URS

September 26, 2003

Ms. Susan Goss, RG, CHG
AHTNA Government Services Corporation
1115 Shore Street
West Sacramento, CA 95691

SUBJECT: Former Fort Ord Capture Analysis for OU 1 Technical Memorandum Contract Number 30034-10

Dear Ms. Goss:

Enclosed is the former Fort Ord Capture Analysis Technical Memorandum for Operable Unit (OU) 1 covering the period January 2002 through December 2002.

Thank you for the opportunity to perform capture analysis activities. We appreciate your significant communication and data coordination efforts during this effort. We look forward to continued cooperation with AHTNA Government Services Corporation. Please call me at (916) 679-2398 or Kent Parrish at (916) 679-2220 if you have any questions.

Sincerely,
URS Group, Inc.

Amir Kh. Matin

Amir K. Matin, RG, CHG

Kent E. Parrish

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Enclosure

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CAPTURE ANALYSIS
FORMER FORT ORD OPERABLE UNIT 1

Technical Memorandum

Prepared for:

Contract No. 30034-10
AHTNA Government Services Corporation
1115 Shore Street
West Sacramento, California 95691

Prepared by:

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September 2003

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1.0 INTRODUCTION

This technical memorandum describes the methodology and results of capture analyses for Operable Unit (OU) 1 at the former Fort Ord in Monterey County, California. Groundwater cleanup and infiltration systems are operating at this former U.S. Army facility, and this analysis is part of the ongoing environmental remedies. URS Group, Inc. (URS) performed capture analysis activities for AHTNA Government Services Corporation (AGSC) under contract number 30034-10.

This memorandum documents the requested particle-tracking methodology, which used the existing numerical groundwater flow and particle-tracking model for OU 1. URS was supplied with the existing model in electronic format. The model was updated with average annual flow (extraction and injection) and September 2002 groundwater elevation data supplied by AGSC.

2.0 BACKGROUND

Remedial groundwater monitoring programs are designed to measure the effectiveness of an extraction system in achieving hydraulic containment and cleanup objectives. The success of hydraulic containment (and groundwater cleanup) depends on groundwater COCs flowing into (i.e., being captured by) the extraction system (Cohen et al., 1997; Cohen et al., 1994).

In general, containment (capture zone) monitoring involves the following: (1) measuring hydraulic heads and evaluating them to determine whether the extraction (and injection, if applicable) prevents groundwater flow and dissolved contaminant migration across the capture zone boundary; and (2) monitoring groundwater quality to verify that no contaminant movement or increase in contaminant mass is occurring across the capture zone boundary. Monitoring activities, therefore, typically include some combination of hydraulic head measurement, groundwater sampling and analysis, tracer monitoring (occasionally for verification purposes), and pumping rate measurement (Cohen et al., 1994). Capture zone analysis has evolved to use particle-tracking (or groundwater streamline) analysis. In capture zone analysis, theoretical particles are mathematically placed into a groundwater regime, and their migration paths are predicted based on groundwater velocity calculations. Various methodologies are available for particle tracking.

Performance of the former Fort Ord groundwater cleanup remedies has been implemented. Hydraulic capture performance at this site is being estimated and evaluated by AGSC using three approaches: groundwater elevation contour interpretation; model-simulated groundwater flow interpretation; and measured groundwater chemistry interpretation. As previously stated, this memorandum focuses on capture evaluation using particle-tracking methods based on numerical flow modeling.

3.0 CAPTURE ANALYSIS USING PARTICLE TRACKING

Numerical groundwater flow modeling was conducted to evaluate hydraulic capture of the A-Aquifer and the Upper 180-Foot Aquifer chemicals of concern (COC). Hydraulic capture was estimated using the updated former Fort Ord groundwater flow models for OU 1. The model was used to simulate groundwater flow paths; specifically, paths induced by operation of the OU 1 extraction systems. The following sections summarize the origin, development, and results of the former Fort Ord OU 1 groundwater flow model.

3.1 FLOW MODEL DEVELOPMENT

All of the former Fort Ord numerical groundwater flow models are based on the finite difference MODFLOW model code (McDonald and Harbaugh, 1988) originally completed for the former Fort Ord basewide hydrogeological characterization and used in the basewide remedial investigation/feasibility study (RI/FS) (Harding Lawson Associates [HLA], 1995b). Particle tracking was originally generated using the PATH3D model code (Zheng, 1989) and is currently generated using the MODPATH model code (Pollock, 1994) in conjunction with MODFLOW. The current models for each location (OU 1, OU 2, and Sites 2 and 12) use a graphical preprocessor/ postprocessor interface called the Department of Defense Groundwater Modeling System (GMS). The Engineering Computer Graphics Laboratory of Brigham Young University, in partnership with the U.S. Army Engineering Waterways Experiment Station, developed the GMS interface. The GMS program is commercially available. The GMS modules, including the model codes, have been extensively tested and validated against numerical and analytical solutions for a variety of flow prototypes.

The OU 2 model uses an earlier version of GMS (v. 2.1), whereas the models for OU 1 and Sites 2 and 12 use GMS v. 3.1. The OU 2 model is a quasi-three dimensional representation and consequently must use the earlier version of GMS. The other two models are true-layer representations and may use later versions of GMS. The only differences between the models used for OU 1 and Sites 2 and 12 are their finite difference grids. Each grid is refined for greater resolution in their two distinct pumping/infiltration areas. More detailed descriptions of the current models may be found in the Harding ESE (formerly Harding Lawson Associates) documents: (Harding ESE, 2001a), (Harding ESE, 2001b), (HLA, 1995a), (HLA, 1995c).

3.2 CAPTURE MODELING RESULTS

Groundwater capture is evaluated by comparing the simulated groundwater particle pathlines (streamlines) and associated capture zones to the aquifer areas requiring groundwater capture. The areas requiring groundwater capture are represented by 5 micrograms per liter (µg/L) trichloroethene (TCE) concentration contours (isopleths) from September 2002. The 5-µg/L TCE isopleth is used as the capture criterion because TCE is reportedly the highest concentration COC that is consistently detected in groundwater above the aquifer cleanup level (ACL) of 5 µg/L. Location-specific capture evaluations are described in the following sections. Table 1 lists the average annual groundwater extraction and infiltration flow rates for all three locations.

3.3 OU 1

As previously noted, the OU 1 model (along with the models for OU 2 and Sites 2 and 12) simulates average annual pumping under steady-state conditions at the flow rates listed in Table 1. Figure 1 illustrates the simulated groundwater streamlines for those pumping conditions from January 2002 through December 2002. The streamlines predict groundwater flow directions and rates for this period. The streamlines were simulated by starting theoretical groundwater particles at extraction locations. The

MODPATH program calculated the particle paths backward, upgradient from the extraction point. The length of a streamline between arrows represents the predicted travel distance over one year.

The streamlines on Figure 1 predict that most of the southwestern part of the plume above the ACL is captured upgradient from extraction well EW-OU1-17A. The northern portion of the A-Aquifer plume, downgradient from extraction well EW-OU1-17A, however, is not captured. Analytical data indicate that the northern portion of the plume extends approximately 2,200 feet downgradient of extraction well EW-OU1-17A.

3.4 CALIBRATION CHECKS

A brief check of the calibration state was conducted for each model (Attachment A). Using GMS tools, simulated piezometric surface elevations were compared to groundwater elevations measured in September 2002. September 2002 data were used because they probably constitute the driest quarter of the year and thus represent a stress extreme for the models. The observed versus predicted groundwater elevation comparisons yielded error statistics shown on the layer-specific plots attached to this memorandum. The plots also illustrate calibration targets (observation or monitoring wells used to measure calibration) distributed over the model domains for each model layer. This is a powerful and informative presentation of model calibration that can focus attention on problematic areas of the models.

Calibration targets plot next to the monitoring well used for calibration. The target consists of a vertical line divided in half. The center of the target corresponds to the observed value (measured groundwater elevation). The top of the target corresponds to the observed value plus the calibration criterion interval (e.g., 2 feet) selected during model setup. The bottom of the target corresponds to the observed value minus the interval. The colored bar represents the error between the observed value and the model calculated value. If the bar lies entirely within the target, the color bar is green. If the bar is outside of the target but the error is less than 200%, the bar is yellow. If the error is greater than 200%, the bar is red (GMS, 2000).

The existing OU 1 and Sites 2 and 12 models provided calibration targets. No targets exist for model layer 2 in the OU 1 and Sites 2 and 12 models. No targets exist for layers 2, 4, or 5 in the OU 2 model. Observed values were updated using groundwater elevations measured during September 2002. The calculated errors (residuals) were statistically evaluated using mean error, absolute mean error, and root mean square error (RMS or standard deviation) (Anderson and Woessner, 1992). The calibration plots and error summaries are attached to this memorandum.

For the OU 1 model, layers 3, 4, and 5 exhibit acceptable error with root mean square errors (RMS or standard deviation) less than ±2.4 feet. Layer 1 exhibited an RMS of ±4.19, but calibration in the OU 1 region of the model was within the target range of ±2 feet.

It should be noted that the observed values were from measured groundwater elevations for September 2002, while the pumping and infiltration values were simulated as annual averages. Average pumping rates were used to provide continuity with previous model runs and capture evaluations for this site. The use of average annual pumping and infiltration rates instead of more specific rates during a shorter time period (i.e., September 2002 pumping and infiltration rates) can lead to larger apparent residuals than might be achieved if the more specific rates were modeled. This issue may explain some of the errors noted above.

3.5 LIMITATIONS OF THE ANALYSIS

As with all numerical modeling exercises, limitations and uncertainties in model input directly affect the model results. Model predictions (including the predicted particle pathlines used to evaluate capture herein), therefore, have the same uncertainties and limitations as the numerical model. Uncertainties include uncertainties in model input parameters (such as hydraulic conductivities, recharge, model water balance, or model boundary conditions). Uncertainty is also introduced given the steady-state model conditions. Real conditions are more dynamic (transient). For example, actual pumping rates fluctuate with time and season along with aquifer recharge and model water balance. The current models simulate average annual pumping and infiltration rates along with a fixed recharge value averaged over all model domains.

4.0 CONCLUSIONS

Most of the southwestern part of the OU 1 plume is predicted by the numerical model to have been captured when simulating average pumping for 2002. The northern portion of the A-Aquifer plume in OU 1 that is northwest of extraction well EW-OU1-17A, however, is clearly not captured. This portion of the plume continues to migrate northwest toward Monterey Bay.

5.0 REFERENCES

Anderson, M.P. and W.W. Woessner, 1992. *Applied Groundwater Modeling: Simulation of Flow and Advective Transport*. Academic Press. San Diego, CA. 381 p.

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Water Flow Model. Book 6, Chapter A1. Techniques of Water-Resources Investigations of the United States Geological Survey. U.S. Geological Survey (also Open-File Report 83-875).

Zheng, C., 1989. *PATH3D Version 2.0 User's Manual*. S.S. Papadopulos & Associates, Inc. July.

DISCLAIMER

This technical memorandum has been prepared for AGSL by URS. This document is intended to transmit the information developed by URS for capture analysis of the former Fort Ord groundwater remedies. The existing numerical groundwater flow and particle-tracking models were supplied by AGSL to URS and were developed by other parties. URS has relied on this information as furnished and is not responsible for and has not confirmed the accuracy of this information or other party interpretations of the information.

The limited objective of this memorandum, the ongoing nature of the former Fort Ord cleanup, along with the evolving knowledge of site conditions and chemical effects on the environment and human health, must all be considered when evaluating the memorandum because subsequent facts may become known that may make this document premature or inaccurate.

This memorandum has been prepared by URS under the review of registered and certified professionals. The interpretation of the data and the conclusions drawn were governed by URS experience and professional judgment.

TABLES

TABLE 1

Simulated Average System Pumping Rates
Annual Evaluation Report
January 2002 through December 2002
Groundwater Remedy at OU 1, OU 2, and Sites 2 and 12
Former Fort Ord, California

Well Name	Simulated Flow Rates (gpm) [1]
OU 1 Groundwater Treatment System	
Extraction	
EW-OU1-17-A	8
EW-OU1-18-A	0
OU 2 Groundwater Treatment System	
Extraction	
EW-OU2-01-A	31
EW-OU2-01-180	22
EW-OU2-02-A	26
EW-OU2-02-180	88
EW-OU2-03-A	4
EW-OU2-03-180	90
EW-OU2-04-A	42
EW-OU2-04-180	71
EW-OU2-05-A	27
EW-OU2-05-180	107
EW-OU2-06-A	16
EW-OU2-06-180	130
EW-OU2-07-A	19
EW-OU2-08-A	22
EW-OU2-09-A	18
EW-OU2-10-A	16
EW-OU2-11-A	20
EW-OU2-12-A	14
EW-OU2-13-A	17
EW-OU2-14-A	20
EW-OU2-15-A	14
EW-OU2-16-A	24
Injection	
INF-OU2-01-180	253
INF-OU2-02-180	218

TABLE 1

Simulated Average System Pumping Rates
Annual Evaluation Report
January 2002 through December 2002
Groundwater Remedy at OU 1, OU 2, and Sites 2 and 12
Former Fort Ord, California (Continued)

Well Name	Simulated Flow Rates (gpm) [(1)]
Sites 2 and 12 Groundwater Treatment System	
Extraction	
EW-12-01-U	2
EW-12-01-M	7
EW-12-02-U	19
EW-12-02-M	25
EW-12-03-U	25
EW-12-03-M	28
EW-12-04-U	36
EW-12-04-M	109
Injection	
IW-02-01	76
IW-02-02	80
INF-02-01	148
INF-02-02	241
INF-02-03	99
Water Supply Wells [(2)]	**Average 2001 Flow Rate (gpm)**
FO29	771
FO30	1,030
FO31	1,001

(1) Average annual flow rates.
(2) Data provided by Marina Coast Water District, Marina, CA.

gpm = gallons per minute
OU = Operable Unit

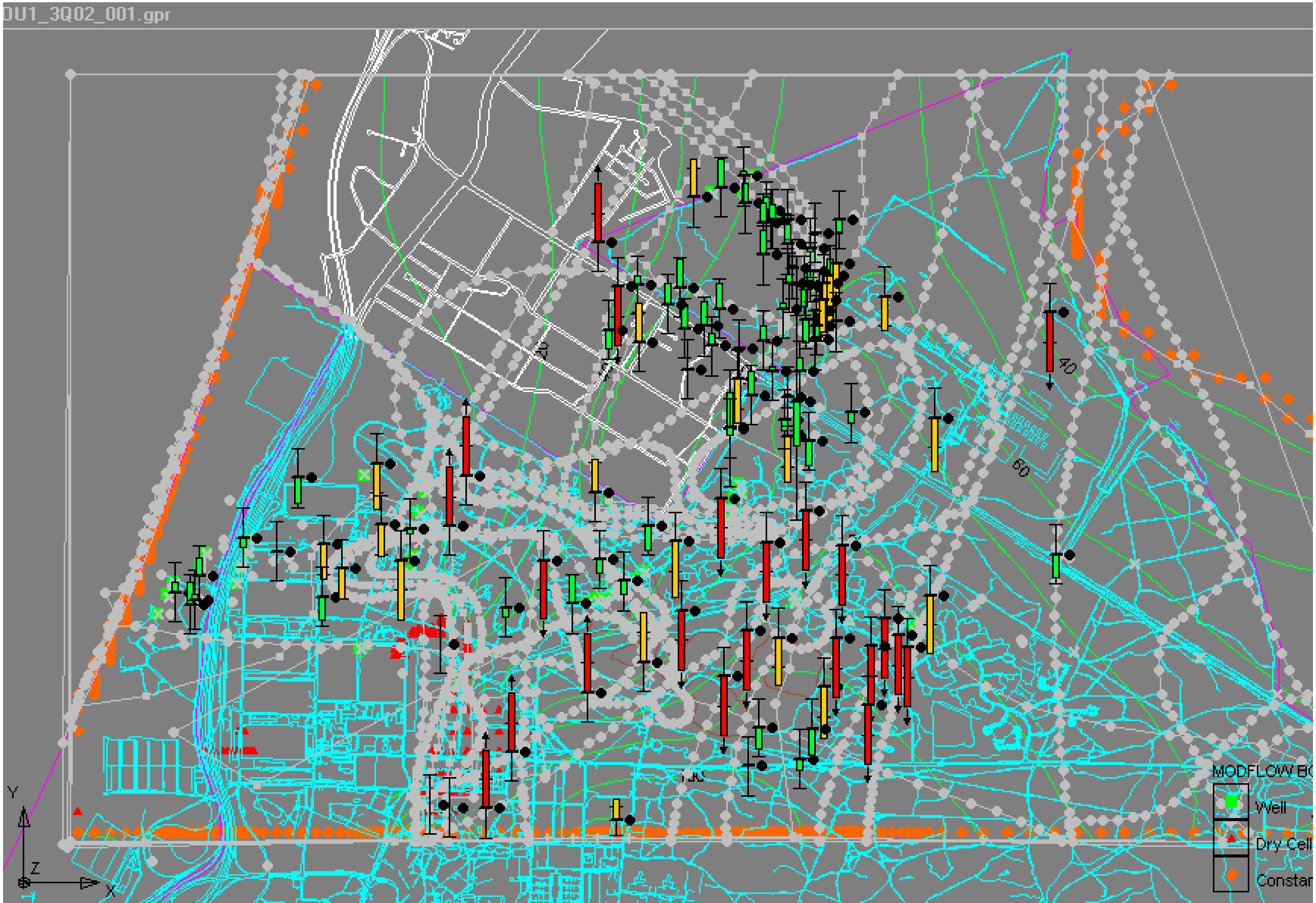
FIGURES

Figure 1

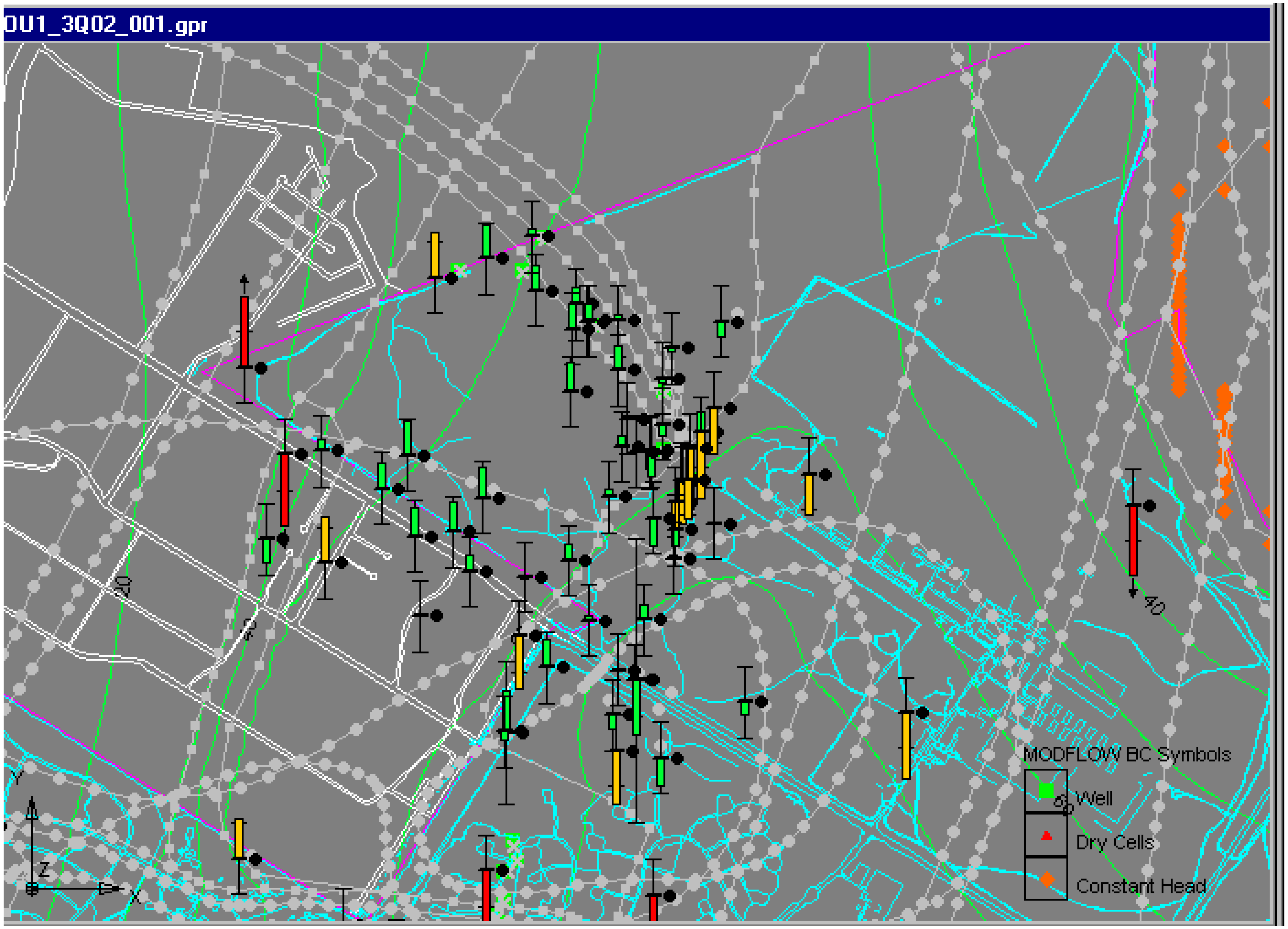
ATTACHMENT A

Calibration Check Plots

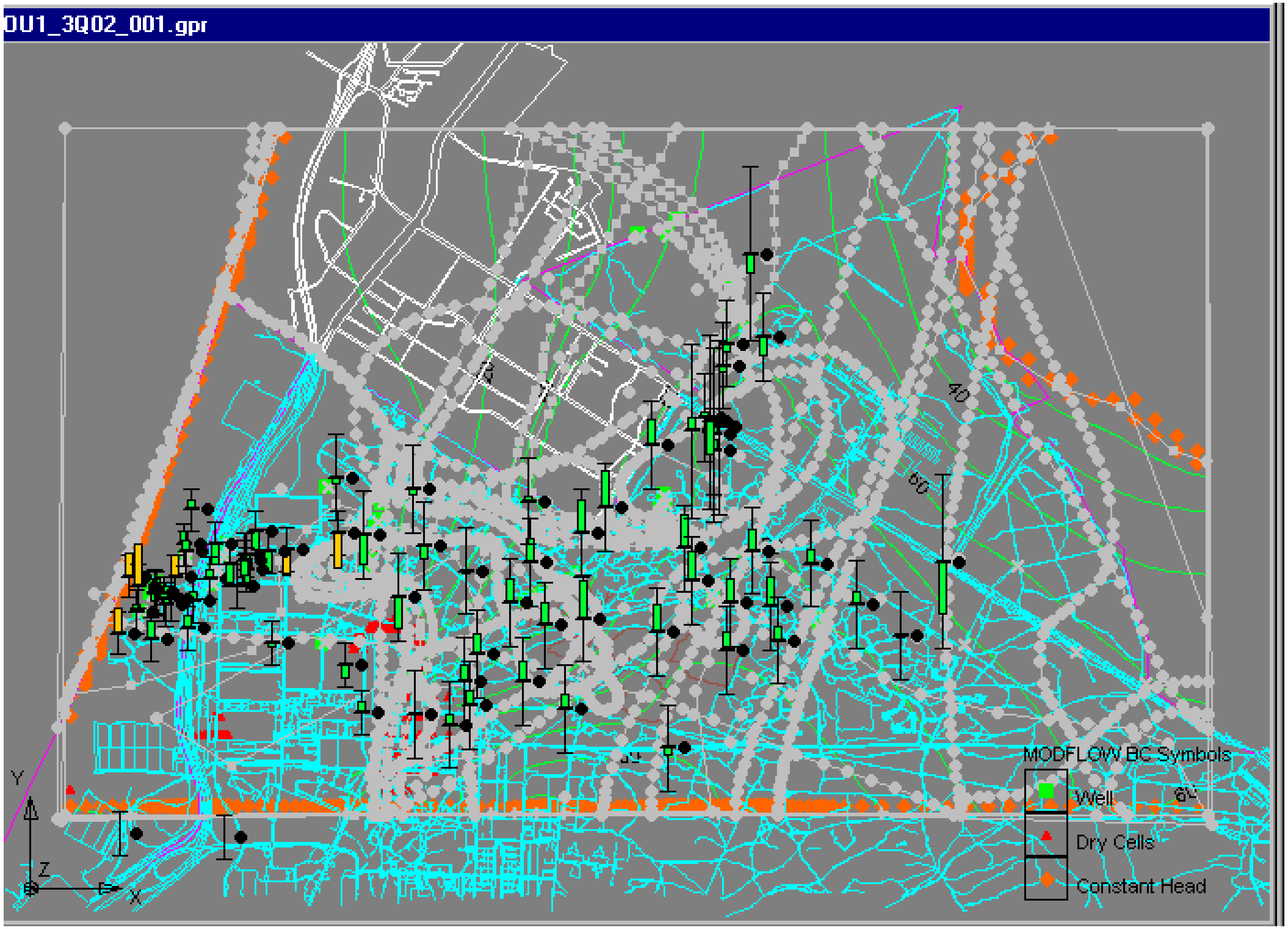
Fort Ord, OU1 3Q02 Layer 1



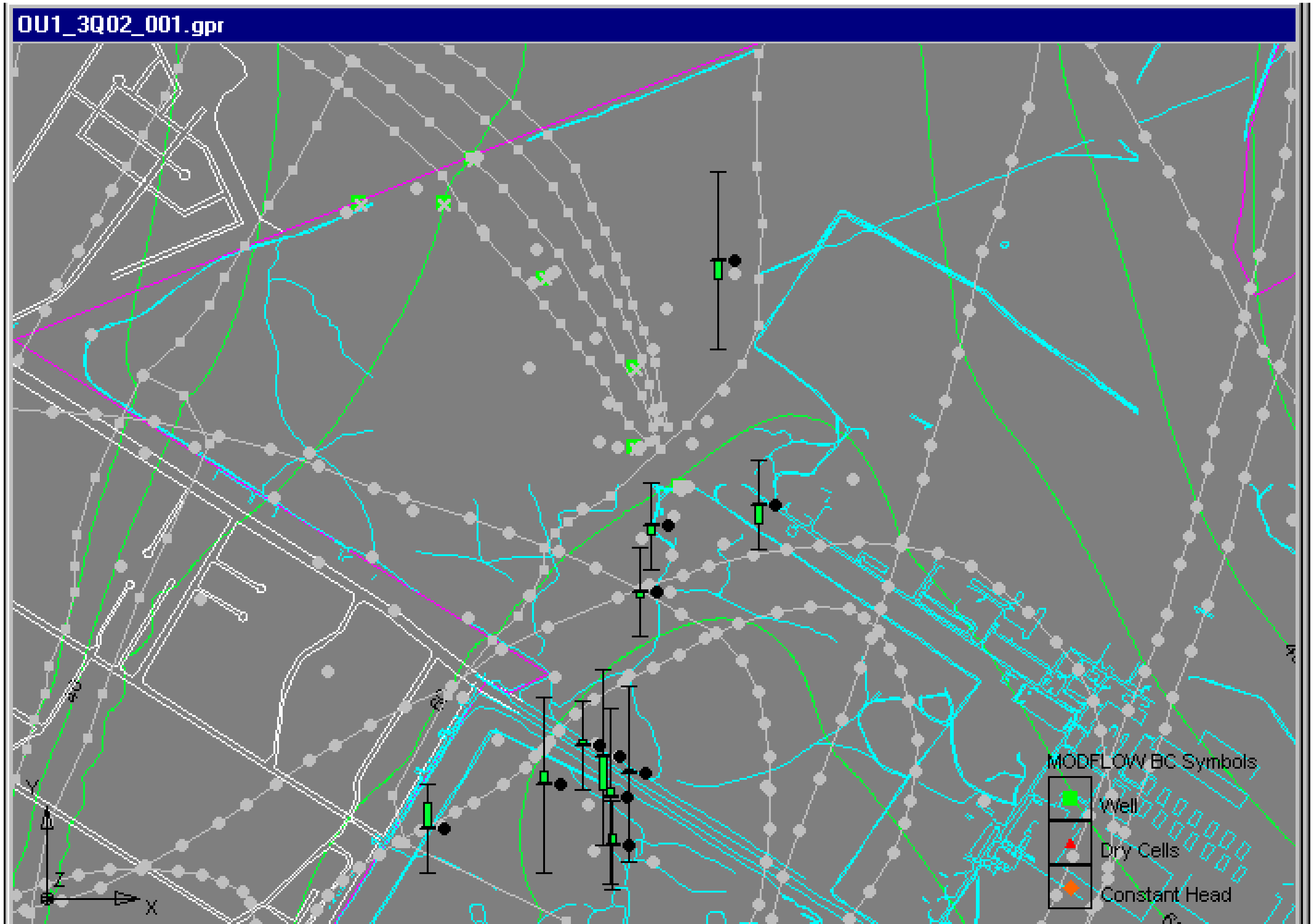
OU 1, 3Q02, Layer 1 Enlargement



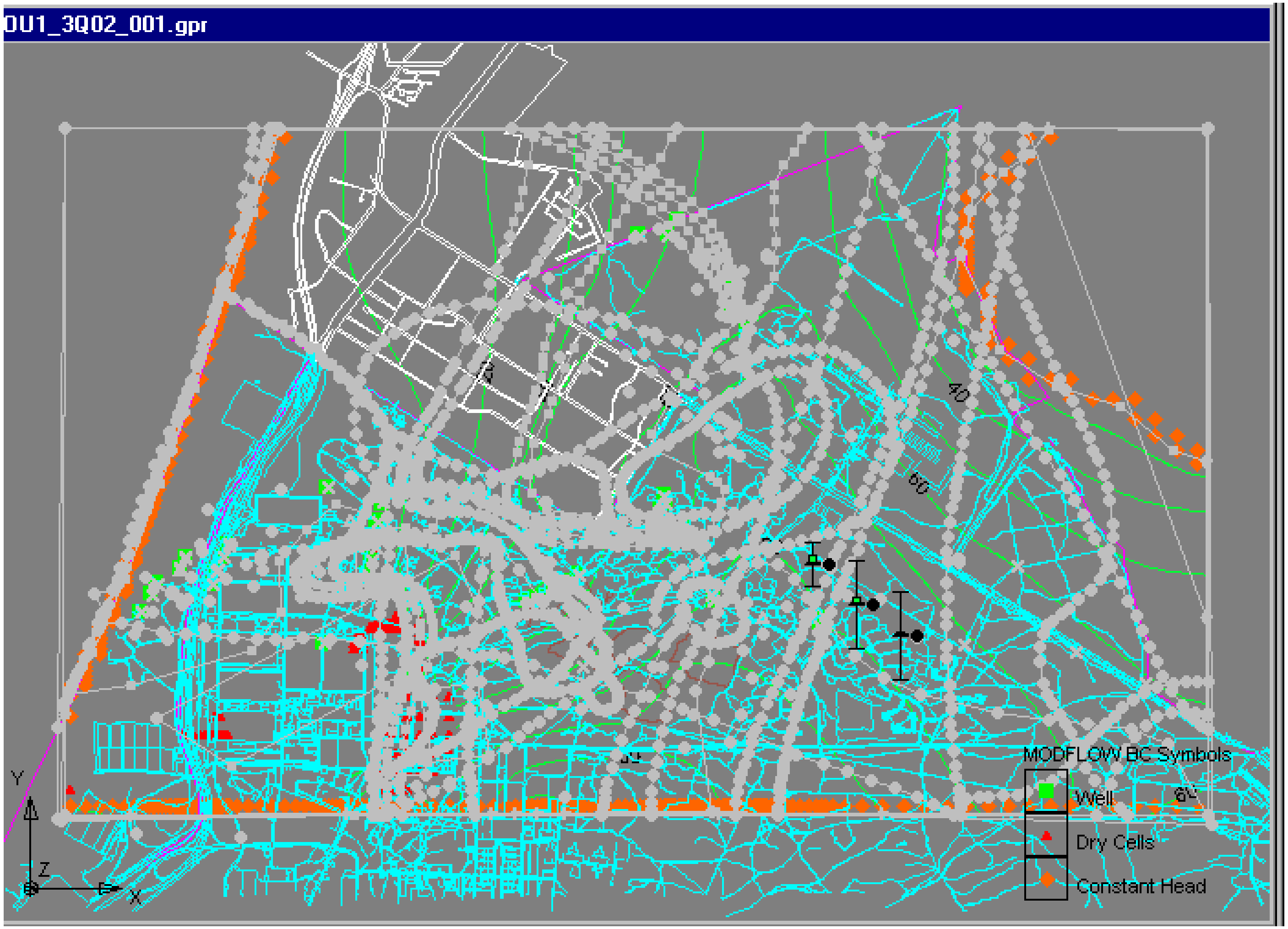
Fort Ord, OU 1, 3Q02, Layer 3



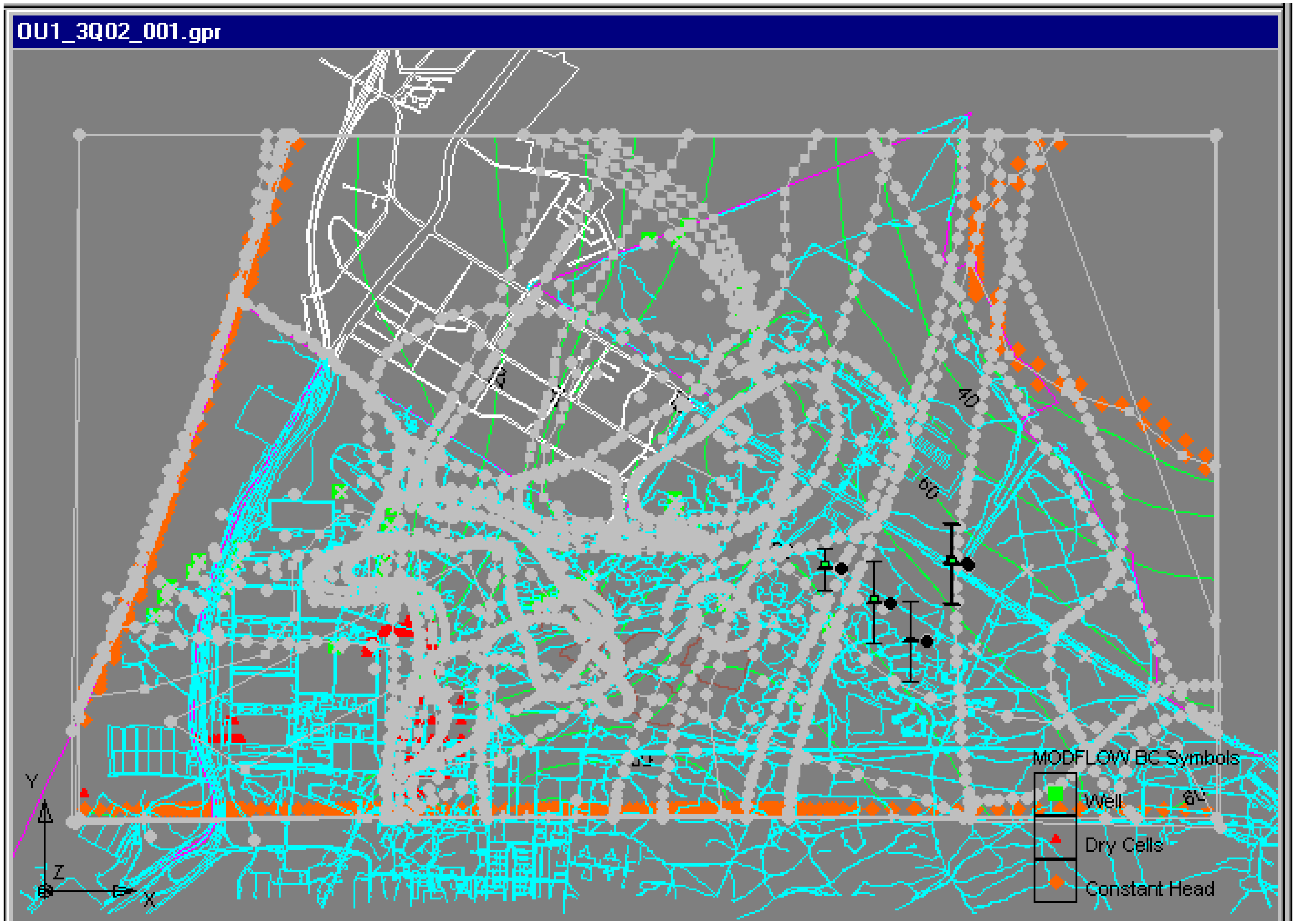
OU 1, 3Q02, Layer 3 Enlargement



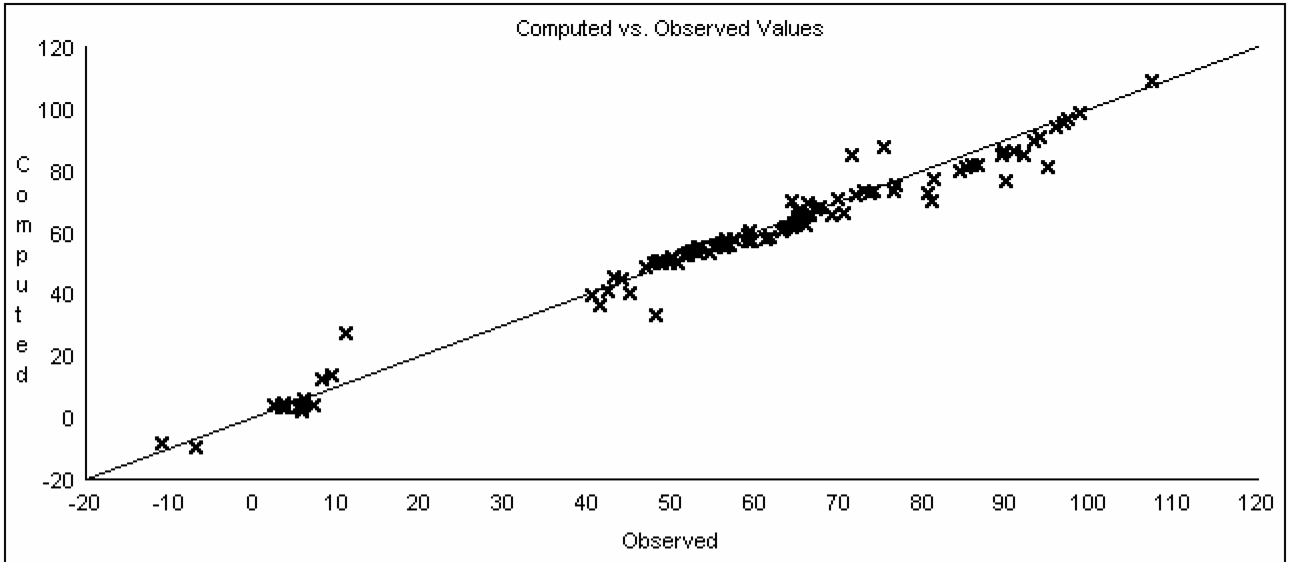
Ft. Ord, OU1, 3Q02, Layer 4



Ft. Ord, OU 1, 3Q02, Layer 5



OU1
Layer 1
A Aquifer



Error Summary

Solution / Data set: OU1_3Q02_002 / OU1_3Q02_002_Heads

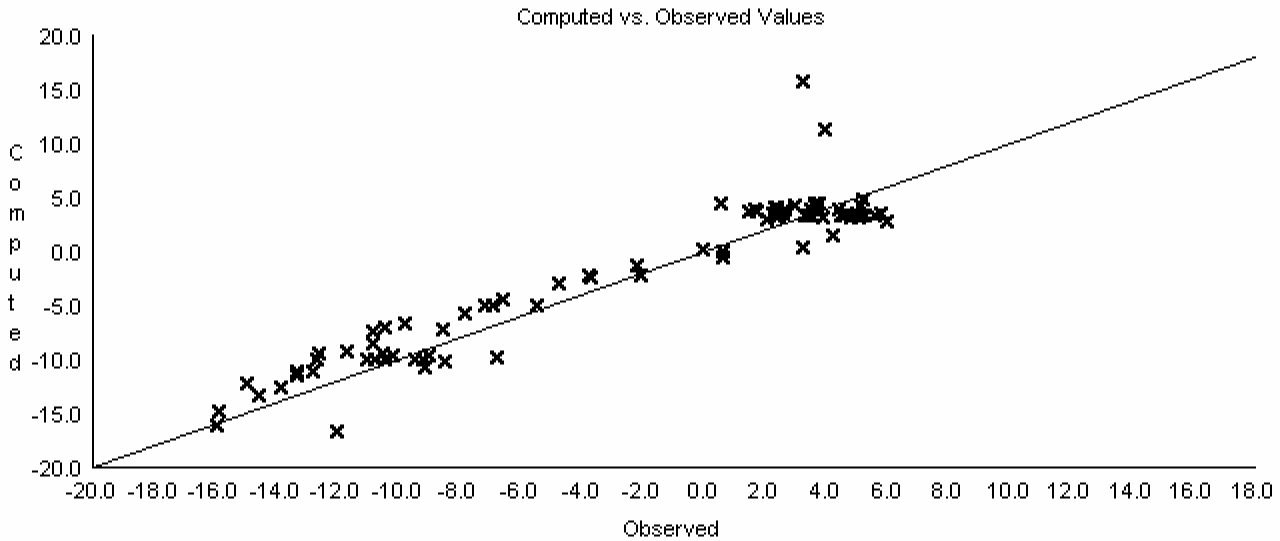
Observed measurement: sep-02

Mean error: -0.83

Mean abs. error: 2.70

Root mean sq. error: 4.19

OU 1
Layer 3



Error Summary

Solution / Data set: OU1_3Q02_002 / OU1_3Q02_002_Heads

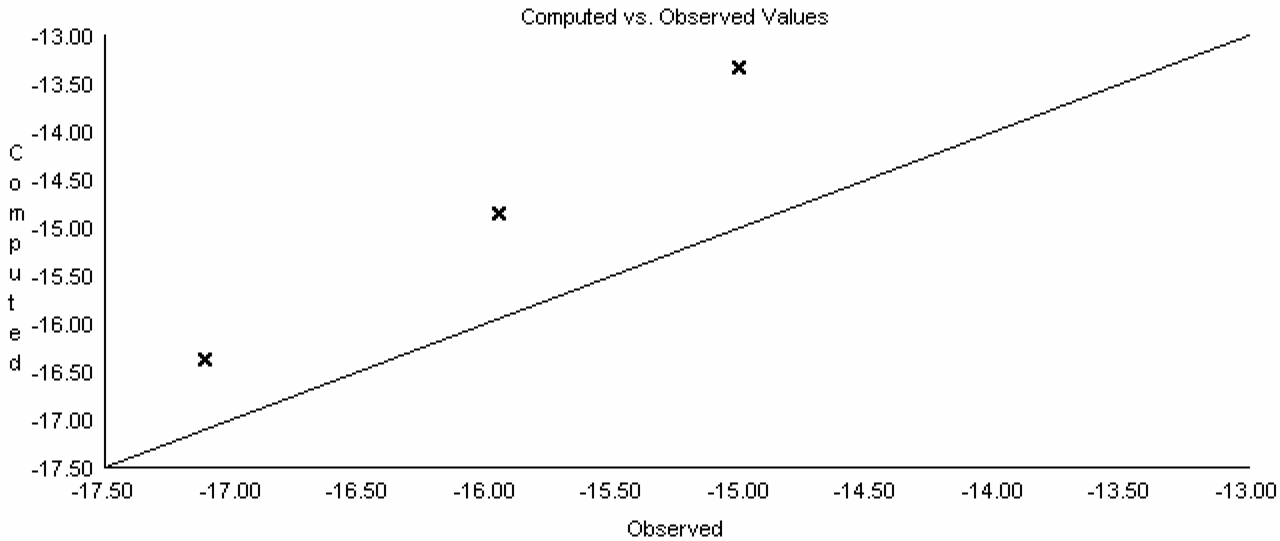
Observed measurement: sep-02

Mean error: 0.66

Mean abs. error: 1.72

Root mean sq. error: 2.40

OU 1
Layer 4



Error Summary

Solution / Data set: OU1_3Q02_002 / OU1_3Q02_002_Heads

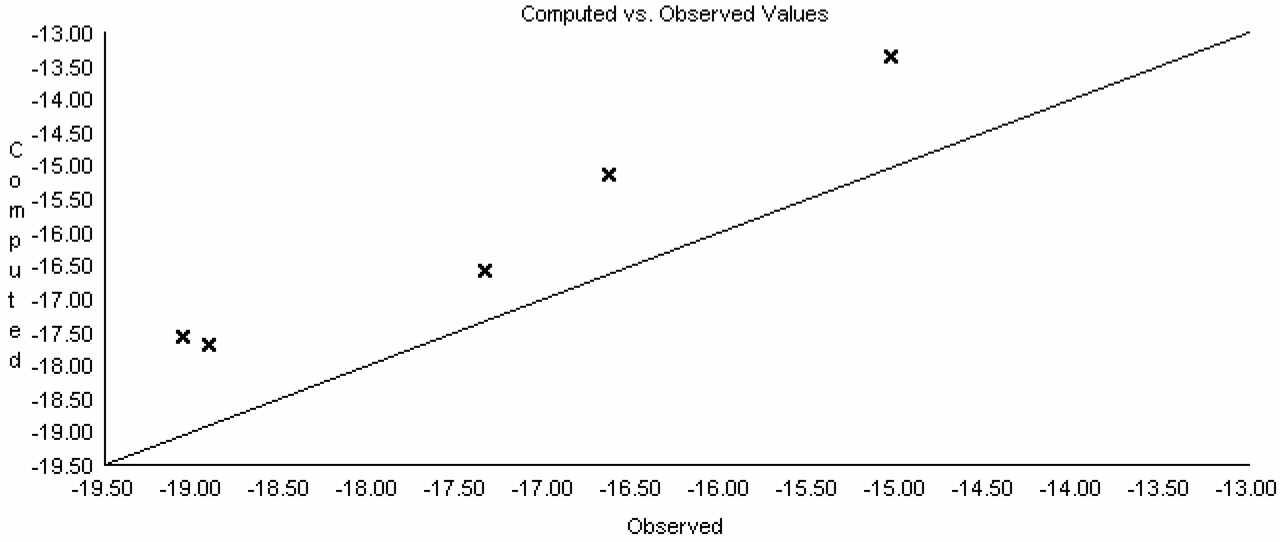
Observed measurement: sep-02

Mean error: 1.17

Mean abs. error: 1.17

Root mean sq. error: 1.23

OU 1
Layer 5



Error Summary

Solution / Data set: OU1_3Q02_002 / OU1_3Q02_002_Heads

Observed measurement: sep-02

Mean error: 1.33

Mean abs. error: 1.33

Root mean sq. error: 1.36