
Number	1	-
Rate	4296.89	ft3/d
Parameter		
Hydraulic Conductivity	4.0	ft/d
Specific Yield	0.25	unitless
Formation Storativity	0.0005	unitless
Porosity	15	percent

Table 5ST (10) Verification Targets and Residuals, 5-Spot Extraction/Injection Test Simulation

Well ID	Simulation Time (days	Observed Drawdown (ft)	Computed Drawdown (ft)	Residual (ft)
IMW-1	2.06	-2.37	-2.77	0.40
	3.06	0.85	0.31	0.54
	3.98	0.76	0.66	0.10
IMW-2	2.06	NU	NA	NA
	3.06	0.62	0.31	0.31
	3.98	0.87	1.17	-0.30
IMW-3	2.06	-2.27	-2.76	0.49
	3.06	-9.48	-5.57	-3.91
	3.98	-14.91	-11.97	-2.94
IMW-4	2.06	-3.79	-2.68	-1.11
	3.06	-9.29	-5.41	-3.88
	3.98	0.30	0.62	-0.32
MW-16	2.06	2.56	3.73	-1.17
	3.06	2.08	3.90	-1.82
	3.98	2.28	4.03	-1.75
MW-17	2.06	0.98	0.68	0.30
	3.06	0.06	0.51	-0.45
	3.98	-0.22	-0.53	0.31
MW-18	2.06	1.31	1.32	-0.01
	3.06	0.85	1.29	-0.44
	3.98	0.91	1.24	-0.33
MW-19	2.06	-0.30	-0.35	0.05
	3.06	-2.50	-0.89	-1.61
	3.98	-3.57	-2.84	-0.73
PMW-1	2.06	14.96	13.18	1.78
	3.06	13.36	13.45	-0.09
	3.98	16.33	14.15	2.18

NU -observed value of 25.94 ft not used in calibration
NA - Not applicable
Residual = Observed - Simulated

5ST (11) Drawdown versus Distance at Simulated Pumping Rates, Hydrologic Test Design

Distance from Extraction Well	400 ft			500 ft			600 ft			700 ft		
	20 gpm	30 gpm	40 gpm	20 gpm	30 gpm	40 gpm	20 gpm	30 gpm	40 gpm	20 gpm	30 gpm	40 gpm
Time of Test	Drawdown (ft)			Drawdown (ft)			Drawdown (ft)			Drawdown (ft)		
1 day	0.11	0.17	0.23	0.03	0.05	0.07	0.01	0.01	0.02	0.00	0.00	0.00
2 days	0.35	0.54	0.72	0.17	0.27	0.35	0.08	0.12	0.16	0.03	0.05	0.07
3 days	0.56	0.89	1.17	0.32	0.51	0.67	0.18	0.28	0.38	0.10	0.15	0.20
4 days	0.75	1.18	1.53	0.47	0.73	0.96	0.29	0.45	0.59	0.17	0.27	0.35
5 days	0.90	1.43	1.80	0.59	0.93	1.19	0.38	0.60	0.77	0.24	0.38	0.49
6 days	0.90	1.52	1.82	0.59	1.01	1.20	0.38	0.67	0.79	0.24	0.43	0.50
7 days	0.90	1.52	1.83	0.59	1.01	1.21	0.38	0.67	0.79	0.24	0.43	0.50
8 days	0.90	1.53	1.86	0.59	1.02	1.23	0.38	0.67	0.81	0.24	0.43	0.52

APPENDIX B5

Moore Ranch Numerical Modeling of Groundwater Conditions – September 2008