CHARNOCK INITIAL
REGIONAL RESPONSE ACTIVITIES
Charnock Sub-Basin; Los Angeles, California

Task 10.1.2
Numerical Groundwater Flow Model Report

Submitted to:

California Regional Water Quality Control Board,
Los Angeles Region

U.S. Environmental Protection Agency,
Region IX

On behalf of:

Shell Oil Company
Shell Oil Products Company
Equilon Enterprises LLC

Prepared by:

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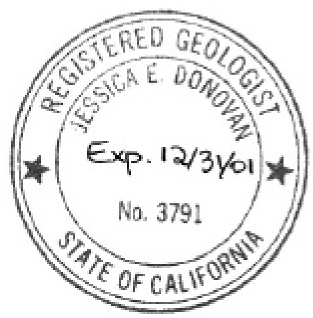

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EXECUTIVE SUMMARY

Pursuant to the Scope of Work of the California Regional Water Quality Control Board, Los Angeles Region (RWQCB) Stipulated Agreement (SA) No. 00-064 and the United States Environmental Protection Agency, Region 9 (USEPA) Administrative Order on Consent (AOC) USEPA Docket No. RCRA 7003-09-2000-0003, this Numerical Groundwater Flow Model Report (the "Report") is submitted to the RWQCB and USEPA (the "Agencies") by Shell Oil Company, Shell Oil Products Company, and Equilon Enterprises LLC (the "Respondents") in partial fulfillment of Task 10 of the *Scope of Work (SOW) for Initial Response Activities to Address MTBE and Other Gasoline Constituents in the Charnock Sub-Basin*. Work to fulfill the SOW is conducted as part of the Charnock Initial Regional Response Activities (CIRRA).

One of the more significant objectives of the SOW is to evaluate groundwater flow and the movement of gasoline-related constituents, including methyl tertiary-butyl-ether (MTBE) within the Charnock Sub-Basin under current conditions and a variety of remedial action scenarios. These objectives will be addressed through development and application of a numerical model of groundwater flow as described in this Report. The model allows the rapid synthesis, analysis, and interpretation of the hydrogeology of the Charnock Sub-Basin and contaminant migration pathways.

The conceptual description of the hydrogeology of the Charnock Sub-Basin was presented in the Task 9 Conceptual Flow and Transport Model Report dated August 17, 2000, In addition, aquifer properties were developed and refined in numerical modeling tasks undertaken by Geomatrix, the Respondents, Chevron Products Company ("Chevron"), and Exxon Company, USA ("Exxon") during a three-year period from 1996 to 1999. These activities included model calibration and model parameter sensitivity analysis.

The numerical model of groundwater flow presented herein is based on the model developed previously by Geomatrix. ENVIRON thoroughly reviewed the Geomatrix model and the needs of the CIRRA project and determined that two primary modifications were necessary. First, the model required extension of the grid to the northwest in order to model potential extraction in that area of the Sub-Basin. Second, improved prediction of water levels in the Shallow Aquifer was necessary to reproduce the observed westward gradient in and around the Sepulveda-Venice area. Aside from these two areas of focus, the revised model retains most of the characteristics of the Geomatrix model, including its degree of calibration and many of the hydrologic properties in the Silverado Aquifer and outlying areas.

Section 1.0 of the report presents a brief background of the site and the resulting motivation for the numerical model. It also outlines the modeling objectives relative to the CIRRA project. Finally, Section 1.0 highlights the steps taken in developing the numerical model.

Section 2.0 of this report summarizes and updates the conceptual model described in the Task 9 Conceptual Model Report. The primary update to the conceptual model is an increase in the amount of flow coming from the shallowest parts of the Overland Avenue Fault. The westward gradient observed in the Shallow Aquifer implies a source of water coming from the east. Although the results of ongoing field investigations will shed further light on the nature of the westward gradient and the source of the water, a more permeable Overland Fault in the shallowest hydrostratigraphic layers provides an explanation for both the westward gradient and the downward vertical gradients observed east of Interstate-405. Other modifications to the conceptual model include the apparent thinning of the Shallow Aquitard to the northwest of the Well Fields and a reduced slope of the top of that aquitard to the northeast of the Well Fields.

Section 3.0 describes the computer codes chosen for numerical modeling.

Section 4.0 presents the numerical model design, including the grid, the modeled parameters, the boundary conditions, and their relationships to the conceptual model. Many of the parameters from the Geomatrix model were retained and are described in this section. This section also describes the methods used to extend the grid, including addition of boundary conditions at the foot of the Santa Monica Mountains and extension of hydrologic parameters between the former boundaries of the model and the new boundaries.

Section 5.0 describes the model calibration. Three different calibration periods were selected for the model. The first calibration period represents the period between 1993 and 1995 when Well Field pumping was relatively constant; this period was then modeled as pseudo-steady-state. Although water level data were not widespread during this period, it provides an approximate calibration measure, and the simulation then allows a measure of where the water sources are to the Sub-Basin during pumping conditions. The results of this calibration period provide the initial water levels to the second calibration period, which is from 1995 to 2000. This period includes the last year of extraction at the Charnock Well Fields followed by the regional recovery. During this period, additional wells were installed as part of individual site investigations and a regional monitoring program, permitting greater calibration to water levels. This calibration period was emphasized the most. During this period, Geomatrix conducted a three-day regional aquifer test at the Charnock-16 well, located at the City of Santa Monica (COSM) Well Field. The third calibration period is a simulation of this aquifer test using the wells that were monitored during the test.

These calibrations were evaluated in slightly different ways, based upon the availability of data and upon the conceptual features they were to represent. The early steady-state period was evaluated primarily through approximate matches to water levels. During this period, water level data often were associated with extraction wells, perched wells, or wells cross-screened across multiple hydrostratigraphic layers. As a consequence, only approximate calibration to available data was done. Comparison of the numerical water budget to the conceptual water budget then demonstrated similar distribution of water sources.

The longer calibration period was evaluated through comparison of hydrographs to data, water level calibration statistics, and review of the Shallow Aquifer gradient predicted by the model relative to observed data. Hydrographs showed generally good fits of model predictions to observed data. Calibration statistics were also good, slightly better than those obtained using Geomatrix's original model. The model also showed a westward gradient of approximately the correct magnitude and direction.

The aquifer test calibration was evaluated through hydrographs and through standard calibration statistics. The model and the data showed drawdown response occurring in the Silverado Aquifer as far south as the Sepulveda-Venice area. Drawdowns in the Shallow Aquifer were generally less, and the model represented most of these adequately.

During calibration, two primary modifications were made in order to achieve the modeling objectives. The first, as mentioned above, was the increased permeability of the Overland Avenue Fault, allowing greater flow of water in from the Crestal Sub-Basin. The hydraulic conductivity of the hydraulic flow barrier representing this fault was increased to 1 ft/d, which was enough to allow water to flow while maintaining a significant head drop across the fault. The second adjustment was to lower the elevation of the top of the Shallow Aquitard in two areas based on a review of existing data along with preliminary results from the CIRRA Task 12 regional investigation. The first area was between the Overland Avenue Fault and the Sepulveda-Venice area. The second area was generally northwest of the Well Fields. Lowering the top of aquitard elevations allowed any flow of water from the east to better reproduce the observed westward gradient in the shallow aquifer.

Section 6.0 outlines the sensitivity/uncertainty analysis carried out on the model. Based on the ranges of data values for hydrologic parameters and boundary conditions, ENVIRON carried out both a point-sensitivity analysis and more refined sensitivity analysis of the Shallow Aquifer gradient. The point-sensitivity analysis identified the areas of the model where changes to hydraulic conductivity, storage, or boundary conditions most affected the 1995-2000 calibration statistics. This sensitivity analysis suggested that the storage and specific yield, which control the rise of water levels in the Shallow Aquifer, tend to be the most important factors in optimizing calibration statistics. The sensitivity to the Shallow Aquifer gradient was evaluated by examining the magnitude and direction of the observed and computed gradients relative to important parameter values, such as the hydraulic conductivity of the Overland Avenue Fault. Although increasing the conductivity of this fault would improve the match to the observed westward gradient magnitude, it would also cause the modeled water levels to be too high.

A third type of sensitivity analysis was also carried out. This sensitivity is of the model to predictions in long-term water levels as a consequence of various extraction rates in the Charnock Sub-Basin. Since the model may be used for an analysis of the safe yield of the Sub-Basin, a preliminary evaluation procedure of safe yield was outlined. For two extraction rates, 6,000 and 8,000 ac-ft/yr, water levels were modeled using the base model and various modifications of the model to evaluate whether the model made different predictions with the modifications. Sensitivity to fault conductances was observed, although the greatest differences were found using fault conductances that generally caused poor calibration. In general, the 8,000 ac-ft/yr simulations consistently showed mining of water from the adjudicated West Coast Basin and declining water levels even after 40 years of pumping.

These simulations also consistently projected the Shallow Aquifer going dry in the Sepulveda-Venice area, potentially inhibiting local remediation systems. Most simulations of 6,000 ac-ft/yr extraction, on the other hand, did not cause water levels to drop below the bottom of the Shallow Aquifer at Sepulveda-Venice. These simulations also reached a nearly stable water level profile after 40 years that does not mine water from the West Coast Basin.

A brief summary of how the model is planned to be used for analyzing remedial alternatives and the potential refinements necessary for that work is presented in Section 7.0.