APPENDIX C

GROUNDWATER FLOW AND SOLUTE TRANSPORT MODELING REPORT
IRIGARAY ISL OPERATION

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APPENDIX C

GROUNDWATER FLOW AND SOLUTE TRANSPORT MODELING REPORT IRIGARAY ISL OPERATION

C.1 INTRODUCTION

As part of the Ground-water Restoration report to demonstrate evidence for mine closure, a numerical groundwater flow and transport model was developed to evaluate the future migration of constituents derived from the Irigaray uranium in-situ leach (ISL) operation in Johnson County, Wyoming. The focus of the model is on reduction of dissolved constituent concentrations resulting predominately from advective flow and dispersion phenomena. Model results indicate that constituent concentrations will be below WDEQ regulatory standards within 400 feet of the ISL wellfield. This report documents the strategy, conceptualization, development, assumptions, calibration and results of the Irigaray groundwater flow and solute transport model.

C.2 MODEL OBJECTIVES/STRATEGY

As discussed in Sections 1, 2 and 4 of the Restoration Report, the Irigaray ISL uranium mine was in production from 1978 through 1994. Production was from the Upper Irigaray Sandstone (UISS) of the Wasatch Formation. Nine mine units, covering an area of 30 acres and utilizing over 1,000 wells, were included in the production operation.

Recovery of uranium resulted in elevated groundwater concentrations of a number of constituents. Restoration of the aquifer has been ongoing since 1990. As discussed extensively in Section 4, the restoration process has significantly reduced constituent concentrations in groundwater. However, concentrations of some constituents remain above WDEQ Class-1 regulatory standards within the boundary of the wellfield.

A groundwater flow and transport model has been developed to assess fate and transport of residual constituents derived from the Irigaray ISL mine. The model was constructed using conservative and simplifying assumptions to address offsite migration under the influence of the regional hydraulic gradient. The objective of the model was to demonstrate that residual concentrations will be below WDEQ regulatory standards at prescribed observation points located approximately 400 feet downgradient from the wellfield boundary.

The complex production and restoration history of the Irigaray ISL mine makes it impractical to attempt to replicate the hydraulic stresses that have been imposed on the UISS aquifer. Furthermore, the focus of this assessment is on the future migration potential of site-derived constituents without additional restoration activities. The model is used to evaluate continued migration under steady-state conditions, without pumping or injection. Therefore, the emphasis on the development of the model is to adequately represent steady-state advective flow within and across the production zone.

Many environmental studies attempt to demonstrate concentration reduction of inorganic constituents with the use of geochemical reaction models. While geochemical processes such as sorption and precipitation undoubtedly contribute significantly to the removal of contaminants from groundwater, the parameters required to develop defensible geochemical reaction models are often difficult to obtain. Many of the processes are dependent on redox conditions that are difficult to quantify or are based on equilibrium assumptions that may or may not exist.

The approach taken for this evaluation is to develop a model that is predominately dependent on advective transport and minimizes reliance on geochemical reactions. The parameters required to simulate steady-state groundwater flow and advective transport include hydraulic conductivity, hydraulic gradient and effective porosity. Each of these parameters has been quantified for the Irigaray site and appropriate values are incorporated into the model. A dispersivity term is included in the model simulations based on the scale of the site and an extensive literature review.

A distribution coefficient (Kd) was included in the model simulations for some constituents. For those simulations, the lowest reasonable Kd available from literature was used. It is noted that while Kd values were used for applicable constituents, complete conservation of mass was assumed. Namely, application of the distribution coefficient retards transport, but no solute is removed from the system by geochemical processes. Minimizing reliance on geochemical processes is extremely conservative and results in overprediction of constituent concentrations downgradient of the site.

Uncertainty in model parameters was addressed with a sensitivity analysis. Although the model incorporates a number of conservative assumptions, the results support a natural attenuation strategy for addressing residual contaminants from the Irigaray ISL site.

C.3 CONCEPTUAL MODEL

Regional and site-specific data were reviewed to develop a conceptual understanding of geologic, hydrogeologic, and, to a limited degree, geochemical conditions at the Irigaray ISL mine site. Much of this information is provided in Section 3 and Appendix B of the Wellfield Restoration Report. A brief summary of the conceptual model follows.

The study area includes the Irigaray ISL mine site and surrounding areas. The aquifer under study is a 100-foot thick sand unit within the Wasatch formation, identified as the UISS, located with the Powder River Basin of Wyoming. The UISS dips to the north at approximately 0.1 degrees.

Typical of roll front deposits, the uranium ore is distributed throughout the host sand. Subsequently, mining has been conducted at varying depths and locations in the UISS. The majority of the UISS has not been mined or significantly impacted by mining operations (historical flare is less than 10 percent); the average completion interval for

the ISL wellfield is 18 feet. For these reasons, only a portion of the UISS (21 feet) was assigned as the "mineralized zone" designated as Layer 2 in the model. Following similar rationale, the portion of the UISS not impacted by mining (Layers 1 and 3) were assigned thicknesses of 39 and 40 feet, respectively. Additional discussion regarding the thickness of the mineralized zone is provided in Appendix B.

The ISL wellfield covers an area of 30 acres and is approximately 4,000 feet long and 700 feet wide. The portion of the UISS underlying the mineralized zone (Layer 3) is represented in the model as 40 feet thick and the overlying unit (Layer 1)is 39 feet thick. The bottom elevation of the UISS is 4,090 ft amsl at south end, and 4,080 ft amsl at the north end. The top of the UISS is at 4,190 ft amsl at the south end and 4180 ft amsl at the north end. Ground surface is ranges from 4,300 to 4,450 ft amsl. The top of the UISS is relatively flat, and ranges in depth from 120 to 270 ft below ground surface.

There are no confining units between the production zone and the two non-mineralized zones of the UISS. However, the UISS aquifer is bounded above and below by confining units. A confining continuous claystone/interburden unit approximately 60 feet thick overlies the UISS aquifer. Beneath the UISS aquifer is a 20 to 60 foot thick shale and silt unit. The shale/silt unit hydraulically separates the UISS from the Lower Irigaray Sandstone. Based on pre-mining (1978) and post-mining (2002 and 2003) water-level measurements, groundwater flow across the site is generally to the northwest with a hydraulic gradient of 0.005 ft/ft. Transmissivity of the UISS within the wellfield ranges from 40 to 120 ft^2/d and storativity ranges from 8 x 10^{-5} to 7 x 10^{-4}. Hydraulic conductivity ranges from 0.4 to 1.1 ft/d. Porosity of the mineralized zone is fairly consistent, and averages 24 percent. For the non-mineralized zone, the average porosity is 29 percent. Based on these site-measured parameters, groundwater velocity under the steady-state ambient hydraulic gradient is on the order 0.01 feet/day or 3.7 feet/year.

There are no perennial rivers, streams or surface water bodies in the immediate vicinity of the wellfield. There is no current pumping or injection occurring within or near the wellfield. Water levels have been recovering to near static levels since completion of restoration activities in late 2001.

Uranium recovery operations resulted in elevated concentrations within the UISS of a number of constituents including; uranium, radium-226, selenium, manganese and TDS. Aquifer restoration activities have significantly reduced concentrations of the indicator parameters (see Section 4) but residual concentrations remain in the wellfield above regulatory standards. Results of the modeling discussed in this report demonstrate that, without additional restoration activities, offsite migration will be mitigated by advective transport processes.

C.4 MODEL CODES

Three-dimensional analysis of groundwater flow in the UISS aquifer system was performed with the finite difference groundwater flow model (MODFLOW) developed by

the U.S. Geological Survey (USGS) (McDonald 1988, 1996). MODFLOW was selected for simulating groundwater flow at the Irigaray site because it is capable of a wide array of boundary conditions, in addition to being a public domain code that is well accepted in the scientific community. MODFLOW can be used to simulate transient or steady-state saturated groundwater flow in one, two, or three dimensions. The code simulates groundwater flow using a block-centered, finite-difference approach. Modeled aquifers can be simulated as unconfined, confined, or a combination thereof.

Advective transport in the UISS aquifer system was evaluated using MODPATH, developed by the USGS (Pollock 1989, 1994). MODPATH was selected for the Irigaray model because it is compatible with MODFLOW outputs, is suitable for flowpath analysis of steady-state or transient simulations, and is a widely accepted public domain code.

MT3DMS, developed by the U.S. Army Engineering Research and Development Center (Zheng and Wang, 1999) was selected as the contaminant transport code for the Irigaray model because it is capable of simulating advection, dispersion/diffusion and chemical reactions of contaminants in groundwater flow systems under a variety of hydrogeologic conditions. The code has options for several solution techniques, can simulate multi-species transport, and is fully compatible with MODFLOW outputs.

In addition to the computer codes MODFLOW, MODPATH, and MT3DMS, a pre-processor was used to assist with data input and a post-processor was used for contouring the modeling results and providing graphical outputs. The pre-processor used in the modeling effort was Groundwater Vistas, Version 3.0 (Environmental Simulations, 2001). The post-processor was Surfer for Windows, Version 7.0 (Golden Software, 1999).

The solver used within MODFLOW was the preconjugate gradient solver (PCG2) developed by M.C Hill (USGS). The PCG2 method for solving a set of linear equations is iterative. Convergence of the solver is determined using both head change and residual criteria. The PCG2 solver was selected because it provides a good match for the mathematical problems to be assessed at Irigaray, and is more efficient than other solvers available with the Groundwater Vistas packages.

C.5 MODEL DEVELOPMENT

C.5.1 Model Domain/Grid

The model grid encompasses approximately one square mile with dimensions of 7,250 feet by 4,800 feet. The model grid is centered over the Irigaray ISL Wellfield (Figure C-1) and is rotated 15 degrees northwest. For comparison to previous submittals, mine coordinates are included on Figure C-1.

The model consists of 290 rows by 192 columns in 3 layers for a total of 167,040 finite difference cells. A uniform cell dimension of 25 feet by 25 feet was used throughout the

model domain. The central layer (Layer 2) represents the mineralized zone. Layer 2 is assigned a uniform thickness of 21 feet. As previously stated, the mineralized zone thickness averages 18 feet, consistent with detailed site information and data from Harshman (1974) related to the typical thickness of roll-front deposits. However, to account for flare (typically less than 10 percent), a Layer 2 thickness of 21 feet is used. As demonstrated in the sensitivity analysis provided later in the this document, this is a conservative value.

Layers 1 and 3 represent the bounding non-mineralized sand unit above and below the production zone. The thickness of Layer 1 and 3 are 39 and 40 feet, respectively. All three layers are simulated as distinct units, however, no boundaries were input between the layers themselves.

C.5.2 Boundary Conditions

Boundary conditions imposed on a numerical model define the external geometry of the groundwater flow system being studied as well as hydrologic stresses within the model domain. Three types of boundary conditions include specified-head, specified-flux and head-dependent flux boundaries. Boundary conditions assigned in the model were determined from observed conditions.

The specified-head boundary condition in MODFLOW is implemented as a constant-head or constant water-elevation boundary. The head at a constant-head boundary is specified independently of the simulation results, and is fixed at the specified value throughout the simulation. Constant head boundaries should be included in any model to insure non-zero matrix eigenvalues and solution convergence (Kipp 1987). The constant head boundary condition was used in the Irigaray model. Constant heads are assigned along the south-southeast boundary of the model. The values assigned to the constant head boundaries are based on potentiometric surface maps generated from data collected from the Irigaray groundwater-monitoring network. There is no indication that vertical gradients exist within the sand unit that is represented by the three layers. Therefore, the constant heads were assigned to all three layers to replicate a horizontal flow system.

The head-dependent flux boundary condition may be implemented in MODFLOW in several ways including; general-head boundaries, drains, rivers and evapotranspiration. The head dependent flux boundary is typically used when flux entering or exiting the groundwater flow model is dependent upon the head difference between the model and a constant level outside the model. The source/sink is connected to the model through a conduit aquifer material. The conductance of the aquifer material may be estimated as (McDonald 1988):

$$C = K A / b$$

where:

K is hydraulic conductivity,
A is the area across which flow occurs,

b is a representative distance.

McDonald & Harbaugh further describe the implementation of the head-dependent flux packages. The general-head boundary condition and package was used in the Irigaray model. General head boundaries were assigned to the remaining three sides of the model. The values assigned to the general head boundaries are based on potentiometric surface maps generated from data collected from the Irigaray groundwater-monitoring network. As with the constant head boundaries, identical general head boundaries were assigned in each of the three model layers to represent horizontal groundwater flow. There are no perennial rivers or streams within the model domain, therefore the river and drain packages of MODFLOW were not used. Evapotranspiration was not considered in the model because of the depth of the aquifer.

The specified flux boundary condition is implemented in MODFLOW as recharge, well injection/extraction, and the no-flow (flux equals zero) boundary condition. The recharge and well packages were not utilized for the following reasons. Vertical recharge was not considered in the model because the sand is located over 100 feet below ground surface and has been extensively demonstrated to be confined (see Section 3 and Appendix B for additional information). Regional recharge to the aquifer occurs upgradient of the site in areas where the sand crops out, approximately 3 miles away. The well package was not used for the baseline simulations because all pumping within the modeled aquifer has stopped. However, the well package was incorporated into the validation simulation as described later in this document.

The no-flow boundary condition allows specification of those areas that are outside the model domain and do not contribute flow to the model domain. Although the no-flow boundary was not explicitly assigned to any cells within the model domain, it should be noted that the base of Layer 3 and the top of Layer 1 represent no flow boundaries for the Irigaray model (based on the confining units previously described). All recharge and discharge occurs laterally through the general head and constant head boundaries at the perimeter of the model and vertically between the model layers.

The locations of the general head and constant head boundary conditions are illustrated in Figure C-1.

C.5.3 Parameter Zonation

Parameters entered into MODFLOW for the Irigaray model included hydraulic conductivity, bottom elevation, top elevation, and storage coefficient and porosity of the UISS aquifer system.

- Hydraulic conductivity zonation was based on pumping test data collected during exploration and operation of the Irigaray wellfield. A summary of the pumping test data is provided in Table C-1. A value of 1.0 feet/day was used for Layers 1 and 3 (the non-mineralized zones) and a value of 0.5 feet/day was used for Layer 2 (the mineralized zone). An extensive discussion of hydraulic conductivity data,

as well as other physical parameters of the UISS is found in Appendix B of this report.

- Porosity used in the model for the mineralized zone (Layer 2) was 25 percent. A porosity value of 29 percent was used for the non-mineralized zones (Layers 1 and 3) (see Appendix B for additional discussion).

- Bottom and top elevations for the UISS aquifer were based on structure maps derived from site boring logs. The model was constructed such that each layer had a uniform slope and a uniform thickness. The bottom elevation of Layer 3 represents the base of the UISS aquifer system. The bottom elevation of Layer 3 ranges from 4,090 feet at the southeast side of the model to 4,080 feet at the northwest side of the model. The thickness of Layer 3 is 40 feet. The top of Layer 3 coincides with the bottom of Layer 2, and the top of Layer 2 coincides with the bottom of Layer 1. Layer 2 is 21 feet thick and Layer 1 is 39 feet thick. The top of Layer 1 represents the top of the UISS aquifer and ranges from 4,190 feet along the southeast side of the model to 4,180 feet along the northwest side. Figure C-2 illustrates a cross sectional view of the model layers.

C.6 MODEL CALIBRATION

Calibrating a numerical groundwater flow model involves adjusting model parameters to obtain an acceptable correlation between field measured values and model predicted values of heads and fluxes (Woessner, 1992). The calibration procedure is generally executed by varying estimates of model parameters (hydraulic properties) and/or boundary condition values from a set of initial values until an acceptable match of calculated and observed water levels and/or flux is achieved. This process is known as inverse modeling and can be accomplished using manual trial and error methods or with automated calibration techniques. In addition to observed water levels and flux, groundwater velocity and flow direction are also considered in model calibration (Duffield, 1990). Successful calibration of a flow model to observed water levels, velocities, and flow directions, enables the model to be used in the predicted travel times and transport of dissolved constituents.

Adequacy of model calibration is judged by examining model residuals. A residual (as defined for use in this report) is the difference between the observed groundwater elevation and the groundwater elevation predicted by the model. Model convergence should be accompanied by minimizing the residual mean, residual standard deviation, and residual sum of squares (RSS) (Duffield 1990). The residual mean 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, a negative sign indicates overprediction. 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 1992). The RSS is computed by adding the square of each

residual and is a measure of overall variability. For a statistically accurate model calibration, the residuals and the statistics based on the residual should approach zero.

C.6.1 Calibration Targets

Calibration targets are a set of field-measured values, typically groundwater elevations and flux measurements, to which model predicted values are compared. One of the difficulties in selecting a representative set of calibration targets for the Irigaray model is that the aquifer system is rebounding from years of hydraulic stress imposed by production and restoration activities. As previously stated, it is impractical to simulate the entire hydraulic history of the Irigaray ISL mine. The purpose of the model is to simulate future migration of site-derived constituents under ambient hydraulic gradients. Therefore, the targets used to calibrate the Irigaray model should be representative of the natural steady-state hydraulic gradient for the UISS aquifer system. Unfortunately, few thorough and defensible water-level data were collected prior to mining operations. For this reason, the following method was used to select a suitable data set for use in calibration of the Irigaray model.

Data collected since the end of 2001 show that water levels have been steadily rising across the site and that the increase is relatively uniform (Figure C-3). Although water levels will continue to rise in the near future, the hydraulic gradient across the site will remain relatively constant. A comparison of the hydraulic gradients measured between December 2001 and October 2002 is shown in Table C-2. Figure C-4 shows the locations of the transects used to calculate the hydraulic gradients. Although water levels generally increased across the site by 10 to 15 feet during that period, the change in hydraulic gradients was less than 10 percent. Based on this analysis, water level data sets collected during 2002 are considered to be representative of long-term steady-state hydraulic gradients across the Irigaray ISL mine site and are suitable for use as calibration targets. The hydraulic gradient was also calculated based on more recent data (June and December, 2003) collected after the modeling was conducted in 2002. The recent data indicate that the hydraulic gradient is consistent with that obtained using the 2002 data.

The Irigaray groundwater flow model was calibrated to water level data collected on March 18, 2002. Twenty-four monitoring wells were used as calibration targets for the model. The locations of the calibration targets are listed in Table C-3 and shown on Figure C-5.

C.6.2 Calibration Results

Calibration was achieved using manual trial and error techniques. Only the boundary conditions of the model were adjusted to optimize the calibration. The hydraulic head distribution in the model is relatively insensitive to the parameter of hydraulic conductivity for the following reasons: a uniform value of hydraulic conductivity is used for each layer; there are no hydraulic stresses to the model; and the model is run as a steady-state system without vertical gradients. However, the modeled groundwater velocity is sensitive to the hydraulic conductivity and porosity and these parameters are evaluated under the sensitivity analysis as discussed later in this report.

The results of the calibration simulation are shown on Figure C-6. For comparison, a map of the water table constructed from field-measured data collected in March 2002 is shown in Figure C-6a (additional water-level plots are provided in Section 3). The general configuration of the March 2002 potentiometric surface is reasonably reproduced with the model.

The spatial distribution of residuals for the Irigaray model are shown in Figure C-7. The largest residuals are at T12 (-1.78 ft) and T24 (1.39 ft). Overall, the model adequately reproduced the observed values in the UISS aquifer. A summary of calibration targets, predicted water levels, and residuals are presented in Table C-3. The mean residual and standard deviation for the final calibration simulation of the steady-state groundwater flow model are 0.06 ft and 0.86 ft, respectively. Note that the mean residual is close to zero indicating no significant bias to either overprediction (negative) or underprediction (positive) of water levels. The standard deviation for the model represents less than five percent of the total head change across the model domain, indicating that the residual errors are only a small part of the overall model response. Table C-4 presents a summary of the calibration statistics.

The calibration target water elevations are plotted versus model simulated water elevations in Figure C-8. The tight clustering and even distribution of points around the line indicate that the model was accurate in reproducing the calibration targets without consistently overpredicting or underpredicting the observed values. If the observed and predicted water levels matched exactly they would fall on a straight line at forty-five degrees with the intercept at equal values of simulated and observed groundwater elevations.

C.7 FLOWPATH ANALYSIS

Results of the final calibration simulation were coupled with the MODPATH particle tracking code to assess groundwater flowpaths across the site. Results of the particle tracking are shown on Figure C-6. Under the non-pumping conditions simulated, groundwater enters the site from the south and east sides of the ISL wellfield and leaves the site along the north and west.

C.8 MODEL VALIDATION

It has been stated that the focus of the modeling effort is toward replicating a steady-state flow system under natural regional hydraulic gradients. However, in order to provide validation of the model under known hydrologic stresses, the following simulation was developed.

Because few water level data are available that represent pre-mining and pre-restoration conditions, the strategy employed was to simulate conditions near the end of the restoration period to determine if the aquifer system could recover to current conditions (the calibration simulation). A water level map was developed from data collected in June 2000. At that time, only Mine Units 6 and 7 were still undergoing active restoration. The potentiometric surface for June 2000 (shown in Figure C-9) was

imported into the model as initial conditions for a transient simulation. The transient simulation was divided into eight time steps representing the operational history from June 2000 through March 2001. Each time step represents a significant change in operational rates for the wellfield. No attempt was made to assign specific pumping rates to individual wells within the wellfield. Instead, the net difference between injection and recovery was evenly distributed across the entire mine unit for the specified time step. The length of the time steps and the distribution of water are summarized in Table C-5.

From November 2000 through March 18, 2001 there was no significant pumping activity within or near the ISL mine. During this period, water levels in the aquifer were returning to the natural steady-state conditions that existed prior to mining. A comparison between the final head distribution of the transient simulation and the calibration simulations indicates they are essentially the same (Figure C-10). The simulated response of the aquifer is similar to the actual recovery observed from field data.

C.9 SOLUTE TRANSPORT MODEL DEVELOPMENT

The calibrated flow model was coupled with the MT3DMS code to simulate migration of the following site derived constituents/parameters: selenium, manganese, uranium, radium-226 and Total Dissolved Solids (TDS). Simulations were made for each of these constituents using baseline conservative values for key parameters. The transport simulations were run for a minimum of 300 years. Sensitivity analyses were performed on key parameters used in both the groundwater flow and solute transport codes.

Unless stated otherwise, reported concentrations from the transport simulations are for Layer 2 (the mineralized zone). This is conservative, as it represents the layer with the highest concentrations. Because of dispersion, concentrations in Layers 1 and 3 will eventually increase, but will remain at levels below those in Layer 2.

For each transport simulation the initial conditions included a uniform concentration of the constituent distributed across the footprint of the ISL wellfield within the mineralized zone layer. All other portions of the model domain are simulated as having an initial concentration equal to background. Consistent with direction stated in the November, 2001, Clarification Paper, the initial concentrations represent average values within the wellfield (see Section 4 for additional discussion). Because background concentrations outside the wellfield were included, the transport results are total values that represent the concentration from the plume in addition to the background concentration.

C.9.1 Observation Points for Transport Simulations

A series of model observation points were placed around the north and west sides of the wellfield at an approximate distance of 400 feet. The locations of the model observation points are in many cases coincident with actual monitoring wells. However, for ease of discussion and presentation of results the model monitoring points are

identified as OP1 through OP9 going from north to south (Figure C-11). The observation points represent wells screened only within the production zone (Layer 2 of the model) unless noted otherwise.

C.9.2 Solute Transport Model Parameters

Parameters that are incorporated into the transport model that were not already included in the flow model included initial concentration, dispersivity and a distribution coefficient (Kd).

C.9.2.1 Initial Concentration

As previously stated, the initial conditions for the transport simulations included a uniform concentration of the constituent distributed across the footprint of the ISL wellfield within the mineralized zone. All other portions of the model domain outside the wellfield, and Layers 1 and 3, are simulated as having an initial concentration equal to background. The initial values are summarized below.

Constituent/Parameter	Initial Concentration (Layer 2 inside wellfield)	Background Concentration (Layers 1 & 3 inside wellfield; all area outside wellfield)
Selenium	0.04 mg/L	0.0026 mg/L
Manganese	0.18 mg/L	0.0106 mg/L
Radium-226	139.9 pCi/L	0.9026 pCi/L
Uranium	2.1 mg/L	0.0165 mg/L
Total Dissolved Solids	650 mg/L	379 mg/L

Wellfield concentrations were based on 34 monitoring wells sampled during restoration operations (e.g., 1993 on the north end of the wellfield; 2001 [Round 1 stabilization] in Mine Units 6 and 7. Background concentrations were based on the arithmetic average (mean) of pre-mining data from 29 wells collected between 1977 and 1987. Based on additional sampling conducted since 2001, the average stability values are lower than those used in the modeling, except for manganese, which was slightly higher. The average concentrations for Rounds 1-4 were as follows: Se – 0.03 mg/l; Mn – 0.23 mg/l; TDS – 630 mg/l; U – 1.99 mg/l; Ra-226 – 134 pCi/l. Additional discussion regarding background water quality has been provided in Section 4.

C.9.2.2 Dispersivity

Dispersion refers to the spreading of contaminants over a greater area than would be predicted solely from the average groundwater velocity vectors. Dispersion is caused by mechanical dispersion and by molecular diffusion. Mechanical dispersion results from deviations of actual velocity on a small scale from the average groundwater velocity. Molecular diffusion is driven by concentration gradients and, except under conditions of

very low groundwater velocities, is secondary and negligible compared to mechanical dispersion. Quantification of a numerical value for dispersion is difficult. It is often used as a "fitting" parameter to account for apparent differences between observed and calculated contaminant distribution. It is also scale dependent.

The dispersivity determined for a large-scale plume will be much greater than that for a small-scale plume. Literature sources generally indicate that dispersivity is from one to two orders of magnitude less than the distance a plume has migrated (Gebhar, 1992). The focus of this model is to predict solute concentrations over time at a distance of 400 feet from the wellfield. Parallel to the direction of groundwater flow, the wellfield is approximately 500 to 600 feet wide. When the tail end of the plume has passed through the downgradient observation point, the total migration distance will be approximately 1,000 feet. Using the one to two orders of magnitude rule-of-thumb would provide a longitudinal dispersivity value of between 10 and 100. In modeling, greater dispersion will result in faster arrival times, but lower peak concentrations. Because the results of the Irigaray model will be compared against regulatory standards, the more conservative approach is to simulate values of dispersivity that will result in greater concentration peaks. The baseline dispersivity value used to simulate solute transport is 25 feet, on the lower end of the range previously discussed. Other values are evaluated in the sensitivity analysis.

A diffusion term is not used in this evaluation. The effects of molecular diffusion on spreading of a contaminant plume will be negligible in an advective-dominated flow system such as the one at Irigaray.

C.9.2.3 Distribution Coefficient

Sorption was implemented in some of the solute transport simulations. Sorption refers to the mass transfer between the constituent dissolved in groundwater and the constituent sorbed on the porous medium. Equilibrium conditions are generally assumed to exist between the aqueous phase and the solid phase concentrations and the sorption reactions are fast enough relative to groundwater velocity to be treated as instantaneous. A linear sorption isotherm assumes that the sorbed concentration (Cs) is directly proportional to the dissolved concentration (C):

$$Cs = K_d C$$

where Kd is the distribution coefficient (L/kg).

The equilibrium controlled linear sorption isotherm is incorporated into the MT3DMS code through the use of a retardation factor, defined as:

$$R = 1 + p_b K_d / \phi$$

where p_b= bulk density

ϕ= effective porosity

It should be emphasized that the use of a Kd was done with full conservation of mass within the aquifer system. No solute is irreversibly removed via sorption or precipitation from the modeled system. The use of a Kd only serves to slow the velocity of solutes for which it is used.

To assess Kd values that apply to the transport of the constituents of concern related to Irigaray, an extensive literature search was performed (Petrotek Engineering Corporation, 2002; Literature Search and Document Review: Natural Attenuation of Metals and Radionuclides in Ground-water. Internal report prepared for COGEMA Mining, Inc.; July, 2002). This document includes full copies and a summary of conclusions from 22 published references related to advective transport of metals and radionuclides in groundwater. Additional referenced specific to modeling were also utilized to assess Kd values related to advective transport.

As noted previously, the modeling performed for Irigaray assumed complete conservation of mass (e.g., no irreversible geochemical retardation). In simulations where Kds were incorporated into the model, the lowest reasonable Kd available from literature was used, as listed below.

Constituent	Range of Values	Source	Model Value L/kg
Selenium[1]	7 – 22	Aleni, 1991 Fio, 1991	0.1
Manganese	Not applicable	Not applicable	0
Uranium	0.4 – 10	Carlos, 2001 Johnson, 1994 U.S. DOE, 1996 U.S. NRC, 1990	0.5
Radium-226	5 – 6,700 10	Moody, 1982 U.S. NRC, 1980	5
TDS[2]	Not applicable	Not applicable	0

1 – For Se (IV). Limited sampling of ground-water at Irigaray has shown that Se(IV) is the predominant species.

2 - No Kd assigned because this is a composite parameter made of major anions and cations, each with different chemical properties, including Kds. Conservatively assumed no sorption of any of the constituents that comprise TDS.

C.10 TRANSPORT MODEL RESULTS

Results of the solute transport model simulations indicate that constituent concentrations do not exceed regulatory standards at any of the observation points located 400 feet from the wellfield. Results of the simulations for each of the constituents of concern are described below.

C.10.1 Selenium

The selenium transport simulation, using the baseline dispersivity of 25 feet and a Kd of 0.1 L/kg, was run for a period of 300 years. The initial concentration distribution within

and outside the wellfield and (0.04 and 0.0026 mg/l, respectively) is shown on Figure C-12. The modeled distribution of selenium at 24 years indicates minimal offsite migration (Figure C-13). At 100 years the plume has reached one of the observation points, although at concentrations well below the WDEQ standard of 0.01 mg/L (Figure C-14). The modeled selenium distribution at 300 years shows the maximum concentration within the plume is below the regulatory standard (Figure C-15).

Plots of selenium concentration vs. time for the observation points show first arrival and peak concentrations for the selenium transport simulation (Figure C-16). The first arrival of the plume occurs at OP3 at approximately 40 years. The maximum concentration occurs at OP5 approximately 290 years into the simulation with a value of nearly 0.008 mg/L. Figure C-17 is used to illustrate the migration of the plume relative to the wellfield boundary and observation point OP3. Figure C-18 illustrates the vertical distribution of selenium over time at the location of OP3. Note that the selenium concentration is relatively uniform throughout the entire modeled aquifer by the time the plume has migrated 400 feet from the wellfield. Based on the results of the transport simulation, using a conservative value for both Kd and dispersivity, selenium will remain below the WDEQ Class-1 standard at a distance of 400 feet from the Irigaray ISL wellfield.

C.10.2 Manganese

The manganese transport simulation was also run for a period of 300 years using a dispersivity of 25 feet and no retardation (Kd = 0). The initial concentration is 0.18 mg/L within the wellfield, and 0.0106 mg/l elsewhere (Figure C-19). The modeled distribution of manganese at 24 years shows no exceedance of the WDEQ regulatory standard at any of the observation points (Figures C-20). At 100 years the concentration of the entire plume is below the regulatory standard (Figure C-21). The manganese distribution at 300 years shows the plume has migrated beyond most of the observation points but at levels below the standard (Figure C-22). Plots of manganese concentration vs. time for the observation points shows first arrival and peak concentrations for the manganese transport simulation (Figure C-23). The first arrival of the plume occurs at OP3 at approximately 20 years. The maximum concentration occurs at OP5 approximately 170 years into the simulation with a value of 0.034 mg/L. Based on the results of the transport simulation, using a conservative value for dispersivity and no sorption, manganese will remain below the WDEQ Class-1 standard at a distance of 400 feet from the Irigaray ISL wellfield.

C.10.3 Uranium

The uranium concentration used to represent the initial conditions, (2.1 and 0.0165 mg/l, respectively) are already below the WDEQ Class-1 standard of 5 mg/L (Figure C-24). Based on a dispersivity of 25 feet and a Kd of 0.5 L/kg, the modeled distribution of uranium at 24 years shows minimal migration beyond the wellfield (Figure C-25). At 100 years, uranium from the site has not reached any of the observation points (Figure C-26). At 300 years, the maximum uranium concentration within the entire plume is at least an order of magnitude lower than the standard (Figure C-27). Plots of uranium

concentration vs. time for the observation points show first arrival and peak concentrations for the uranium transport simulation (Figure C-28). The first arrival of the plume occurs at OP3 between 125 and 150 years. The maximum concentration within the simulation occurs at OP3 at approximately 300 years with a value of 0.24 mg/L.

C.10.4 Radium-226

Initial radium-266 concentrations assigned were 139.9 and 0.903 pCi/l within and outside the wellfield, respectively. Although the Kd used for the radium-226 transport simulation (5 L/kg) is a conservative value, it is higher than the Kds used for any of the other constituents/parameters (use of this Kd value is supported in published literature). Consequently, the migration rate of the radium-226 plume is much slower than for the other constituents. The initial concentration distribution for the radium simulation is shown in Figure C-29. The transport simulation for radium-226 was run for 1,000 years in order to determine first arrivals of the plume at the observation points (Figure C-30). Based on a dispersivity of 25 feet, plots of radium-226 concentration vs. time for the observation points show first arrivals for the radium-226 transport simulation (Figure C-31). The first arrival of the plume occurs at OP3 between 400 and 500 years. At 1,000 years the maximum concentration for the observation points occurs at OP3 at less than 2.2 pCi\L. The WDEQ Class-1 standard for radium-226 is 5.0 pCi/L.

C.10.5 TDS

Initial TDS concentrations used in the model were 650 mg/l (inside Layer 2 in the wellfield) and 379 mg/l (all other model areas). As previously stated, TDS is a composite parameter, comprised of numerous cations and anions, each with different sorption coefficients. It was conservatively assumed that no sorption of TDS would occur along the groundwater flowpath. The initial concentration distribution for the TDS simulations is shown in Figure C-32. The modeled TDS distribution at 100 years indicates that the TDS plume has reached several of the observation points but at concentrations well below the WDEQ Class-1 standard of 500 mg/L (Figure C-33). By 300 years, the TDS plume has mostly passed beyond the observation points but the maximum concentrations are below the standard (Figure C-34). Plots of TDS concentration vs. time for the observation points show that TDS never exceeds 420 mg/L for the duration of the simulation (Figure C-35).

C.11 SENSITIVITY ANALYSIS

An analysis was performed to evaluate the sensitivity of specific model parameters on simulated concentrations at the model observation points. Because of the large number of simulations required to perform the sensitivity analysis on all key model parameters, the analysis was limited to a single constituent. A review of the baseline transport simulations previously conducted indicated that selenium came the closest to exceeding a specific regulatory standard. Therefore, selenium was selected as the constituent to evaluate with the sensitivity analysis. The sensitivity analyses were performed by changing a single parameter for each simulation. All other parameters were the same

as those used in the baseline selenium transport simulation. The following model parameters were included in the analysis.

- Hydraulic Conductivity/Hydraulic Gradient
- Horizontal to Vertical Hydraulic Conductivity Ratio
- Porosity
- Mineralized Zone Thickness
- Dispersivity
- Distribution Coefficient

C.11.1 Hydraulic Conductivity/Hydraulic Gradient

For the baseline simulation, the hydraulic conductivity values of the mineralized zone (Layer 2), and non-mineralized zones (Layers 1 and 3) were 0.5 ft/d, and 1.0 ft/d, respectively. For the sensitivity analysis, the hydraulic conductivity of Layer 2 was simulated as 0.25 ft/d and 1.0 ft/d. An additional simulation was run where the hydraulic conductivity of the mineralized and non-mineralized zones were switched (Layer 2 was 1.0 ft/d and Layers 1 and 3 were 0.5 ft/d). The results of the simulations for observation points OP3 and OP5 are shown in Figures C-36 and C-37, respectively. The concentration vs. time plots indicate that the hydraulic conductivity strongly effects the initial arrival of the site-derived constituent at the observation point but has minimal impact on the peak concentration. The results are consistent with the groundwater flow equation in that hydraulic conductivity is directly proportional to groundwater velocity. Note that for all simulations, the maximum concentration remains below the WDEQ Class-1 standard for selenium.

As with hydraulic conductivity, hydraulic gradient is directly proportional to groundwater velocity. Therefore, the model response to increases or decreases in hydraulic gradient (with respect to groundwater velocity and solute transport) will be similar to the response to changes in hydraulic conductivity. However, significantly changing the hydraulic gradient in the model will result in a poor match to the observed water levels used as calibration targets and result in a groundwater flow system that is not consistent with available data. Therefore, a sensitivity analysis was not directly performed for this parameter. In the case of hydraulic conductivity, increasing the parameter by a factor of two resulted in an increase in the maximum selenium concentration of approximately 5 percent. The response of the model to a similar change in hydraulic gradient will be of the same magnitude.

C.11.2 Horizontal to Vertical Hydraulic Conductivity Ratio

The baseline simulation utilized a horizontal to vertical hydraulic conductivity ratio (Kh/Kv) of 10. Site-specific core testing data suggest that the ratio may be less (e.g., on the order of 1.4). However, experience indicates that a ratio of 10 is more applicable to a fluvial system over a large scale.

To assess the impact of Kh/Kv ratio, sensitivity analyses included simulations with the Kh/Kv of 5, 7.5, 20 and 30. The horizontal hydraulic conductivity was 0.5 ft/d for each of the simulations but the vertical hydraulic conductivity was modified to achieve the desired Kh/Kv. Results of the simulations indicate no impacts to either arrival times or peak concentrations as shown in the plots for observation points OP3 and OP5 (Figures C-38 and C39). The lack of sensitivity to this parameter is because the model is constructed to simulate horizontal flow without vertical gradients. Vertical movement of the solute is controlled predominately by the dispersion term, which is also included in the sensitivity analysis.

C.11.3 Porosity

The porosity values used in the baseline simulation were 0.25 for Layer 2 and 0.29 for Layers 1 and 3. Sensitivity simulations were run with a Layer 2 porosity of 0.20 and 0.30. Results of the simulations indicate that as the porosity increases, the peak concentration rises as shown in the concentration vs. time plots of observation points OP3 and OP5 (Figures C-40 and C-41). The arrival of the peak concentration is also delayed as the porosity is increased. Both of these occurrences are expected. Increasing the porosity decreases the groundwater velocity and increases the total initial dissolved mass of contaminant in the model. For the simulation with porosity of 0.30, the maximum selenium concentration increases by less than 10 percent over the baseline simulation and is still less than half the regulatory standard.

C.11.4 Mineralized Zone Thickness

As discussed in Appendix B, the mathematical average mineralized zone thickness was 18 feet. To account for flare (historically 10 percent or less), a mineralized zone thickness of 21 feet was used for the baseline simulations. Using the higher value is a conservative assumption because it provides for a greater initial contaminant load in the model. Simulations were run using a mineralized zone thickness of 15', 18', 24' and 27'. As shown in the concentration vs. time plots for the observation points, the maximum concentration increases as the mineralized zone thickness is increases (Figures C-42 and C-43). However, in all cases, the selenium concentrations at the observation points are below the regulatory standard.

C.11.5 Dispersivity

The baseline simulation was run with a dispersivity of 25 feet. Additional simulations performed for the sensitivity analysis included values of 10, 20, 30 and 50 feet. Results of the sensitivity analyses are shown in the concentration vs. time plots for the observation points OP3 and OP5 (Figures C-44 and C-45).

As dispersivity increases, the maximum selenium concentration in the mineralized zone decreases. This reflects the increased dispersion of solute into the sand units above and below the mineralized zone as the plume moves away from the wellfield. For the dispersivity simulation of 10 feet, the maximum concentration at OP3 approaches the

WDEQ Class-1 standard of 0.01 mg/L. However, this value represents the concentration only within the mineralized zone, which is one fifth of the total thickness of the modeled aquifer. Plots of the average weighted concentration of the entire modeled aquifer for the dispersivity simulations of 10, 25 and 50 feet show much lower sensitivity to this parameter (Figure 46).

C.11.6 Distribution Coefficient

A Kd of 0.1 was used for the baseline selenium transport simulations. Kd values of 0 (no sorption), 0.05, 0.2 and 0.5 L/kg were evaluated in the sensitivity analysis. The concentration vs. time plots of selenium at observation points OP3 and OP5 indicate that the value of Kd has minimal impact on the peak concentrations but strongly effects the migration rate of the plume (Figures C-47 and C-48). Increasing the Kd effectively "retards" solute transport. However, because advective dispersion is the primary transport mechanism, and mass is conserved (e.g., no geochemical sorption or irreversible precipitation occurs), peak concentrations are not significantly affected.

C.12 SUMMARY/CONCLUSIONS

CMI has performed extensive restoration operations in the Irigaray ISL wellfield during the period from 1990 to 2001. Restoration efforts have significantly improved water quality for all indicator parameters.

To evaluate future migration of selected ground-water constituents (uranium, selenium, radium-226, manganese, and TDS) at the Irigaray ISL uranium mine, a numerical groundwater flow and solute transport model was developed. The model is designed to represent post-restoration, steady-state conditions of groundwater flow within the UISS aquifer of the Wasatch Formation. As documented in Appendix B, the site has been extensively characterized with regard to geology and the physical characteristics related to ground-water flow. It has been shown that the flow system at Irigaray can be mathematically represented with a flow model (MODFLOW). Calibration and validation of the flow model support the site characterization, and the use of the model as constructed.

The modeling effort focused on advective and dispersive flow components, minimizing the reliance on geochemical processes. The model was constructed with 3 layers, corresponding to the mineralized zone and the overlying and underlying sand units of the UISS. All layers were simulated as distinct units, with no boundaries between the layers themselves. The model simulations were run for a minimum period of 300 years. As discussed in Section 5.6, the concentrations outside the wellfield, and in Layers 1 and 3 within the wellfield, were assigned background values. As such, the transport results indicate the total concentrations that will result from migration of constituents from the wellfield.

Results of the transport modeling (MT3DMS) indicate that residual concentrations of selenium, manganese, uranium, radium-226 and TDS will be below WDEQ regulatory

limits at the prescribed observation points 400 feet from the wellfield (Table C-6) over simulated time period of 300 to 1,000 years.

To address uncertainty with regard to hydrogoelogic parameters, numerous sensitivity transport analyses were conducted. Sensitivity analyses performed on model parameters determined that hydraulic conductivity and distribution coefficient impacted the rate of transport but had minimal impact on peak concentrations at observation points located 400 feet downgradient from the wellfield boundary. Dispersivity had the greatest impact on constituent concentrations within the mineralized zone. However, the weighted average constituent concentration within the UISS (all three model layers) was similar for simulations over a wide range of dispersivities.

The transport model assumed complete conservation of mass. Based on reducing conditions indicated by field parameters (redox potential of –50 to –150 mv), it is apparent that significant geochemical alteration/mass removal will likely occur, especially with regard to selenium, uranium, and radium-226. This is consistent with the low historical concentrations of these constituents observed in the monitoring wells downgradient of the wellfield. As such, the modeling results as presented, are very conservative.

Because the observation points selected were only 400 feet downgradient of the wellfield, the transport results present a worst-case evaluation. In this regard, the point at which impacts to Class-1 waters could potentially become an issue would be the permit boundary, which is an additional distance of 1,000 to 2,200 feet downgradient.

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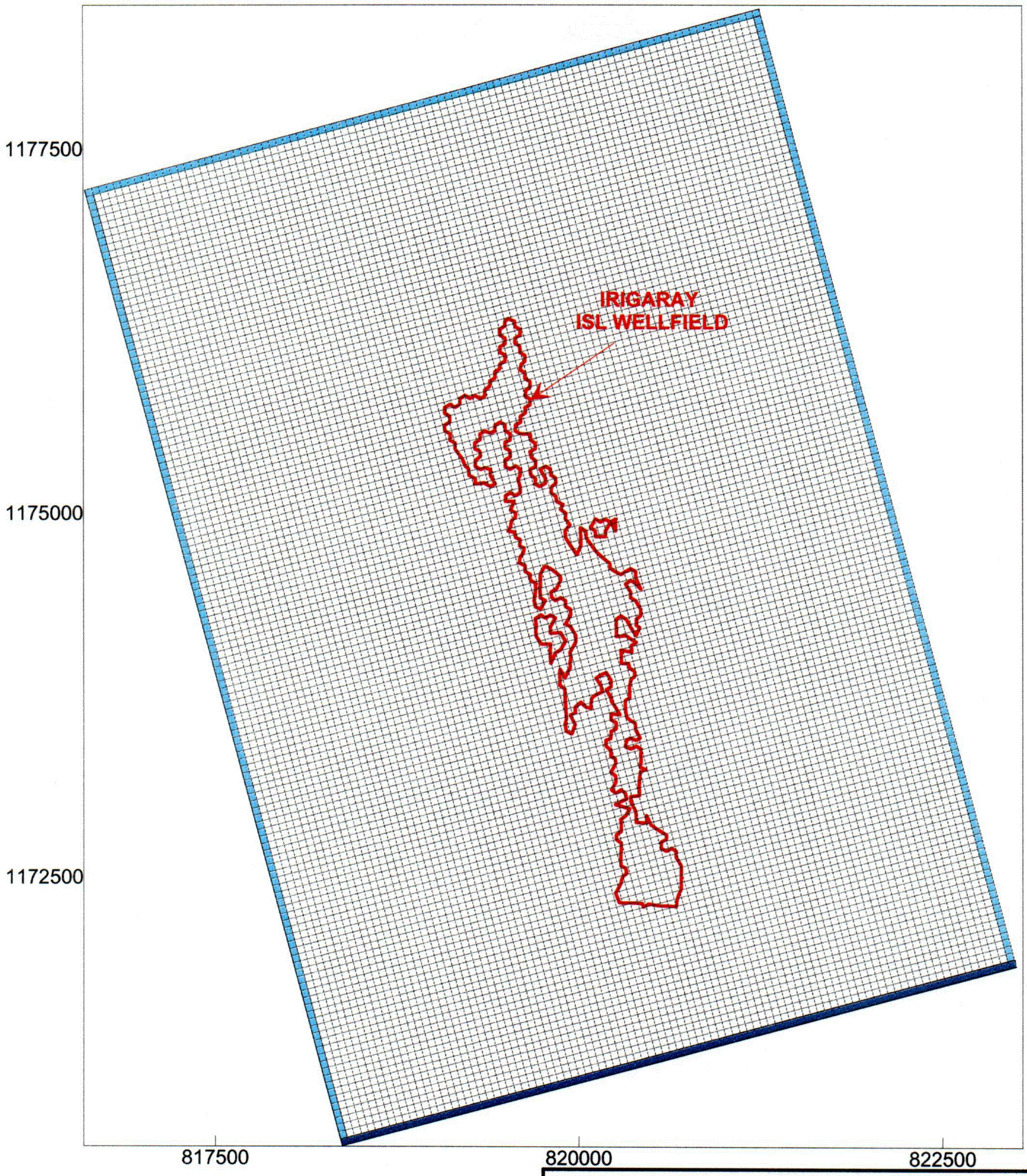

LEGEND

0 500 1000

Model Grid Rotation Is 15 Degrees Northwest

BOUNDARY CONDITIONS

CONSTANT HEAD BOUNDARY

GENERAL HEAD BOUNDARY

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IRIGARAY MINE

FIGURE C-1
MODEL DOMAIN, GRID AND BOUNDARY CONDITIONS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC1.SRF	BY: EPL CHECKED: HPD

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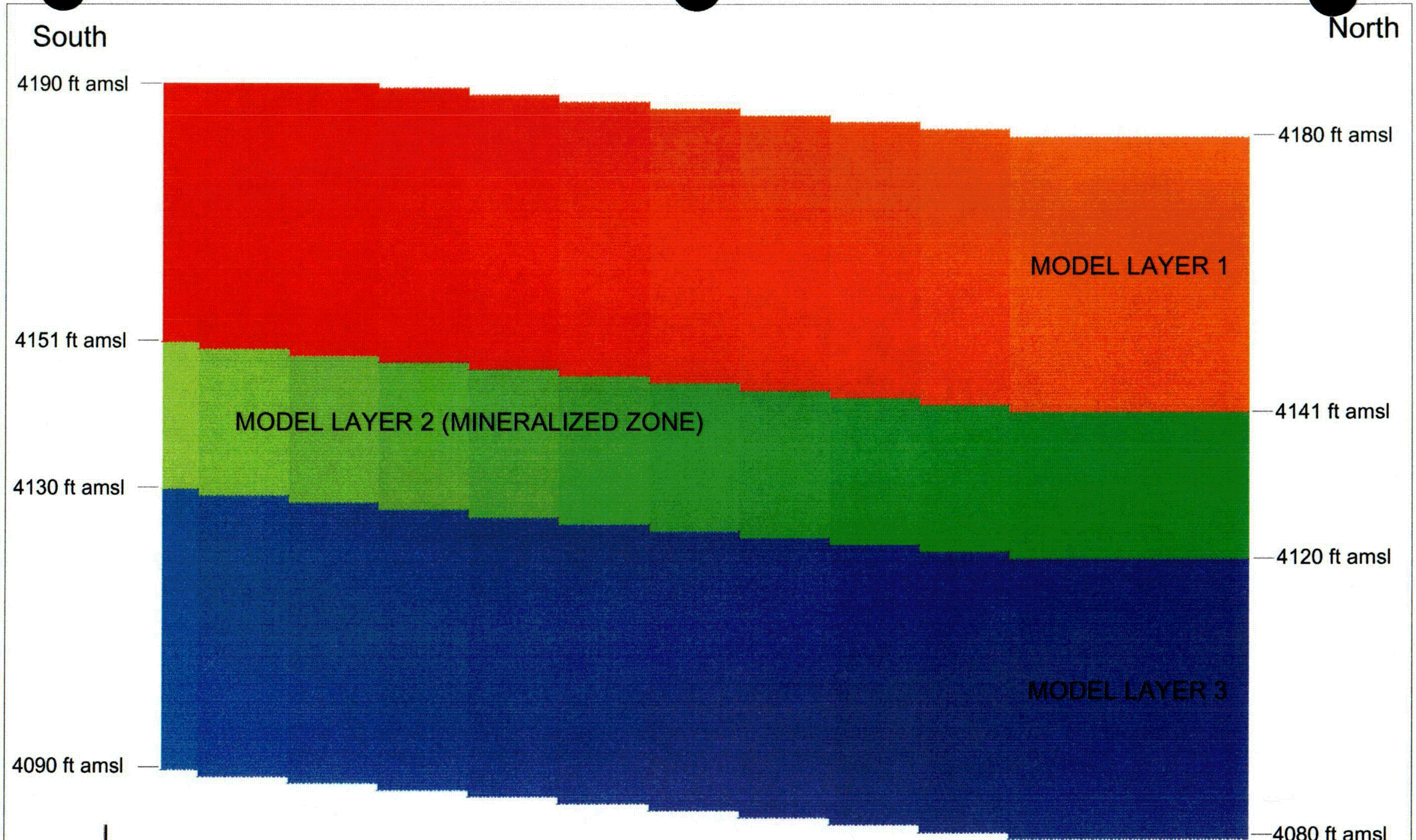
Littleton, Colorado 80129 (303) 290-9414



Cross Sectional View Along Column 100 of the Model

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IRIGARAY MINE

FIGURE C-2
CROSS SECTIONAL VIEW - MODEL LAYERS
IRIGARAY GROUNDWATER FLOW MODEL

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC2r.srf	BY: EPL CHECKED: HPD

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C58

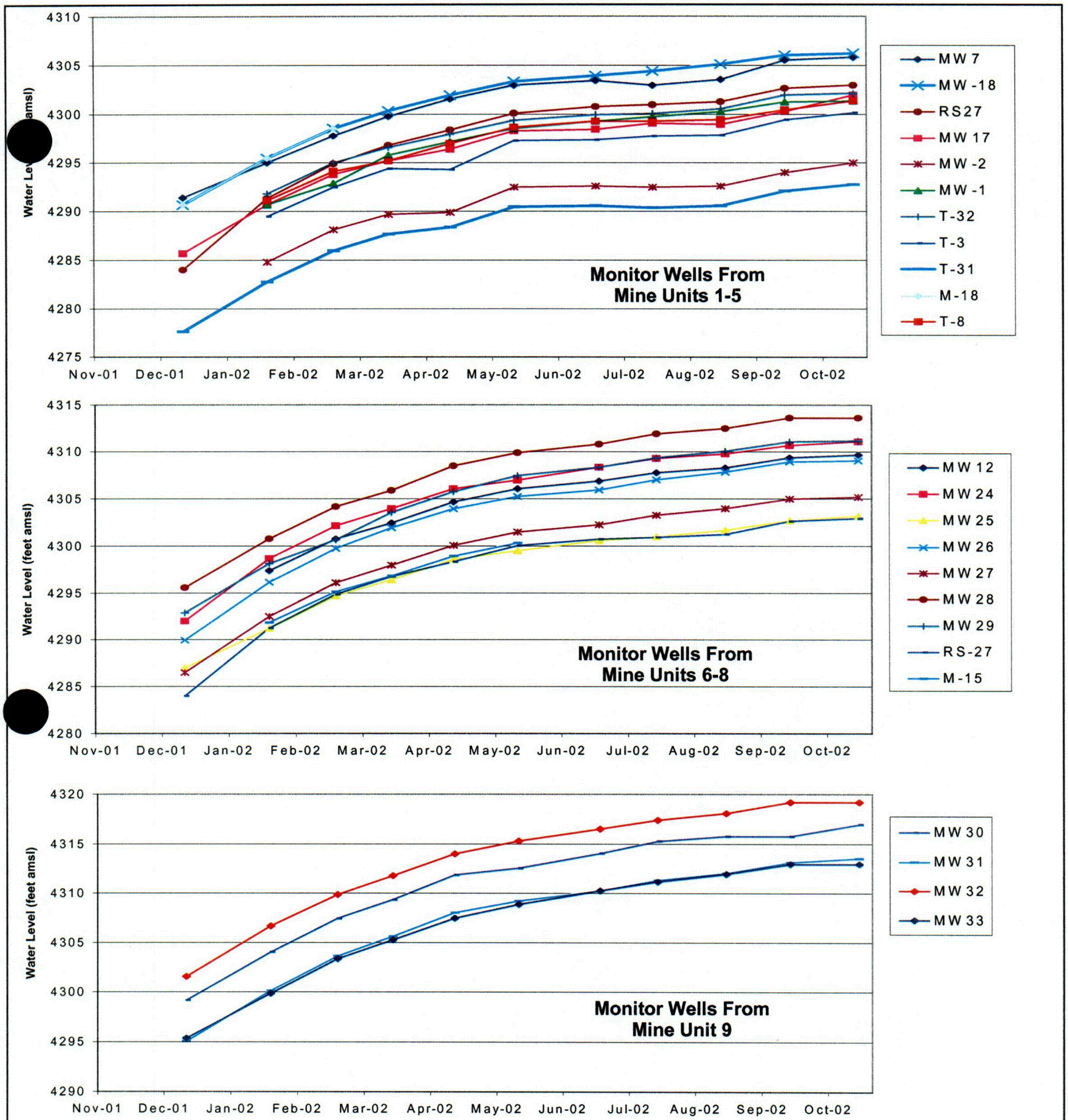

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FIGURE C-3
HYDROGRAPHS FOR MINE UNITS 1-9
IRIGARAY ISL WELLFIELD

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DWG: COGEMAFIGC3.srf	BY: EPL CHECKED: HPD

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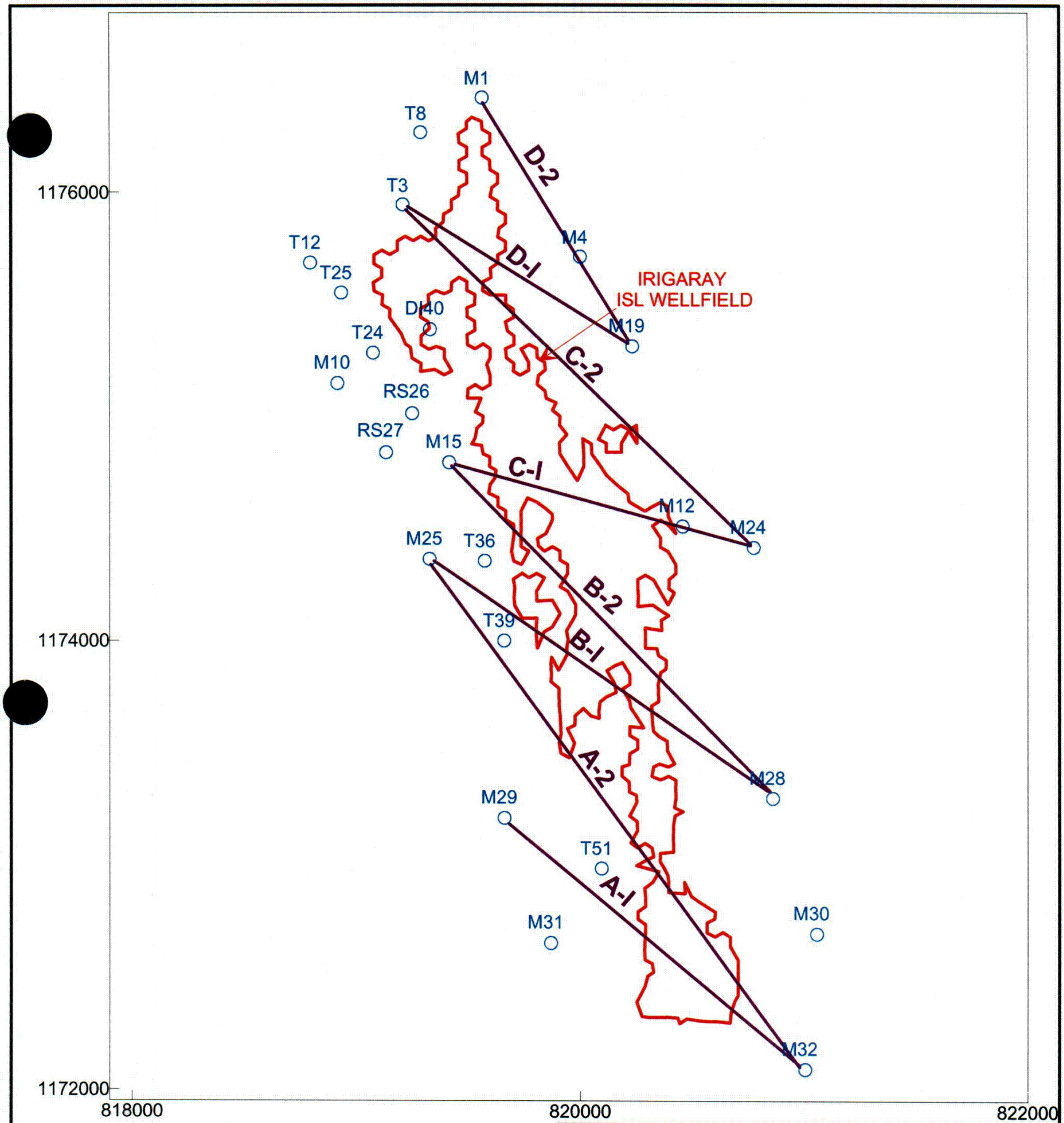

LEGEND

0 600 1200

N

○ MONITOR WELL

A-I TRANSECT USED FOR CALCULATION OF HYDRAULIC GRADIENT (SEE TABLE C-2)

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FIGURE C-4
LOCATION OF TRANSECTS FOR
HYDRAULIC GRADIENT CALCULATIONS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC4.SRF	BY: EPL CHECKED: HPD

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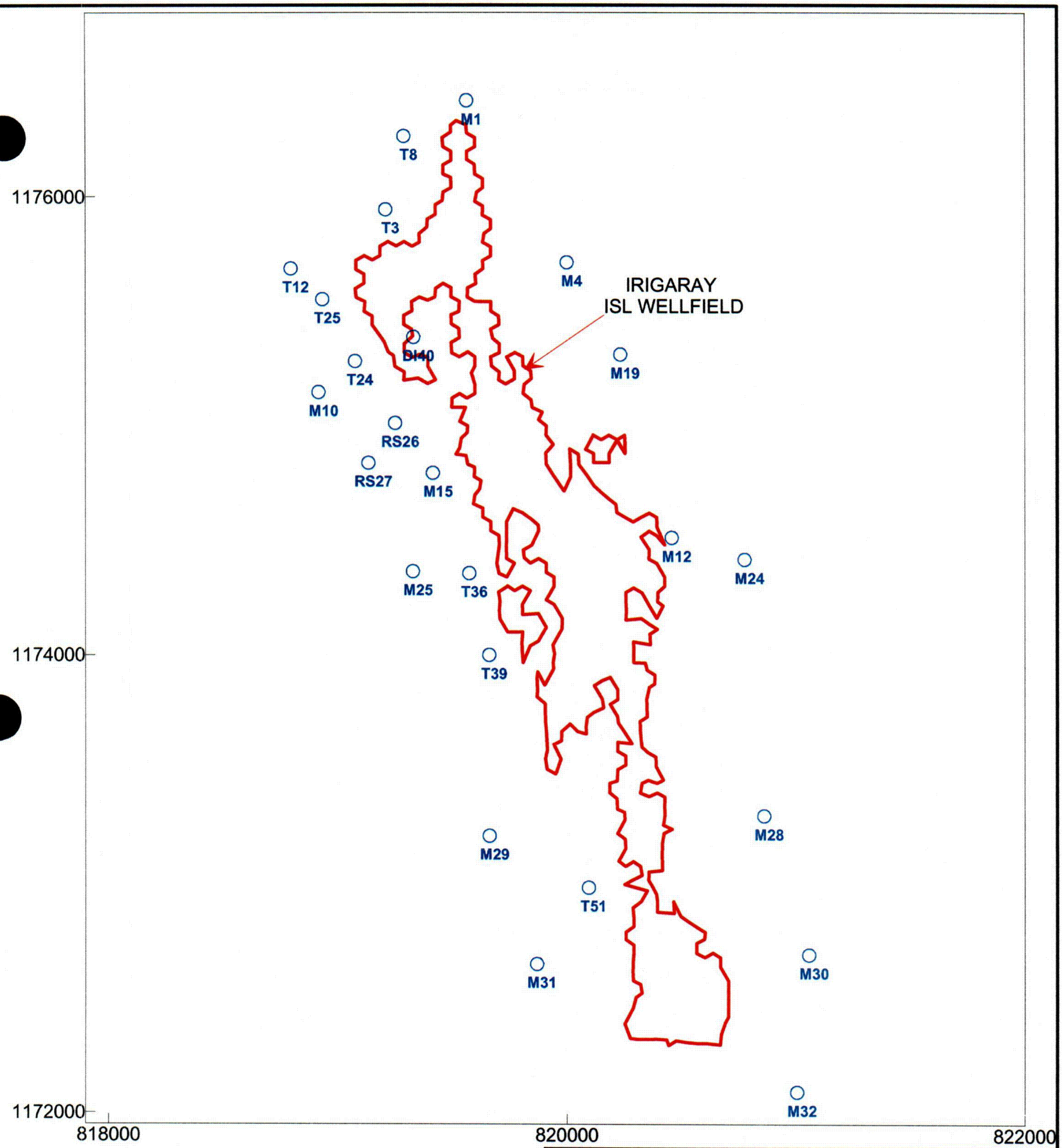

LEGEND

0 600 1200

N

○ CALIBRATION TARGET

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FIGURE C-5
LOCATION OF CALIBRATION TARGETS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC5r.SRF	BY: EPL CHECKED: HPD

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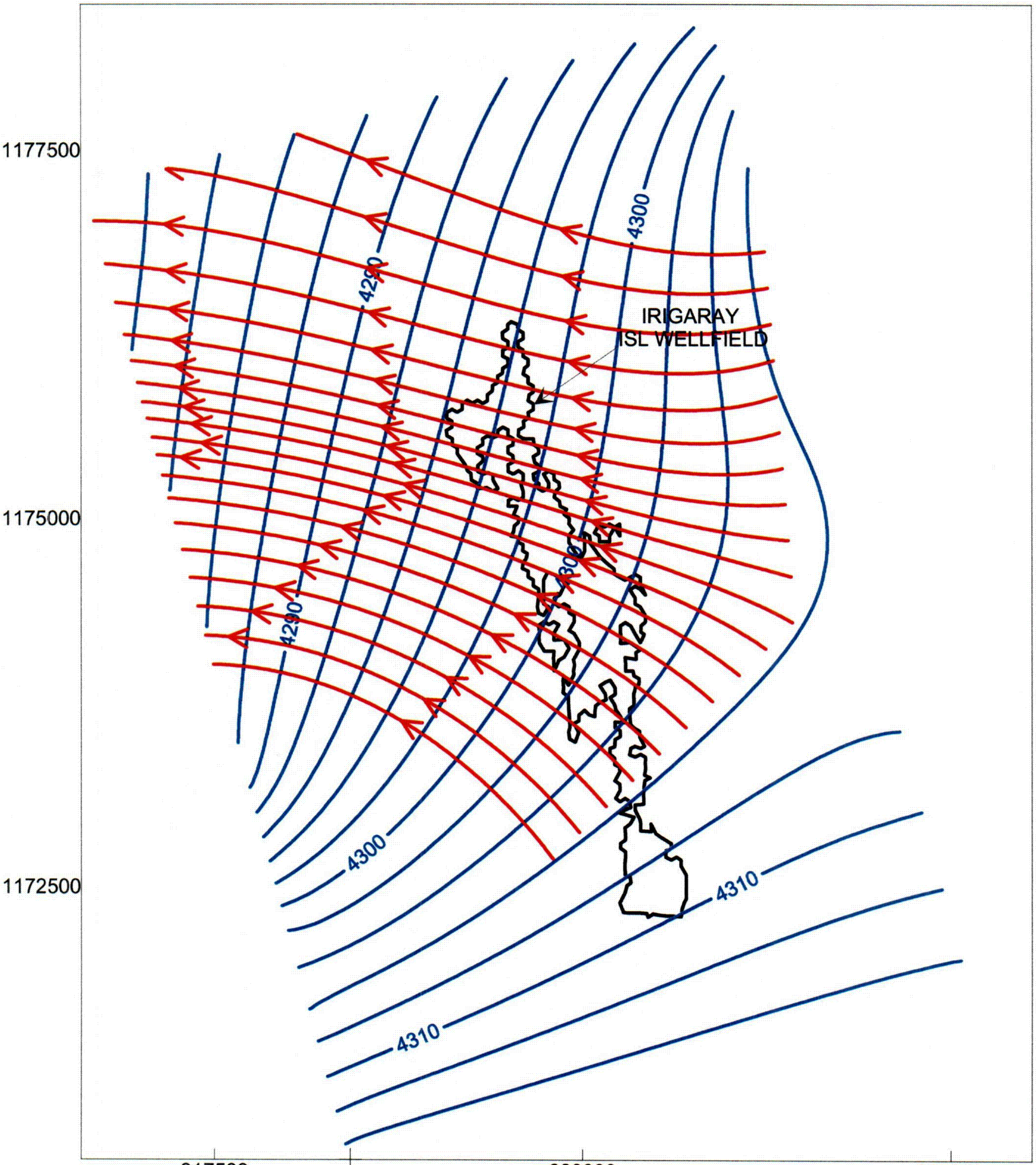
C61



LEGEND

0 500 1000

SCALE IN FEET 1" = 1000'
CONTOUR INTERVAL = 2 feet

4310 Potentiometric Surface (feet above mean sea level)

Groundwater Flowpath

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IRIGARAY MINE

FIGURE C-6
SIMULATED HEAD DISTRIBUTION AND GROUNDWATER FLOWPATHS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC6.SRF	BY: EPL CHECKED: HPD

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C62

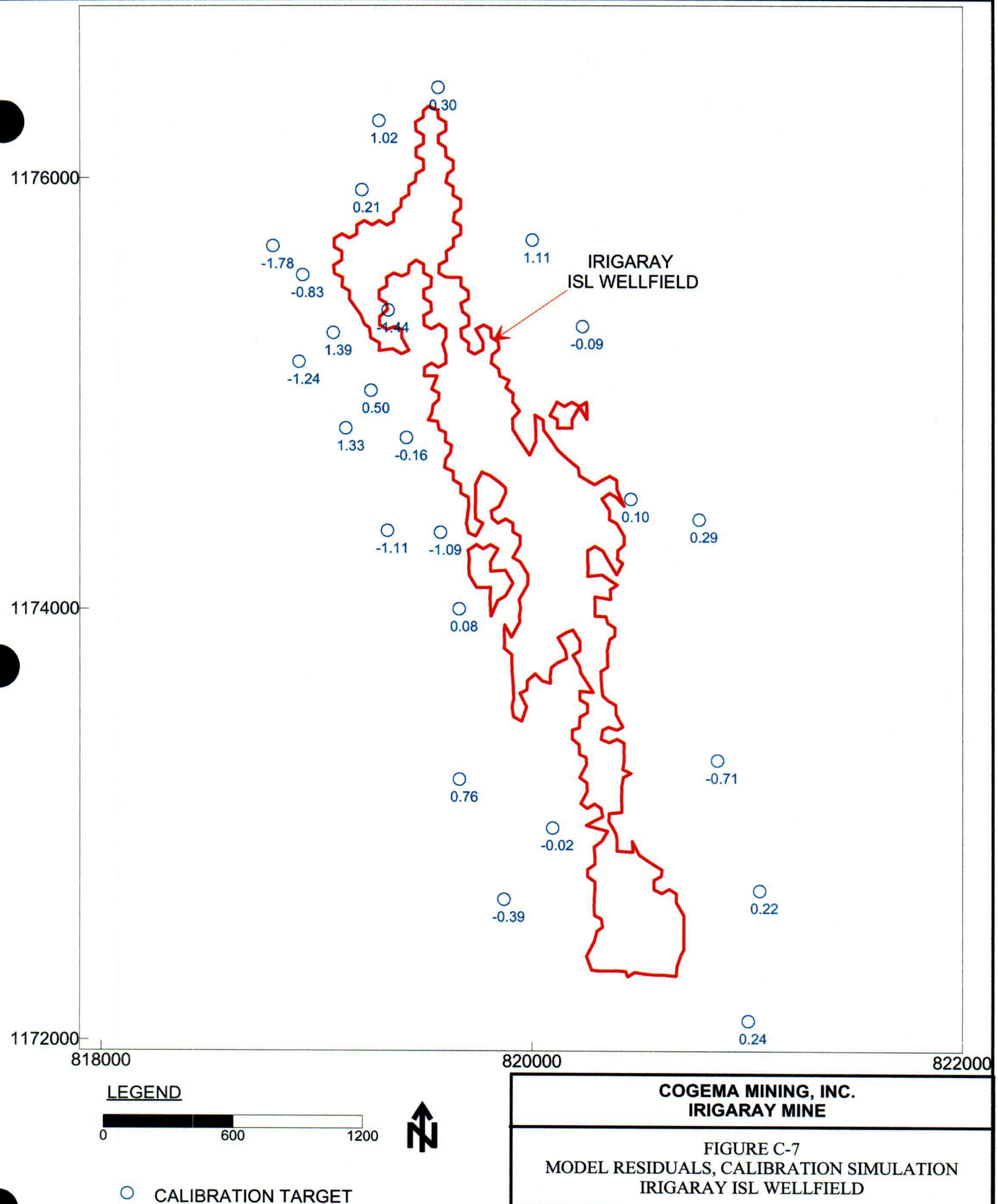

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FIGURE C-7
MODEL RESIDUALS, CALIBRATION SIMULATION
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG:COGEMAFIGC7.SRF	BY: EPL CHECKED: HPD

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C63

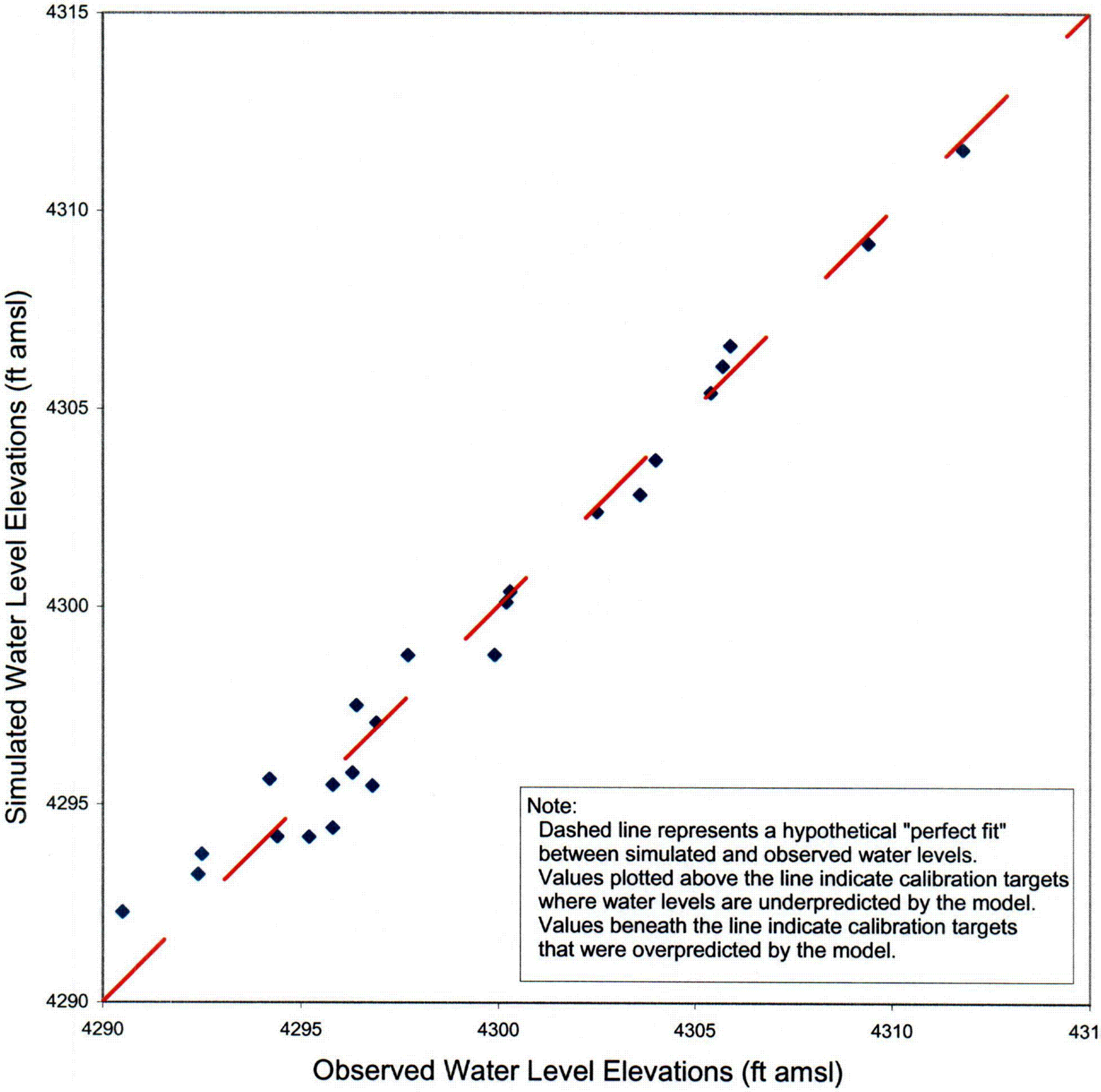

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FIGURE C-8
OBSERVED VS SIMULATED HYDRAULIC HEADS
IRIGARAY GROUNDWATER FLOW MODEL

PROJECT: CMI/IRIGARAY	DATE: MAY 2002	
DWG: COGEMAFIGC8r.srf	BY: EPL	CHECKED: HPD

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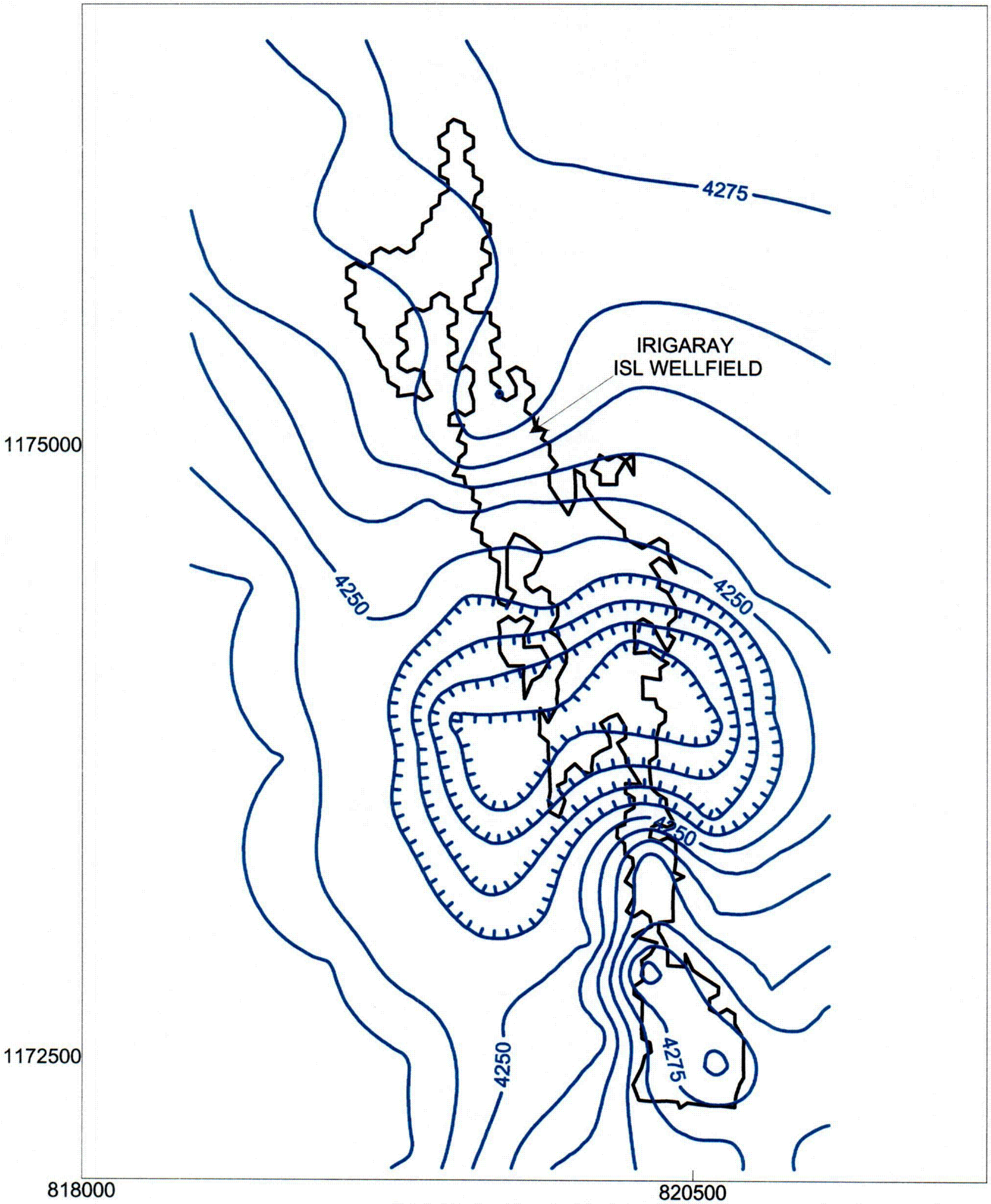
C64



LEGEND

0 500 1000

SCALE IN FEET 1" = 1000'

CONTOUR INTERVAL = 5 feet

4310 Potentiometric Surface (feet above mean sea level)

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-9
POTENTIOMETRIC SURFACE-UISS-JUNE 2000
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC9r.SRF	BY: EPL CHECKED: HPD

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C65

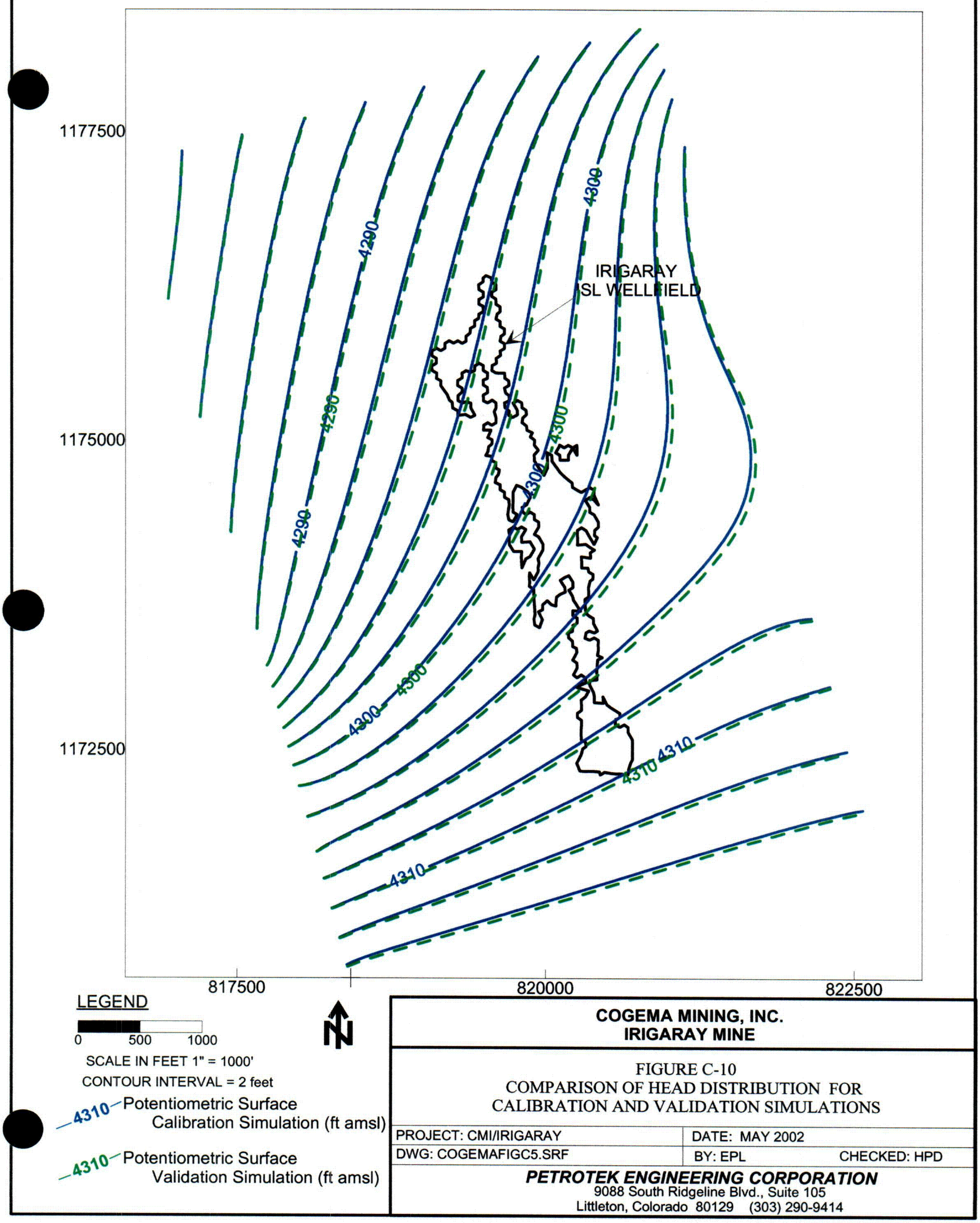

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FIGURE C-10
COMPARISON OF HEAD DISTRIBUTION FOR CALIBRATION AND VALIDATION SIMULATIONS

PROJECT: CMI/IRIGARAY	DATE: MAY 2002	
DWG: COGEMAFIGC5.SRF	BY: EPL	CHECKED: HPD

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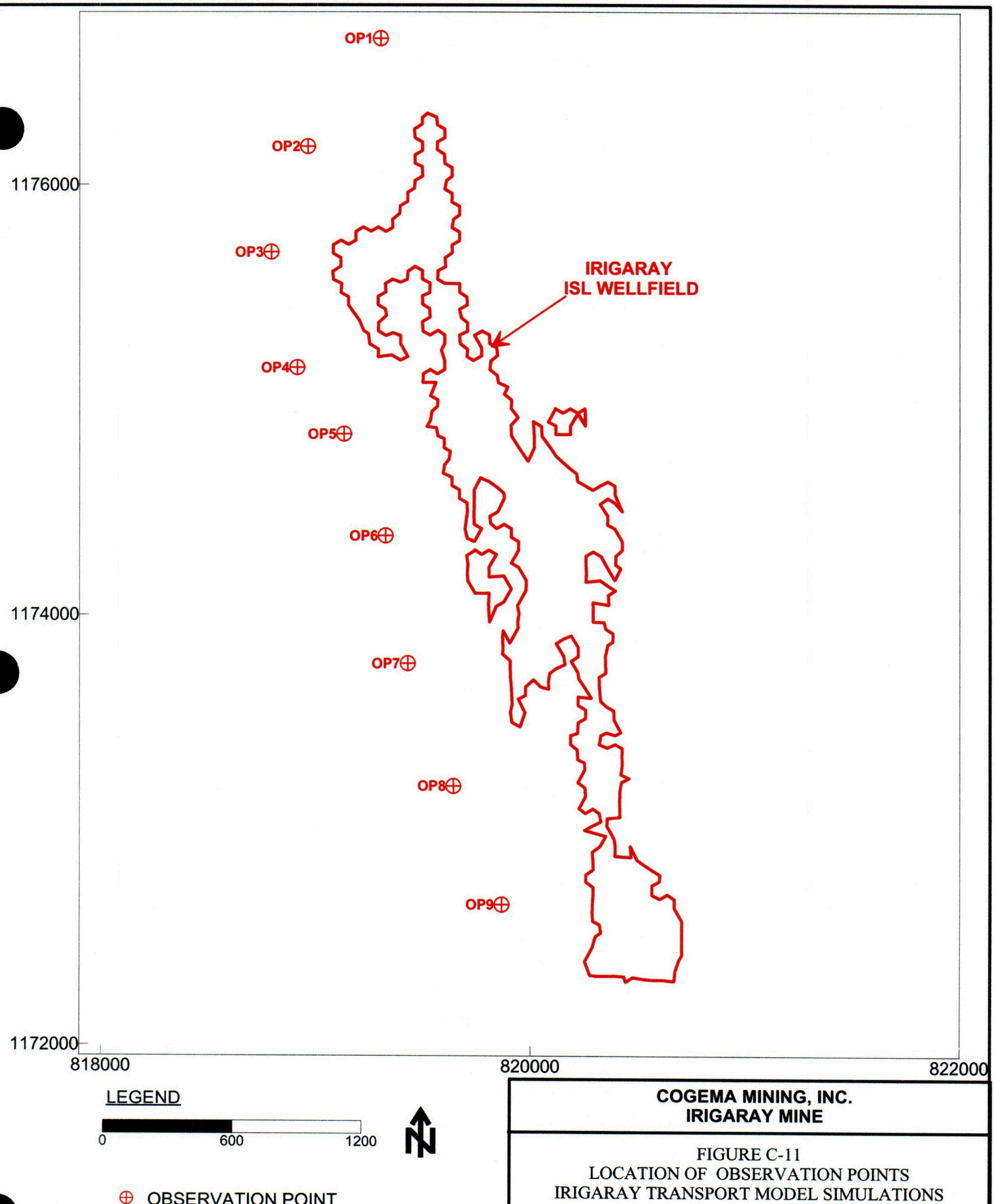
C66



COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-11
LOCATION OF OBSERVATION POINTS
IRIGARAY TRANSPORT MODEL SIMULATIONS

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC11.SRF	BY: EPL CHECKED: HPD

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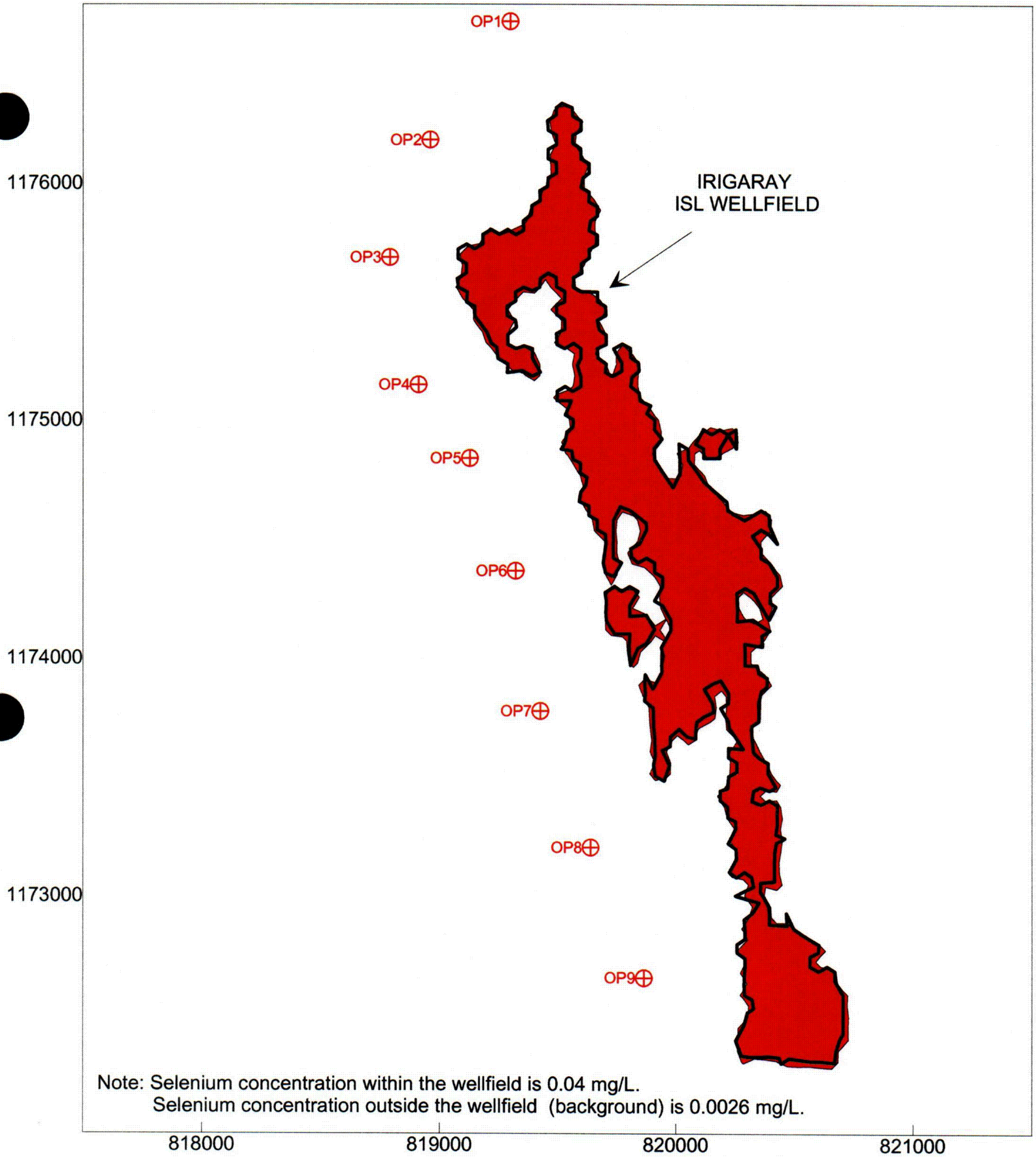

LEGEND

0 500 1000

SCALE IN FEET 1" = 600'

⊕ Observation point for simulated concentrations (400 feet from wellfield)

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-12
INITIAL SELENIUM DISTRIBUTION
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC12r.SRF	BY: EPL CHECKED: HPD

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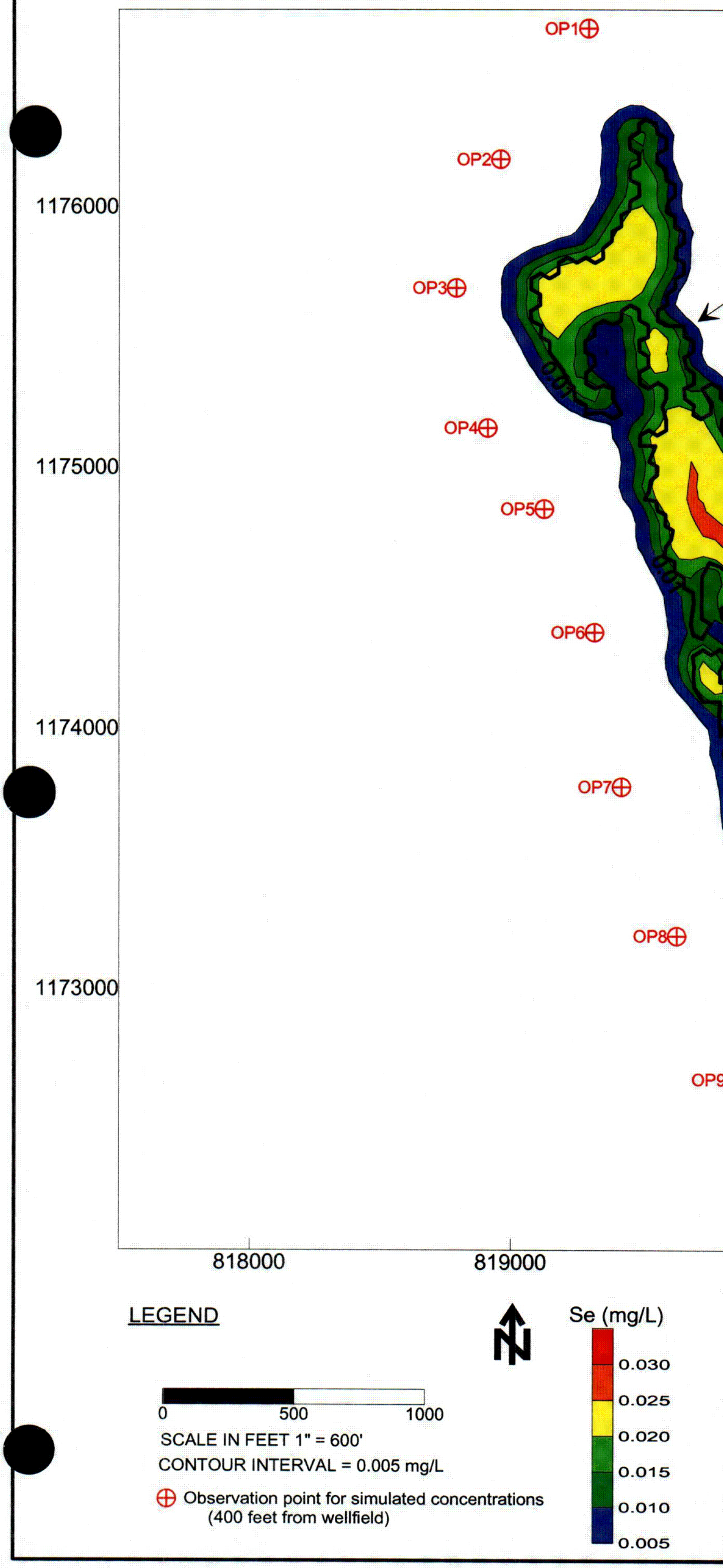

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-13
SELENIUM DISTRIBUTION AT 24 YEARS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002	
DWG: COGEMAFIGC13r.SRF	BY: EPL	CHECKED: HPD

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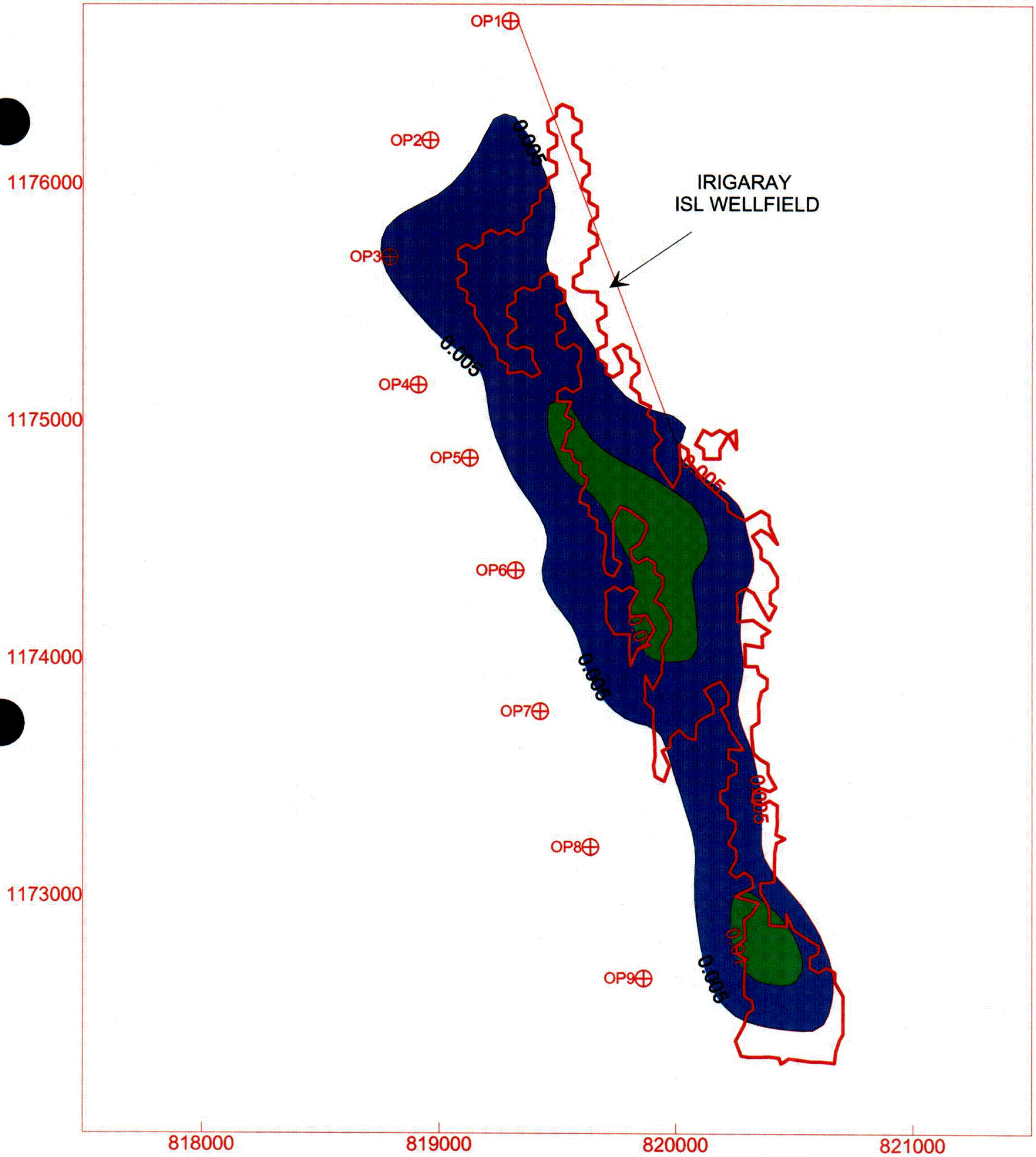
C69



LEGEND

0 500 1000

SCALE IN FEET 1" = 600'

CONTOUR INTERVAL = 0.005 mg/L

⊕ Observation point for simulated concentrations (400 feet from wellfield)

N

Se (mg/L)

0.030
0.025
0.020
0.015
0.010
0.005

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-14
SELENIUM DISTRIBUTION AT 100 YEARS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC14r.SRF	BY: EPL CHECKED: HPD

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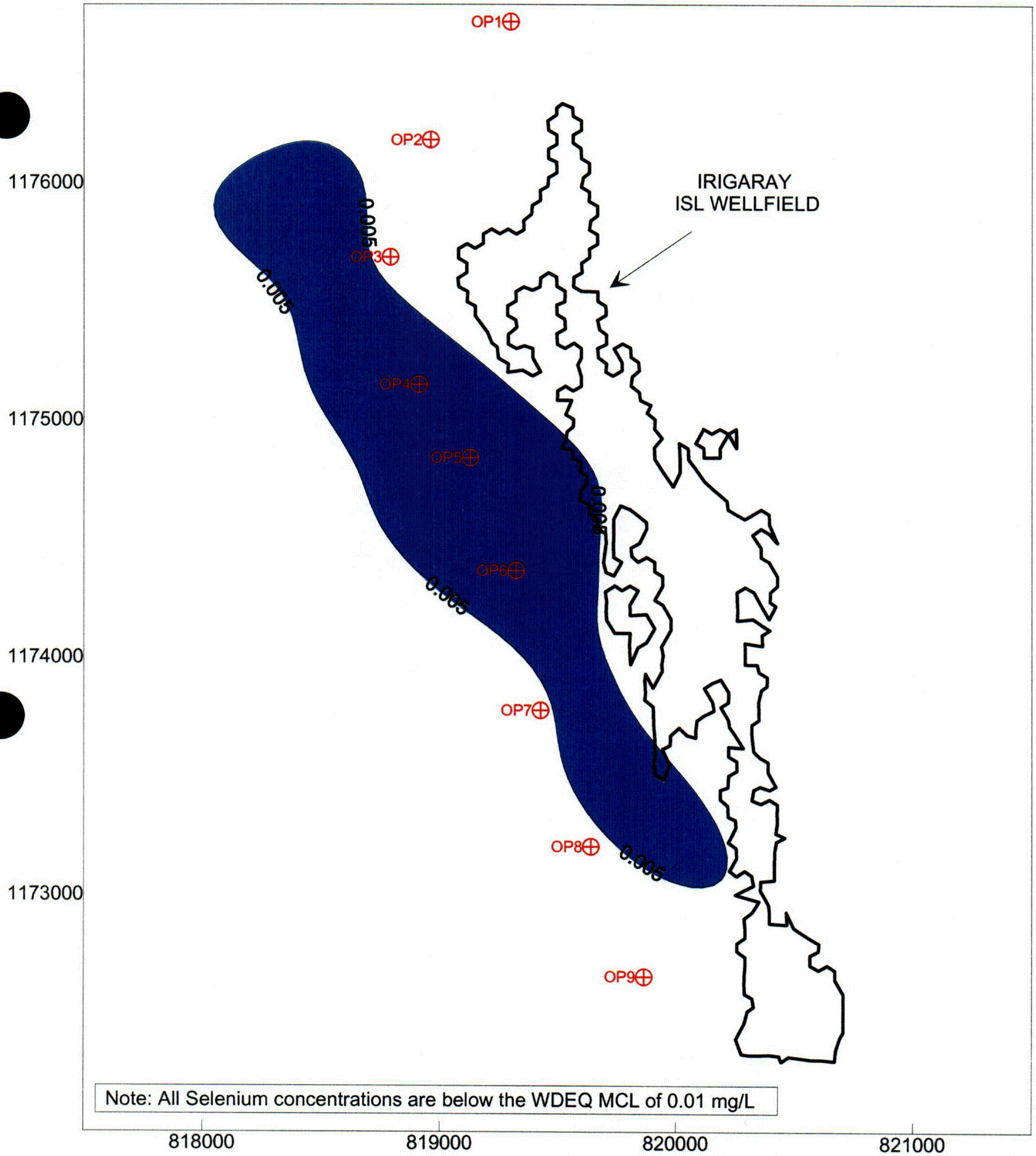

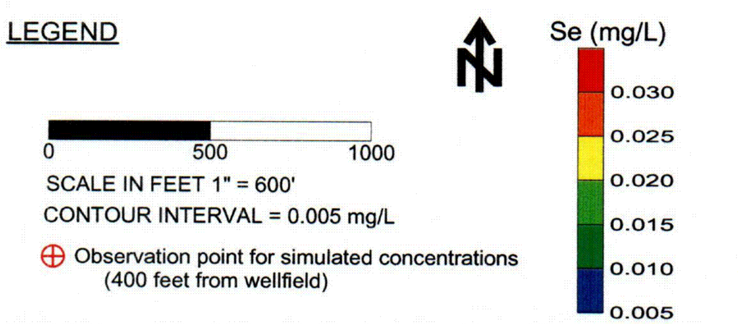

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-15
SELENIUM DISTRIBUTION AT 300 YEARS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC15r.SRF	BY: EPL CHECKED: HPD

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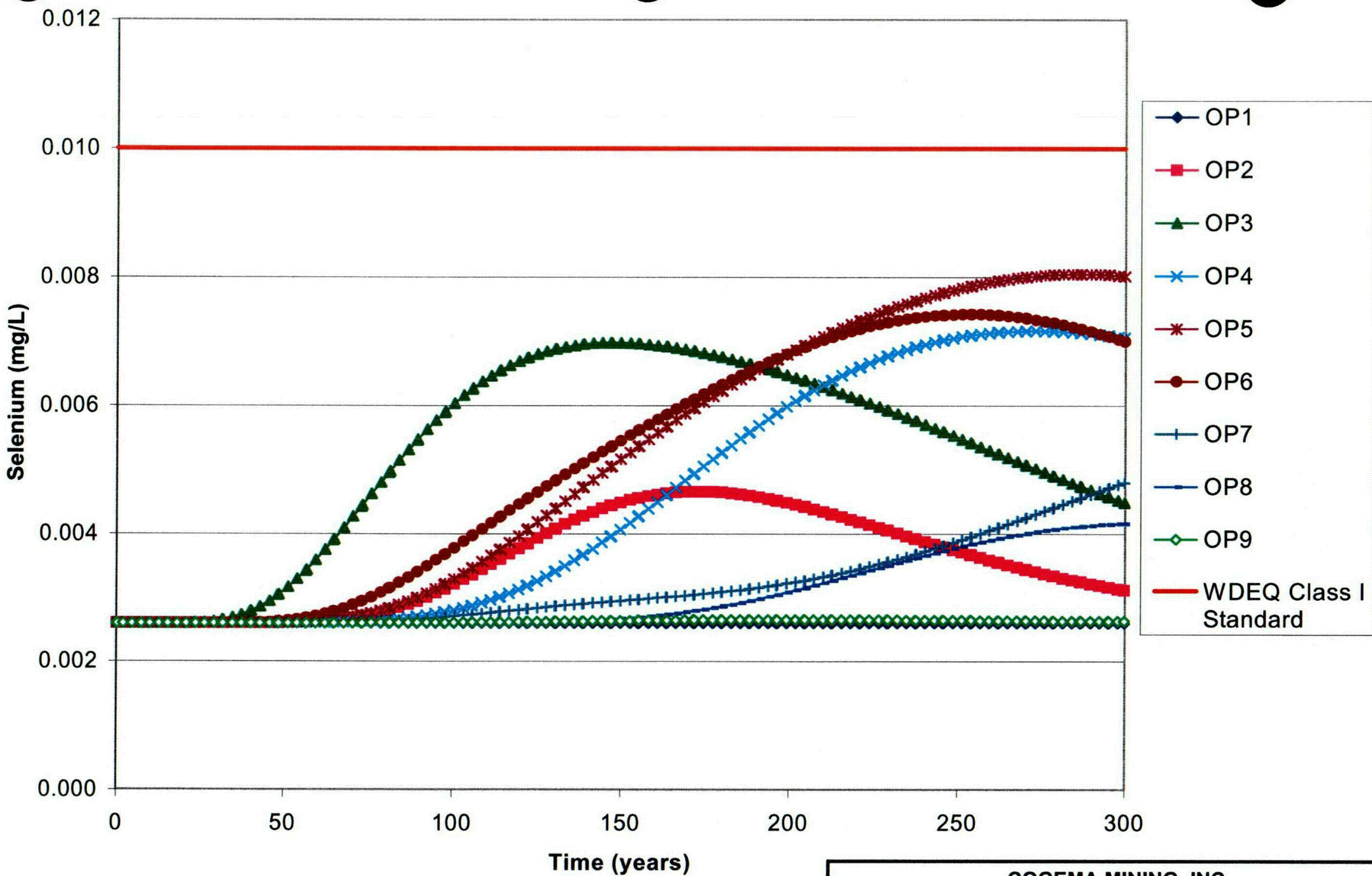
C71



LOCATION OF OBSERVATION POINTS SHOWN ON FIGURE C-11

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-16
MODELED SELENIUM CONCENTRATION vs TIME
AT OBSERVATION POINTS 400 FEET FROM WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC16r.srf	BY: EPL CHECKED: HPD

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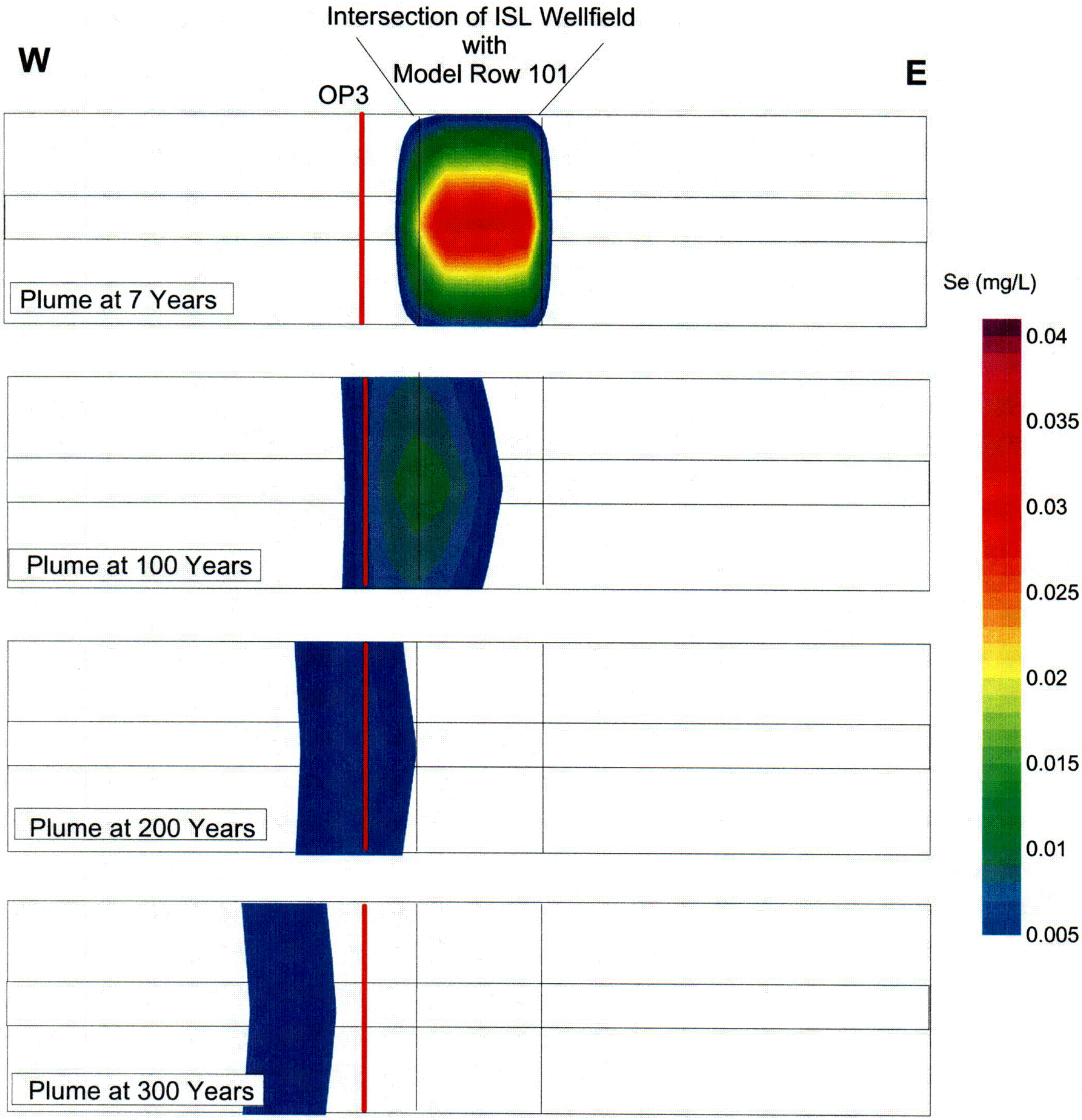
C72



LEGEND

Cross Section Represents Row 101 of the Model, Passing through OP3

CONCENTRATION CONTOUR INTERVAL = 0.001 mg/L

HORIZONTAL SCALE 1" = 735'
VERTICAL SCALE 1" = 73.5'

MINERALIZED ZONE

NON-MINERALIZED ZONE

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-17
SIMULATED MIGRATION OF THE SELENIUM PLUME
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC17r.SRF	BY: EPL CHECKED: HPD

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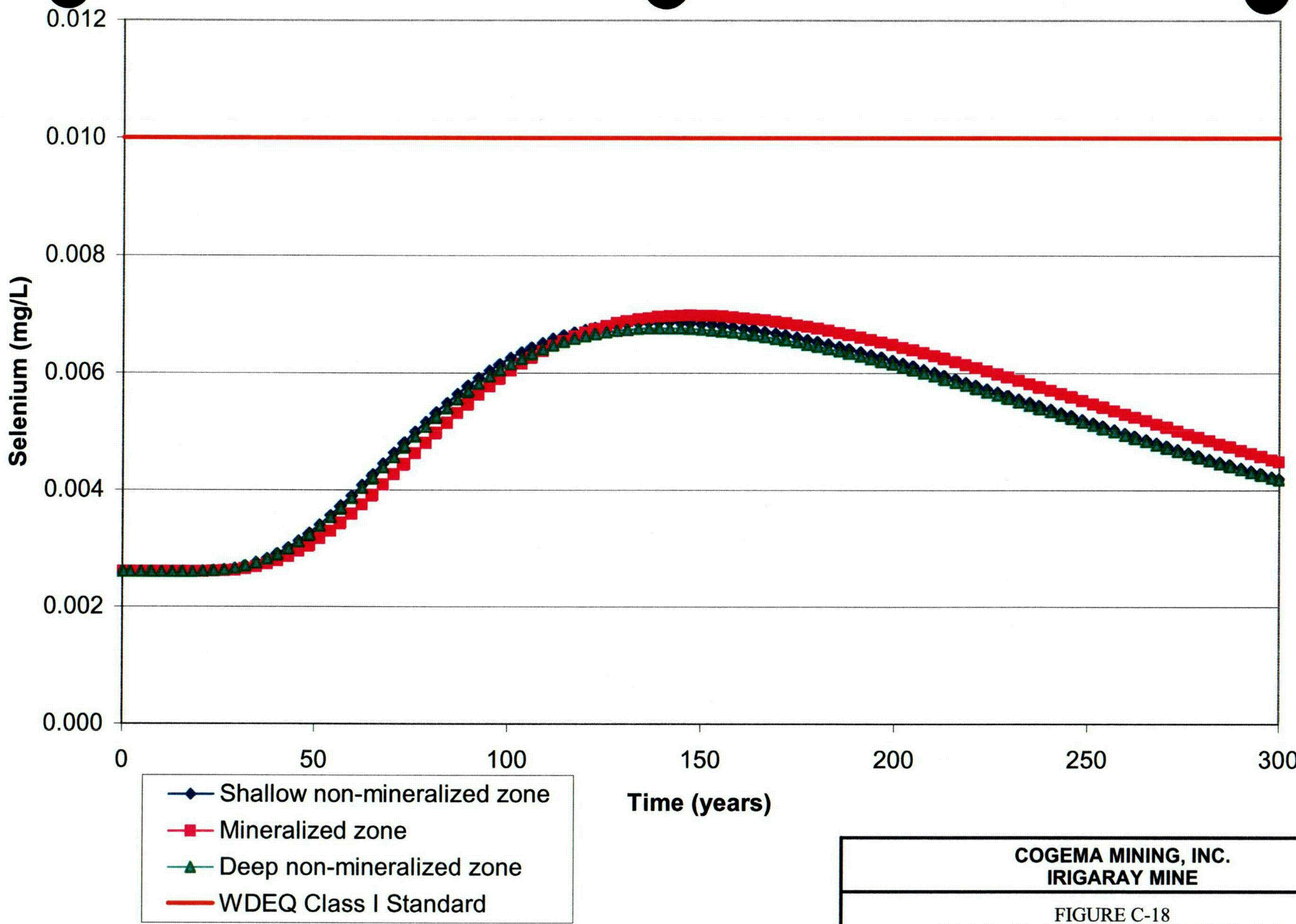

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-18
VERTICAL SELENIUM DISTRIBUTION
AT OBSERVATION POINT OP3

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC18r.srf	BY: EPL CHECKED: HPD

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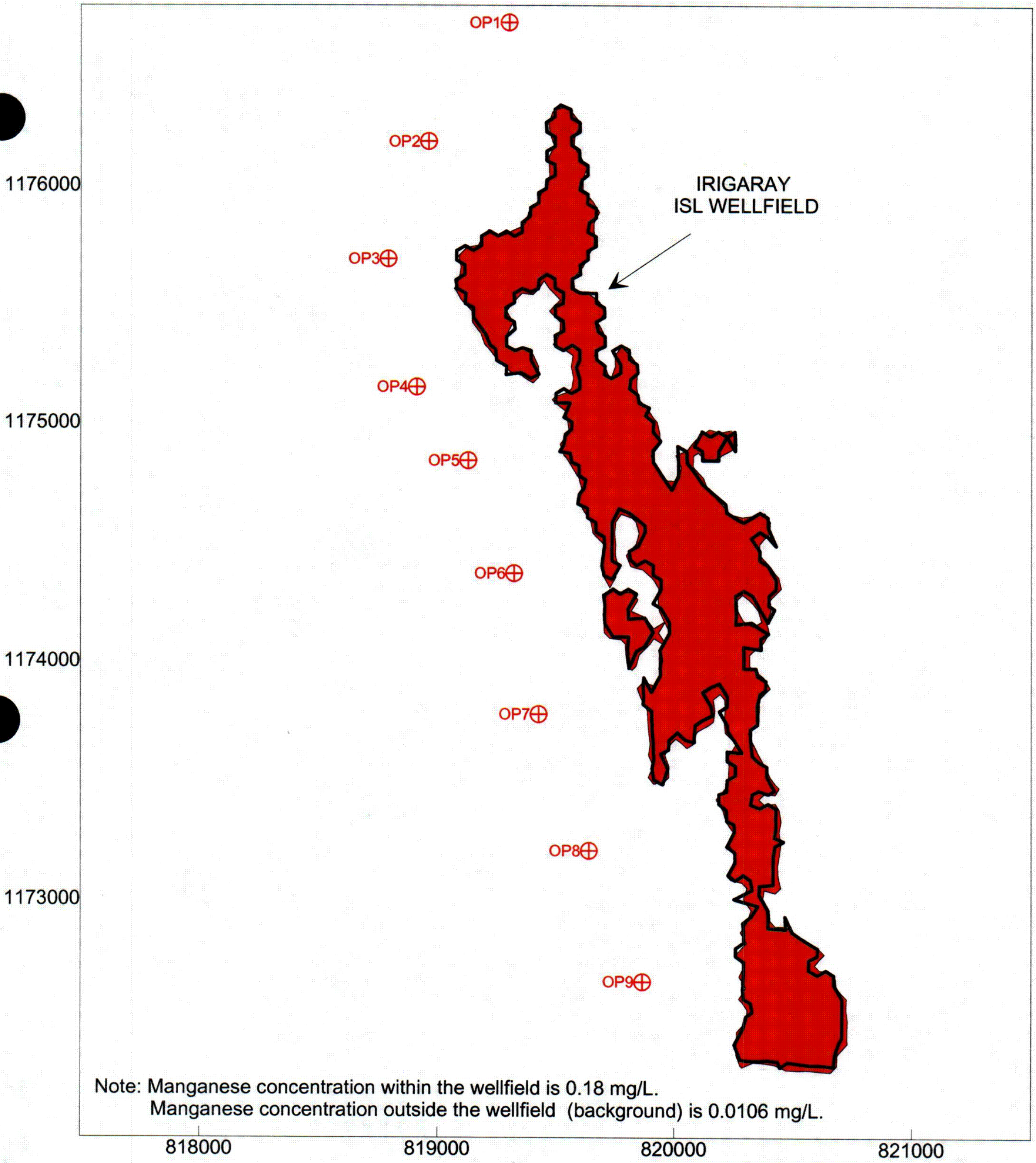
C74



LEGEND

0 500 1000

SCALE IN FEET 1" = 600'

⊕ Observation point for simulated concentrations (400 feet from wellfield)

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-19
INITIAL MANGANESE DISTRIBUTION
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC19r.SRF	BY: EPL CHECKED: HPD

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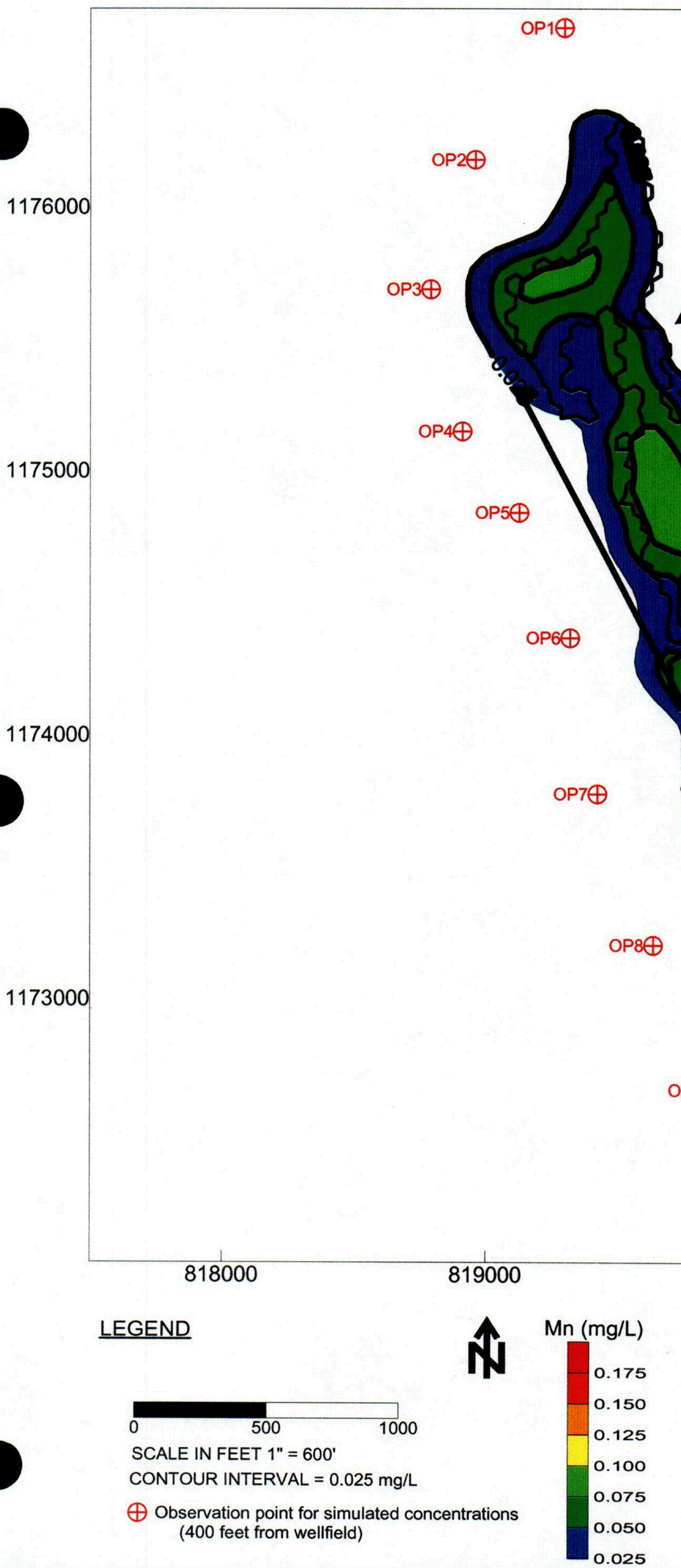

COGEMA MINING, INC. IRIGARAY MINE	
FIGURE C-20 MANGANESE DISTRIBUTION AT 24 YEARS IRIGARAY ISL WELLFIELD	
PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC20r.SRF	BY: EPL CHECKED: HPD
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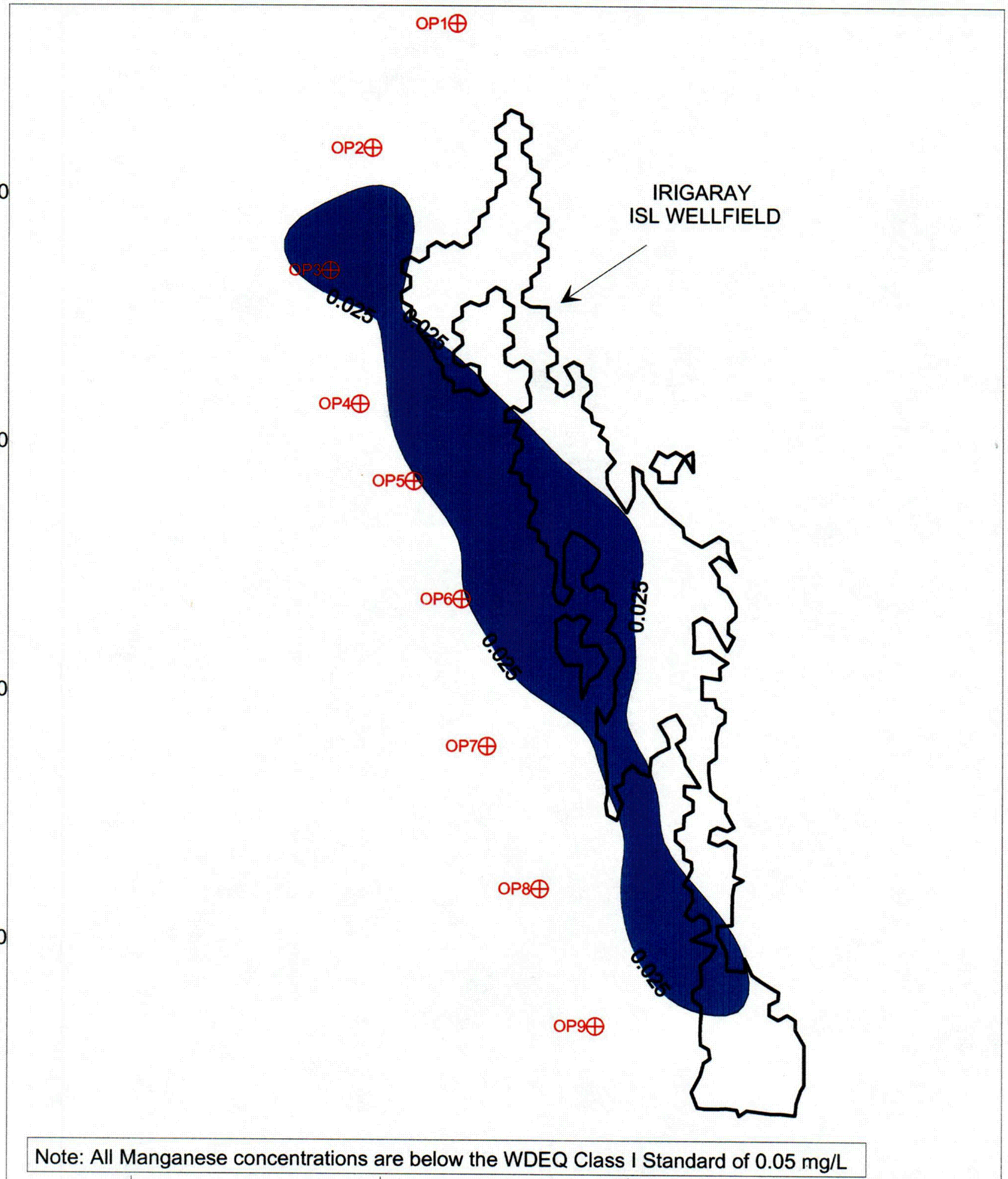

LEGEND

0 500 1000

SCALE IN FEET 1" = 600'

CONTOUR INTERVAL = 0.025 mg/L

⊕ Observation point for simulated concentrations (400 feet from wellfield)

Mn (mg/L)

0.175
0.150
0.125
0.100
0.075
0.050
0.025

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-21
MANGANESE DISTRIBUTION AT 100 YEARS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002	
DWG: COGEMAFIGC21r.SRF	BY: EPL	CHECKED: HPD

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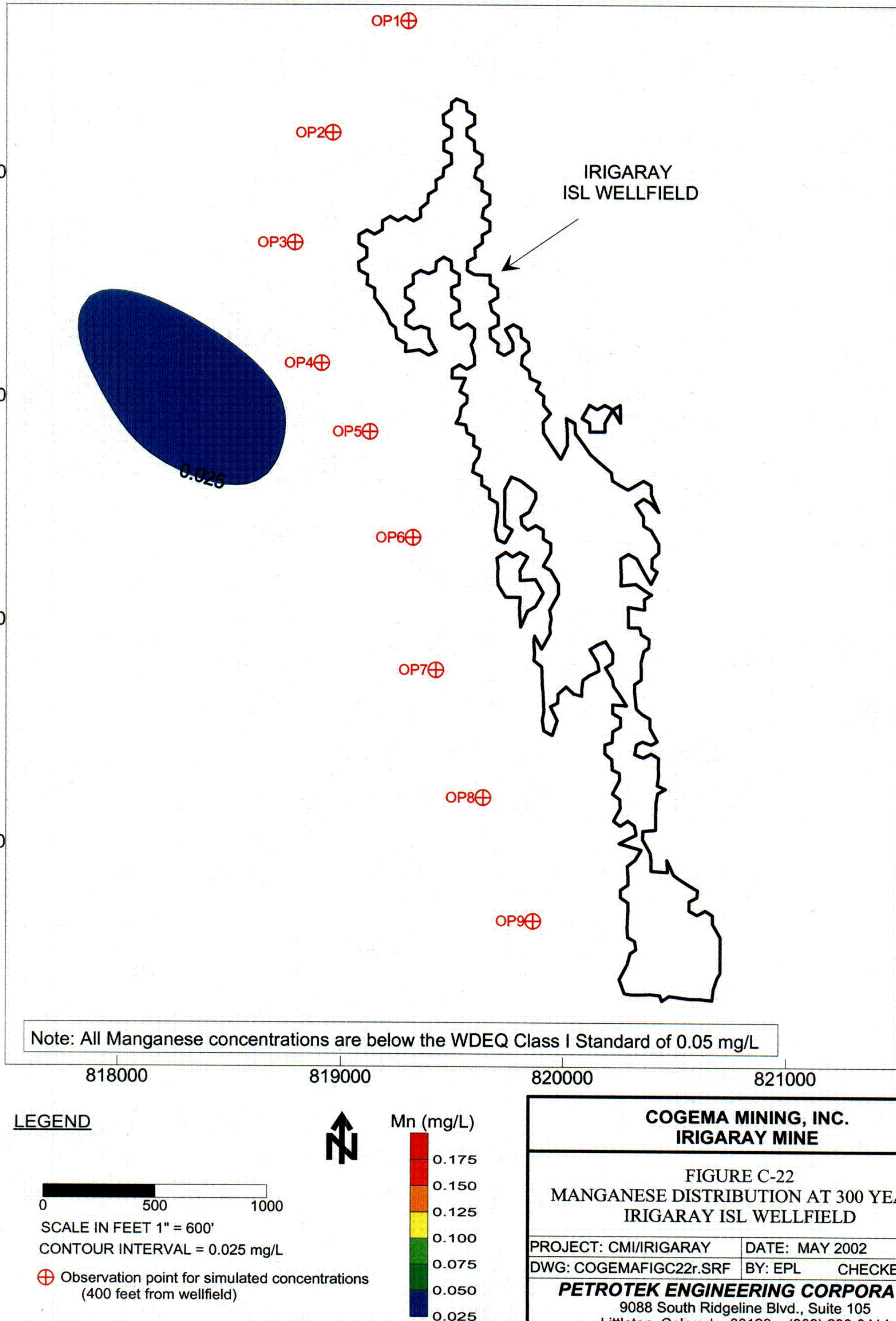
C77



COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-22
MANGANESE DISTRIBUTION AT 300 YEARS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC22r.SRF	BY: EPL CHECKED: HPD

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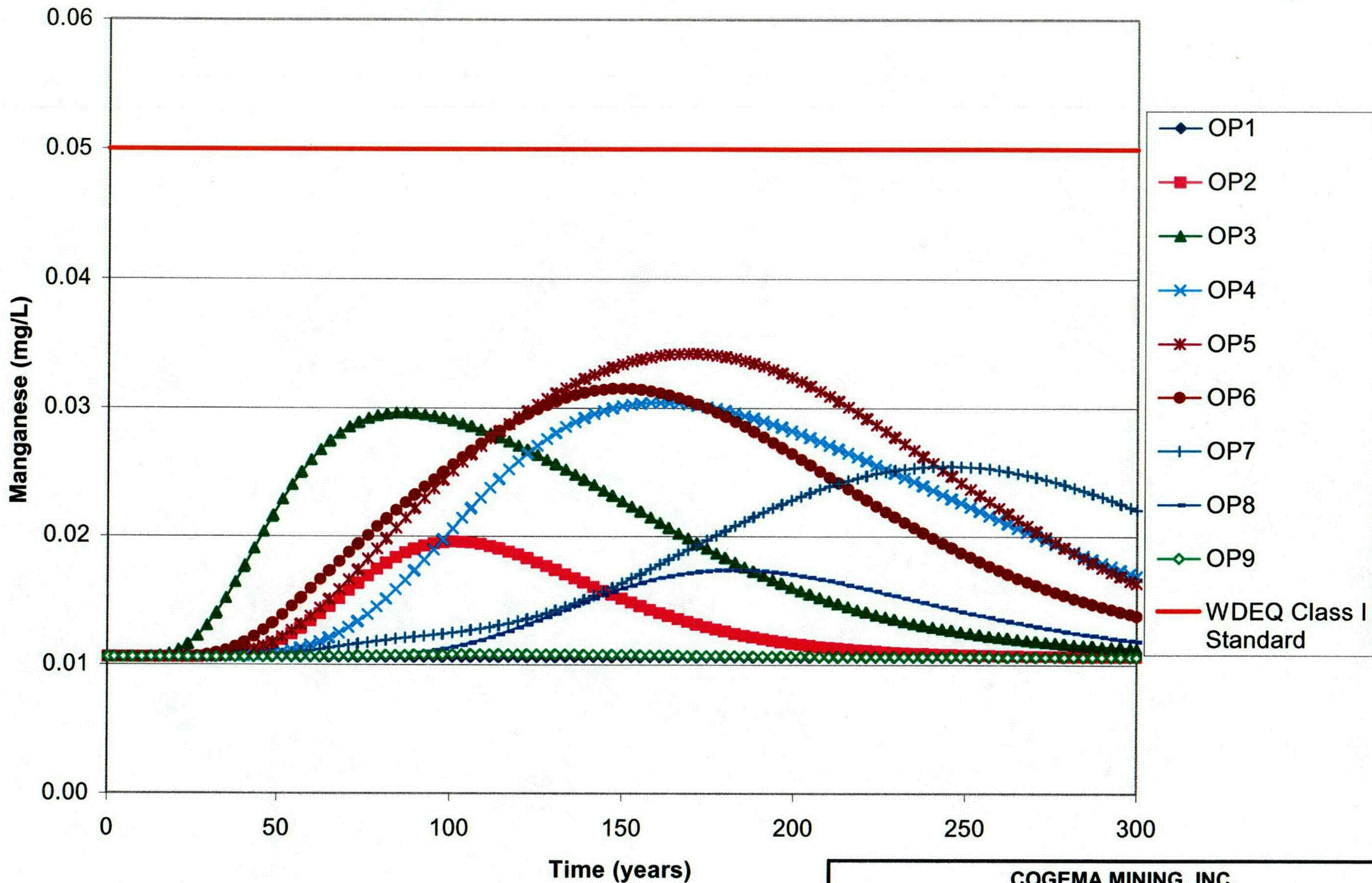

LOCATION OF OBSERVATION POINTS SHOWN ON FIGURE C-11

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-23
MODELED MANGANESE CONCENTRATION vs TIME
AT OBSERVATION POINTS 400 FEET FROM WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC23.srf	BY: EPL CHECKED: HPD

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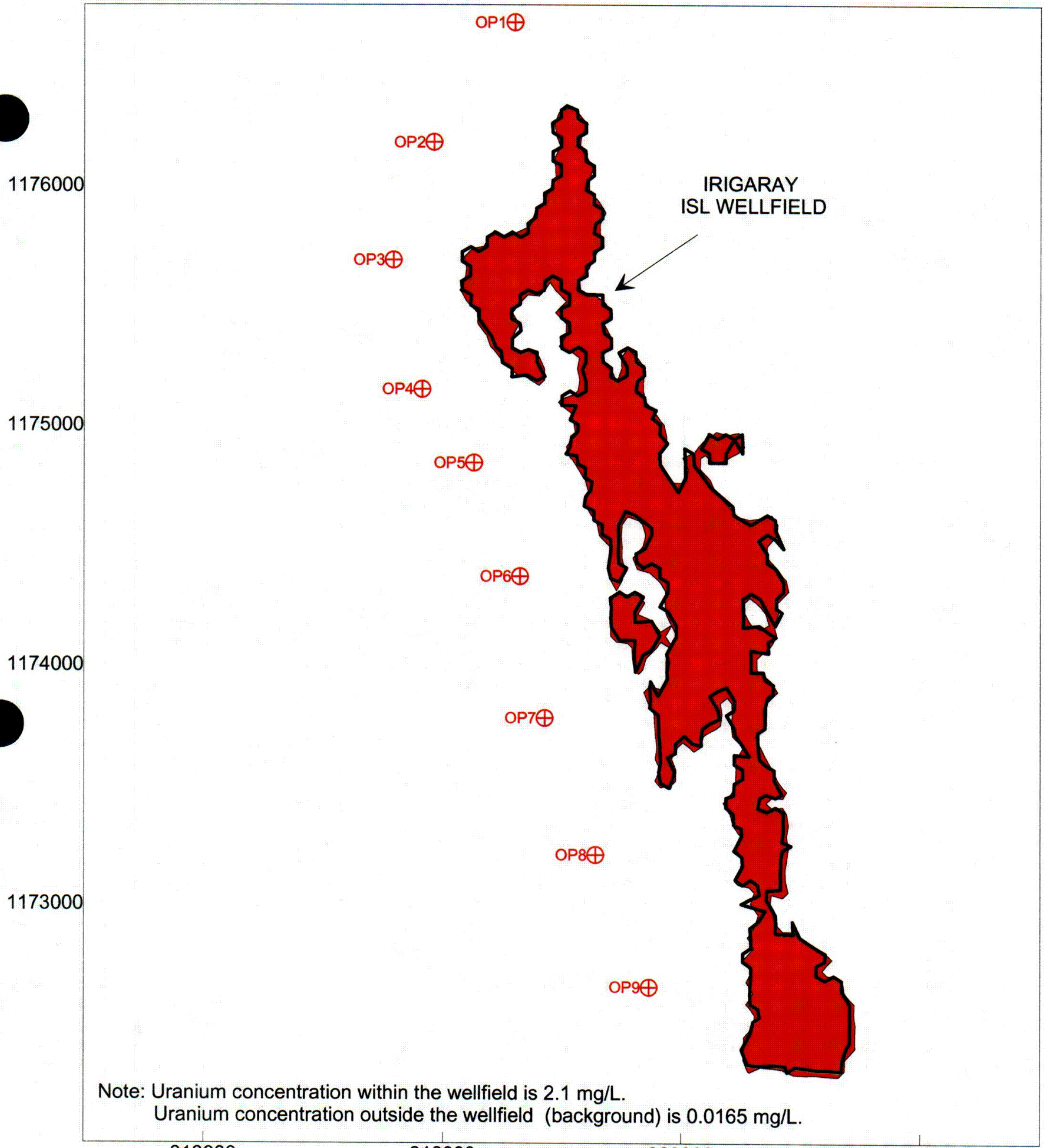
C79



LEGEND

0 500 1000

SCALE IN FEET 1" = 600'

⊕ Observation point for simulated concentrations (400 feet from wellfield)

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-24
INITIAL URANIUM DISTRIBUTION
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC24r.SRF	BY: EPL CHECKED: HPD

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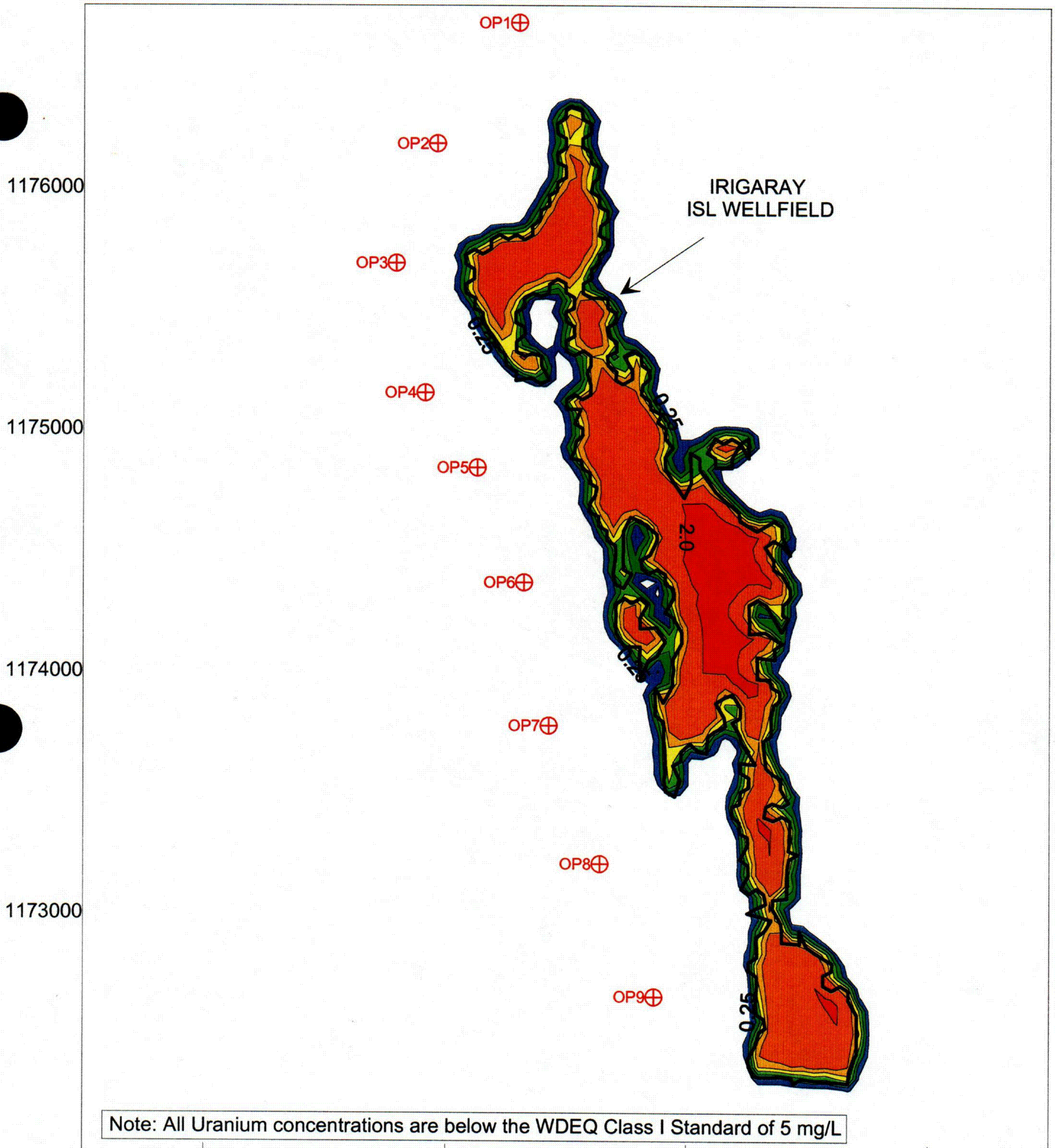
C900



LEGEND

0 500 1000

SCALE IN FEET 1" = 600'

CONTOUR INTERVAL = 0.25 mg/L

⊕ Observation point for simulated concentrations (400 feet from wellfield)

U (mg/L): 2.00, 1.75, 1.50, 1.25, 1.00, 0.75, 0.50, 0.25

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-25
URANIUM DISTRIBUTION AT 24 YEARS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC25r.SRF	BY: EPL CHECKED: HPD

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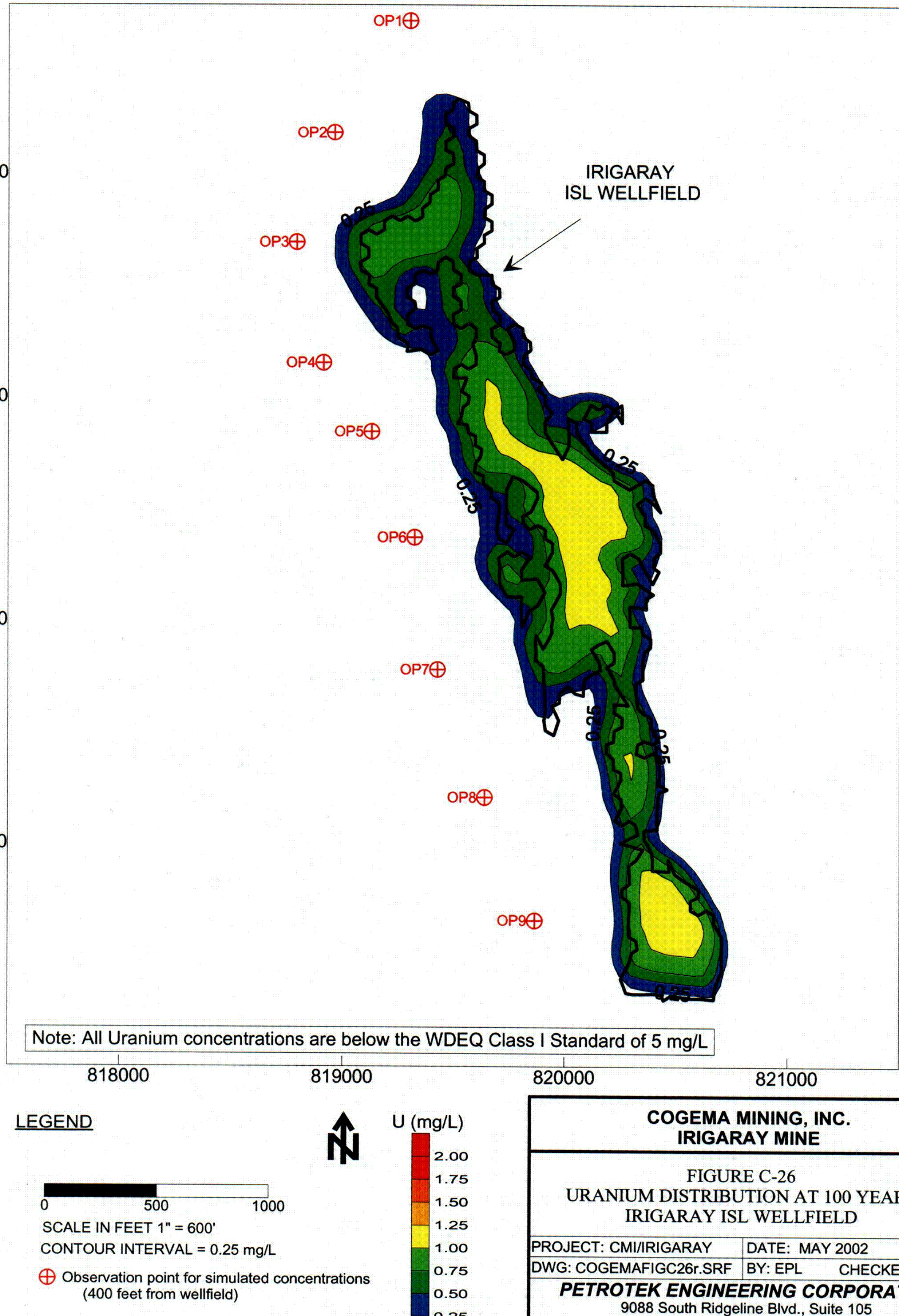
C81



COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-26
URANIUM DISTRIBUTION AT 100 YEARS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002	
DWG: COGEMAFIGC26r.SRF	BY: EPL	CHECKED: HPD

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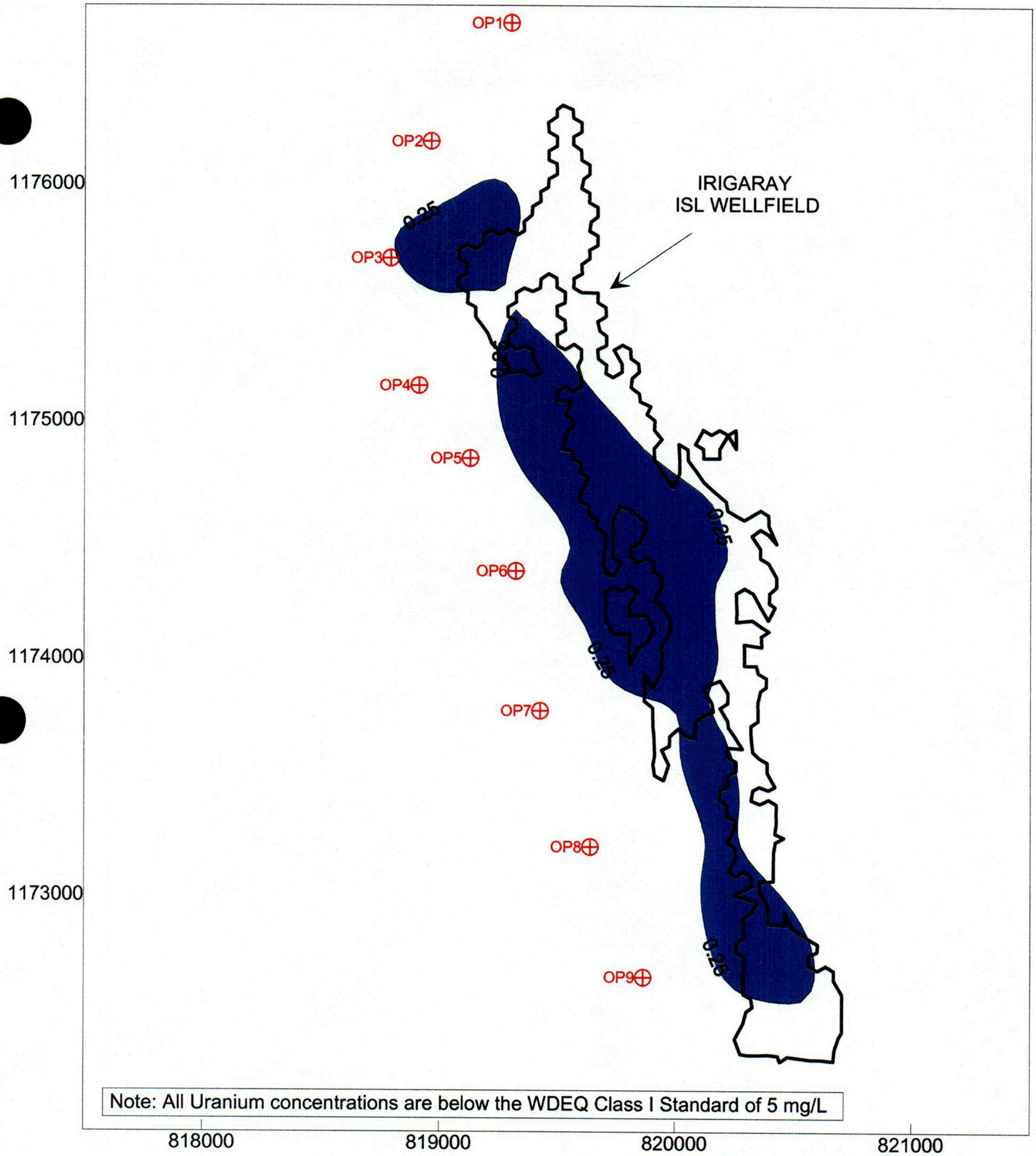
C82



LEGEND

N

0 500 1000

SCALE IN FEET 1" = 600'

CONTOUR INTERVAL = 0.25 mg/L

⊕ Observation point for simulated concentrations (400 feet from wellfield)

U (mg/L)

2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-27
URANIUM DISTRIBUTION AT 300 YEARS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC27r.SRF	BY: EPL CHECKED: HPD

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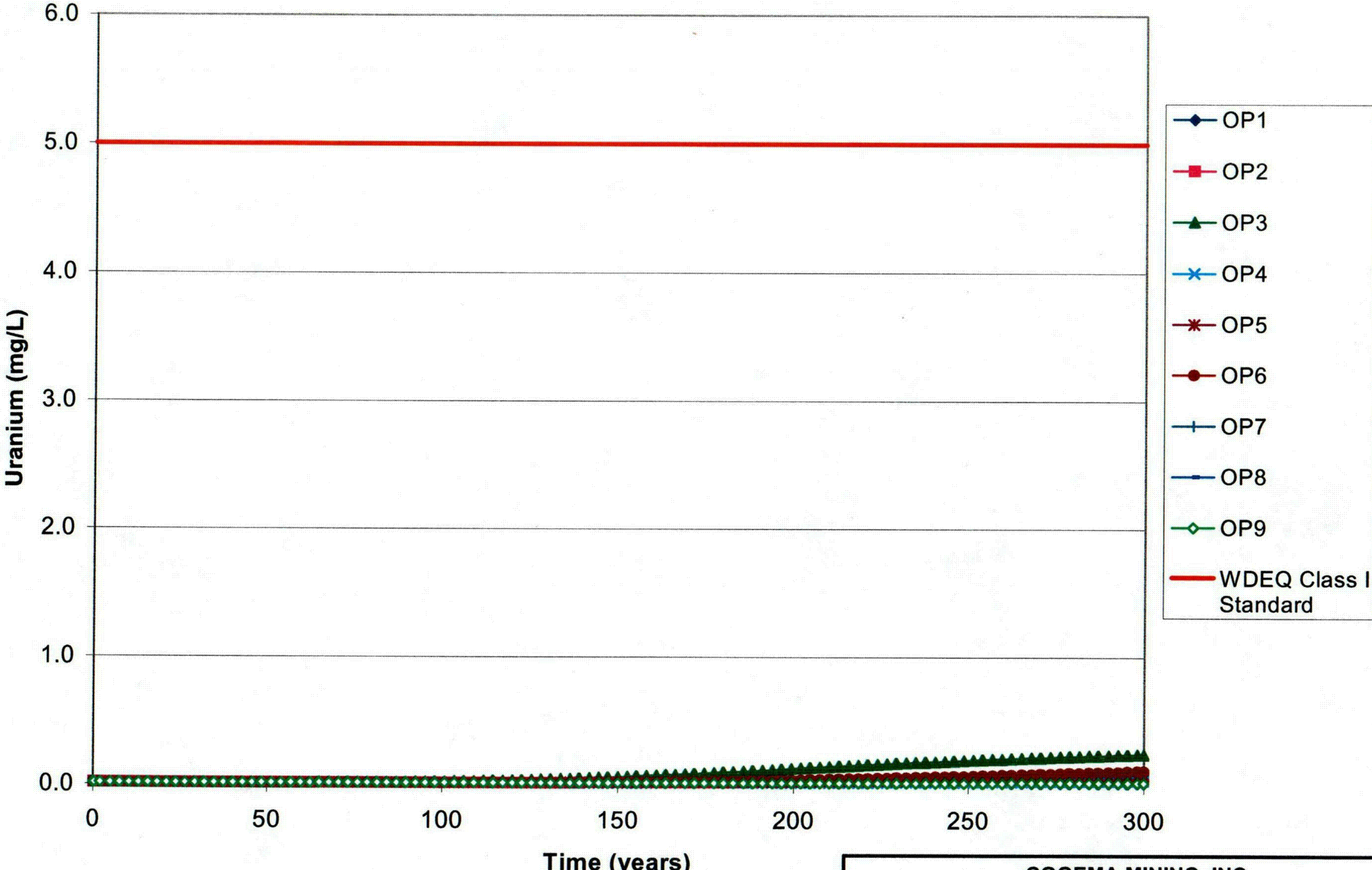
C83



LOCATION OF OBSERVATION POINTS SHOWN ON FIGURE C-11

COGEMA MINING, INC. IRIGARAY MINE	
FIGURE C-28 MODELED URANIUM CONCENTRATION vs TIME AT OBSERVATION POINTS 400 FEET FROM WELLFIELD	
PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC28.srf	BY: EPL CHECKED: HPD
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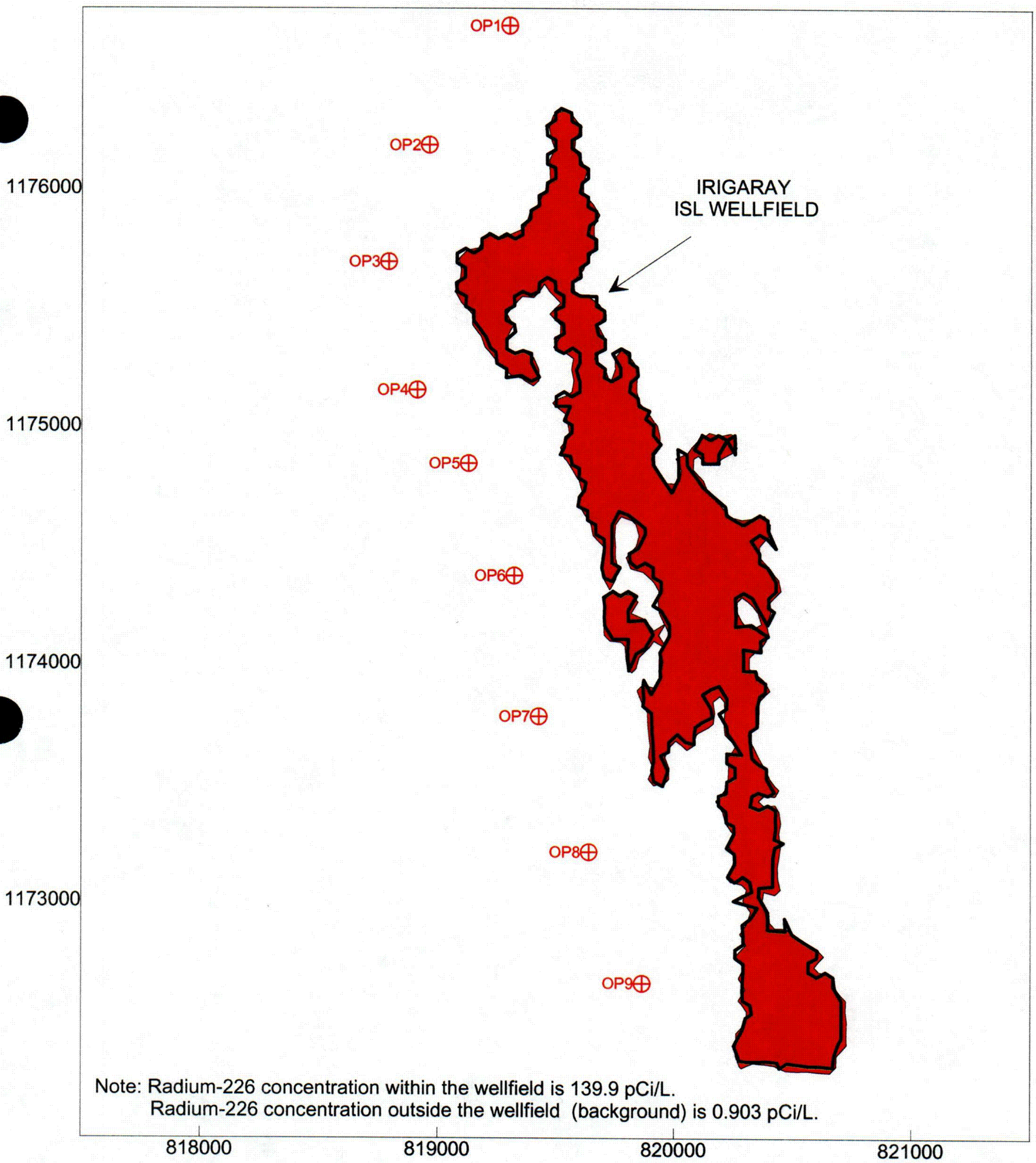
C84



LEGEND

0 500 1000

SCALE IN FEET 1" = 600'

⊕ Observation point for simulated concentrations (400 feet from wellfield)

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-29
INITIAL RADIUM-226 DISTRIBUTION
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC29r.SRF	BY: EPL CHECKED: HPD

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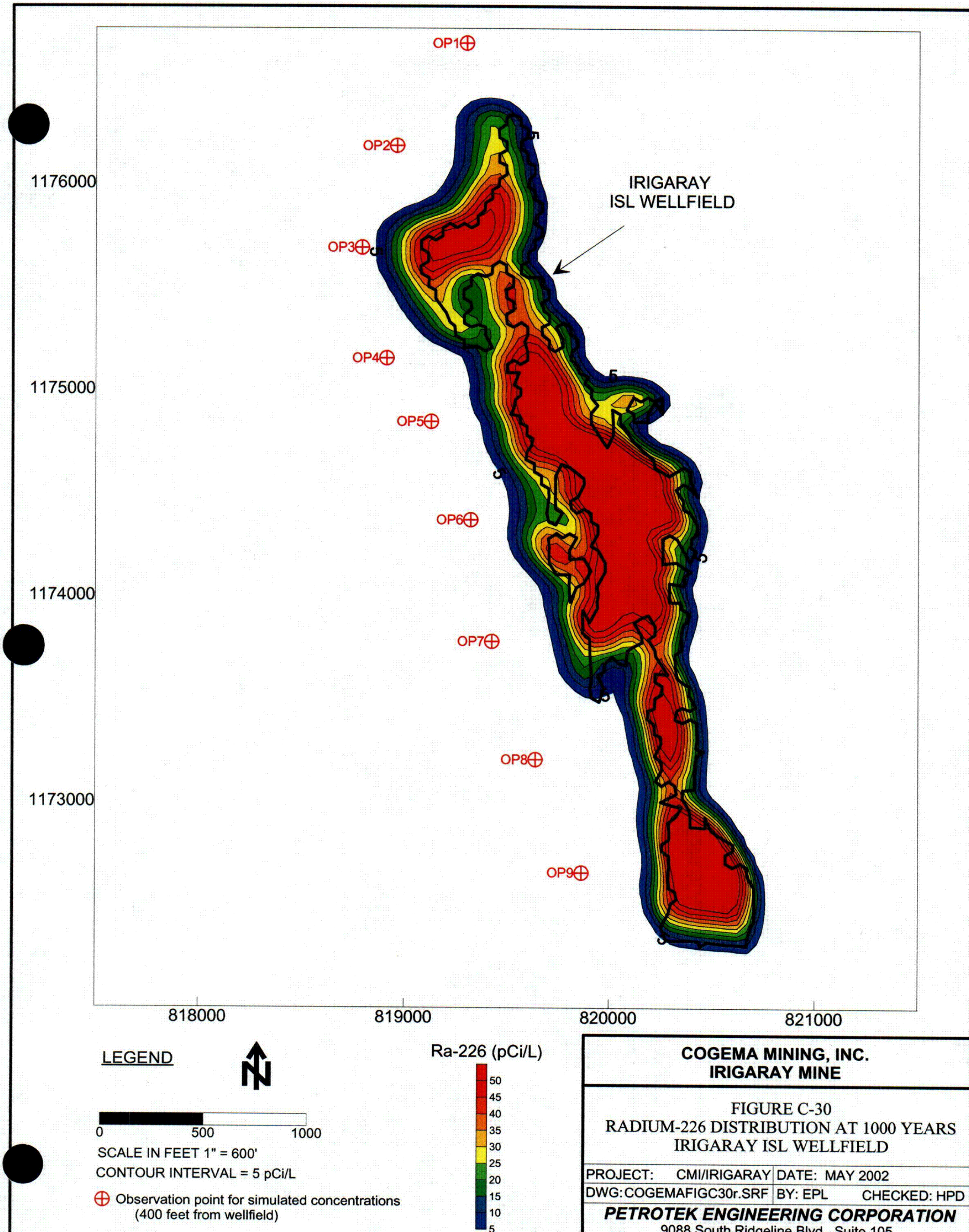

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-30
RADIUM-226 DISTRIBUTION AT 1000 YEARS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002	
DWG: COGEMAFIGC30r.SRF	BY: EPL	CHECKED: HPD

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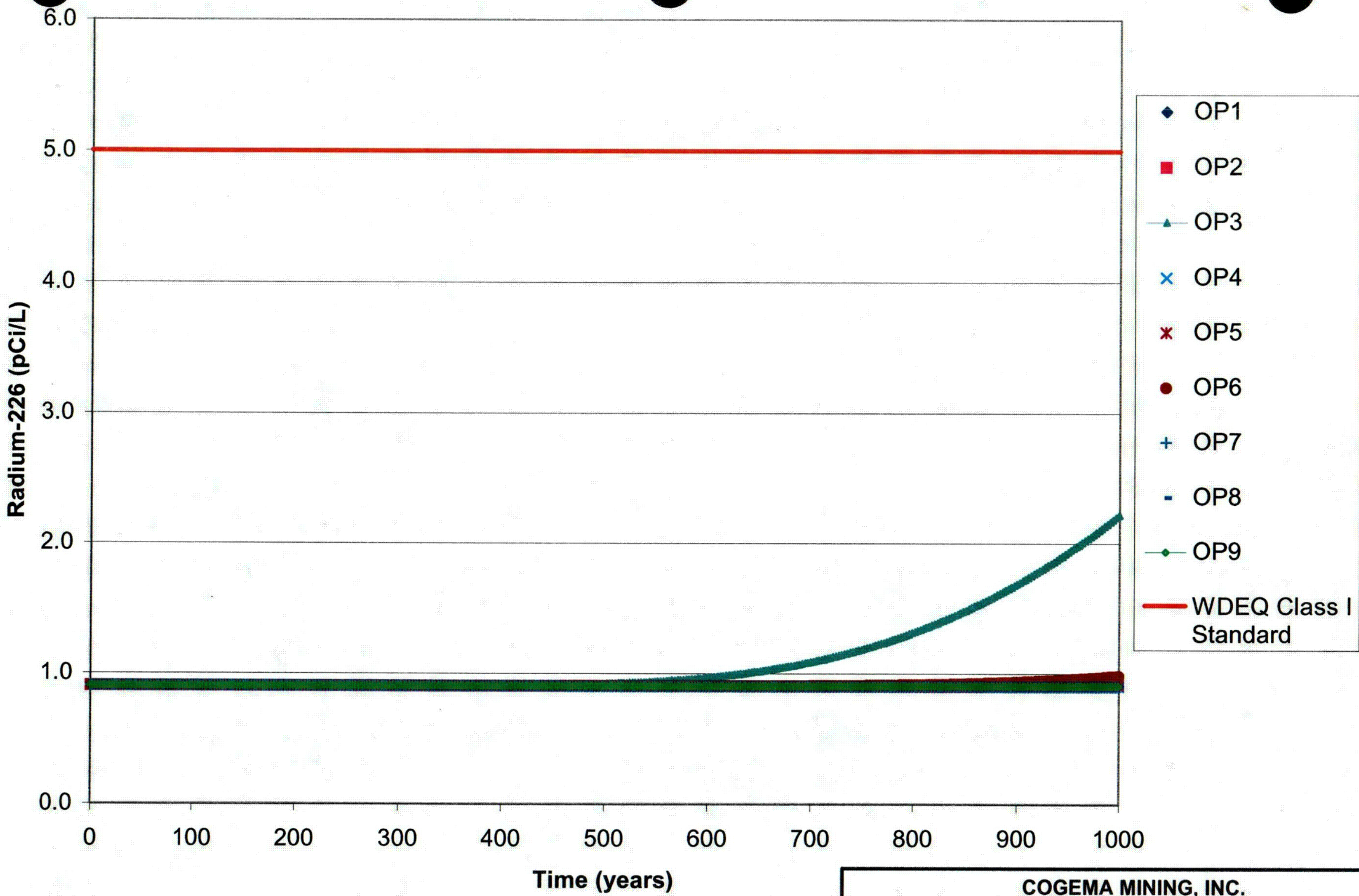
C86



LOCATION OF OBSERVATION POINTS SHOWN ON FIGURE C-11

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-31
MODELED RADIUM-226 CONCENTRATION vs TIME
AT OBSERVATION POINTS 400 FEET FROM WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC31r.srf	BY: EPL CHECKED: HPD

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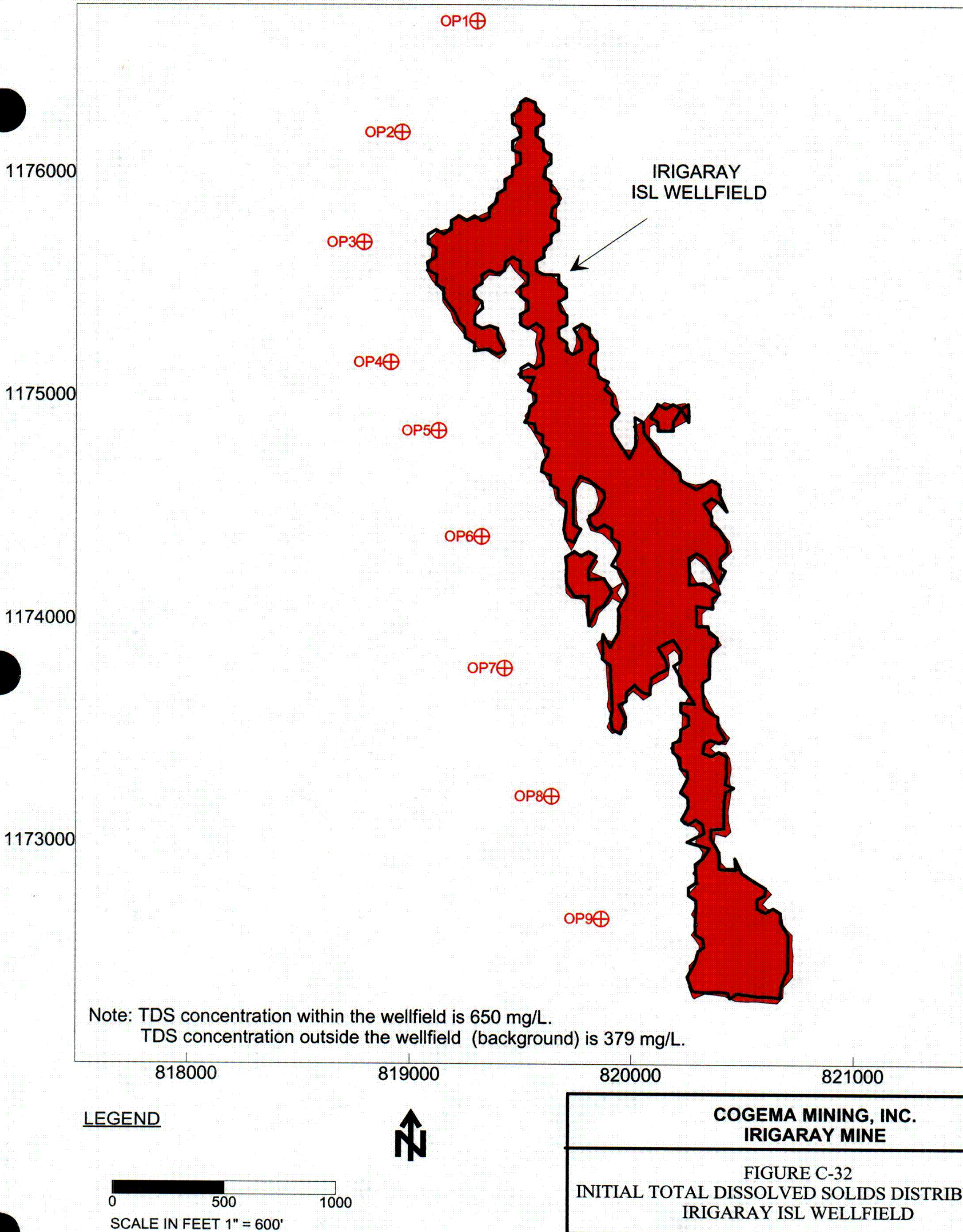

LEGEND

⊕ Observation point for simulated concentrations (400 feet from wellfield)

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-32
INITIAL TOTAL DISSOLVED SOLIDS DISTRIBUTION
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC32r.SRF	BY: EPL CHECKED: HPD

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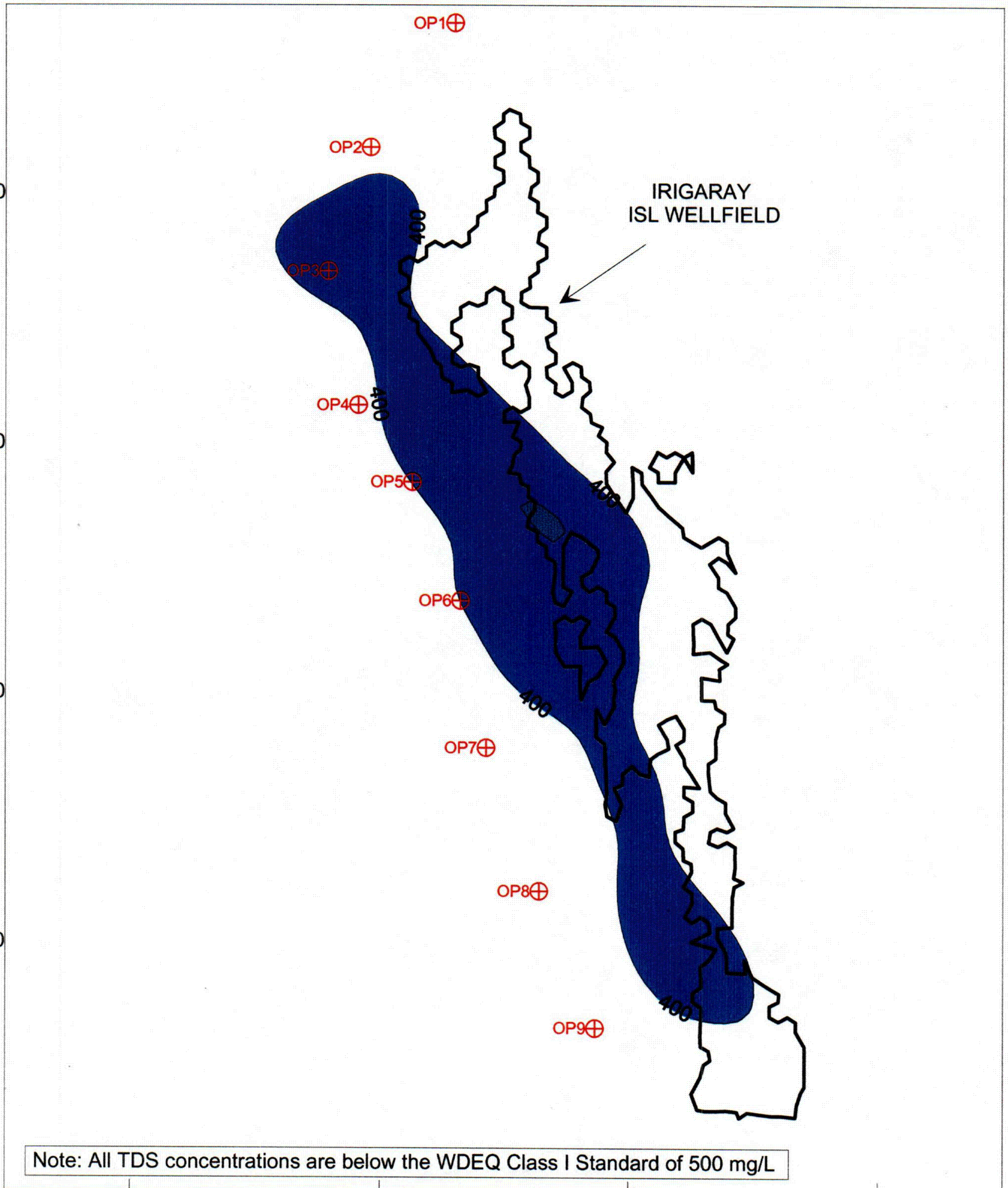

LEGEND

N

0 500 1000

SCALE IN FEET 1" = 600'

CONTOUR INTERVAL = 25 mg/L

⊕ Observation point for simulated concentrations (400 feet from wellfield)

TDS (mg/L)

650
625
600
575
550
525
500
475
450
425
400

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-33
TOTAL DISSOLVED SOLIDS DISTRIBUTION AT 100 YEARS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC33r.SRF	BY: EPL CHECKED: HPD

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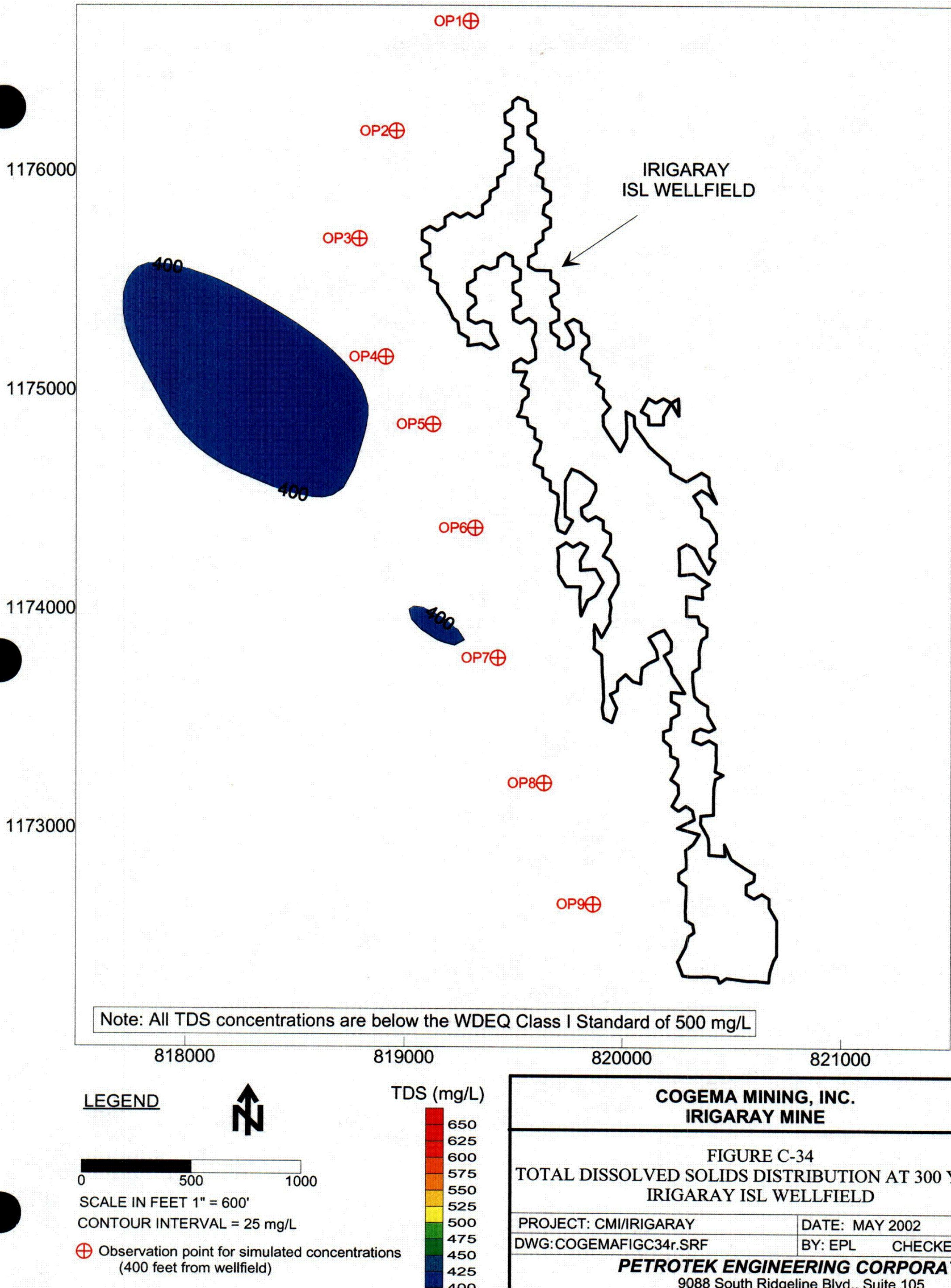

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-34
TOTAL DISSOLVED SOLIDS DISTRIBUTION AT 300 YEARS
IRIGARAY ISL WELLFIELD

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC34r.SRF	BY: EPL CHECKED: HPD

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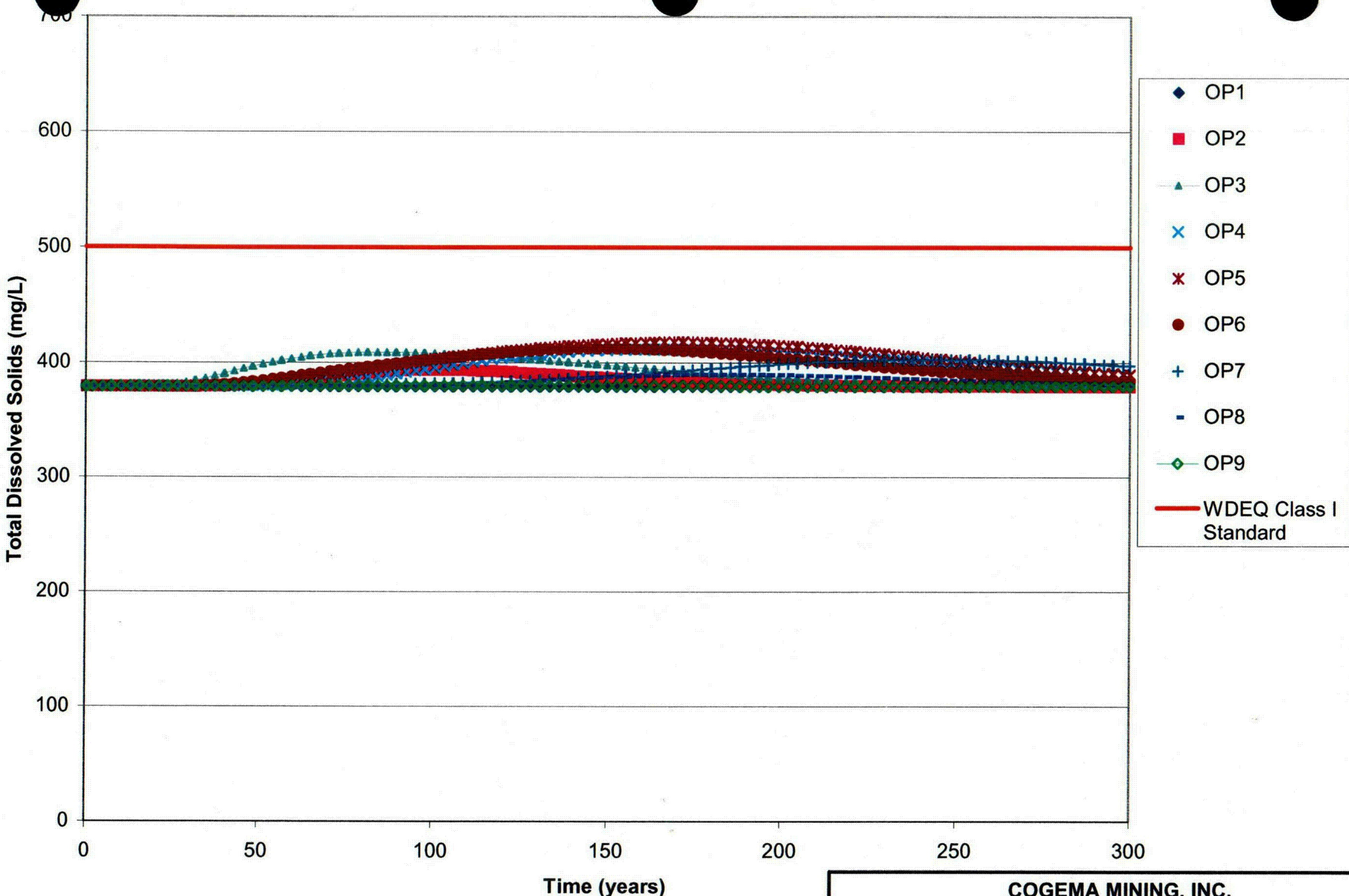
C90



LOCATION OF OBSERVATION POINTS SHOWN ON FIGURE C-11

COGEMA MINING, INC. IRIGARAY MINE	
FIGURE C-35 MODELED TDS CONCENTRATION vs TIME AT OBSERVATION POINTS 400 FEET FROM WELLFIELD	
PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC35r.srf	BY: EPL CHECKED: HPD
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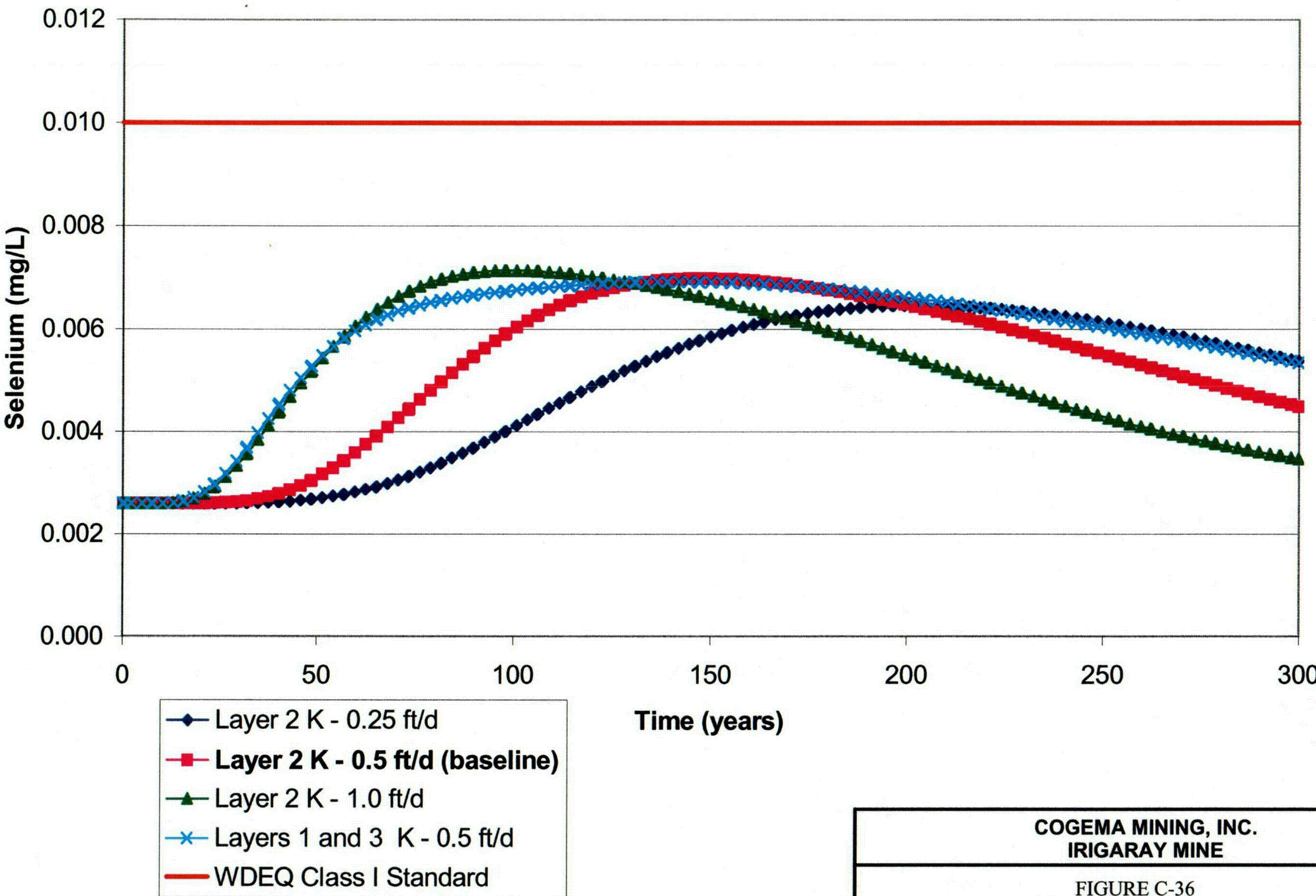

COGEMA MINING, INC. IRIGARAY MINE	
FIGURE C-36 SENSITIVITY ANALYSIS-HYDRAULIC CONDUCTIVITY SELENIUM AT OBSERVATION POINT OP3	
PROJECT: CMI/IRIGARAY	DATE: JUNE 2002
DWG: COGEMAFIGC36r.srf	BY: EPL CHECKED: HPD
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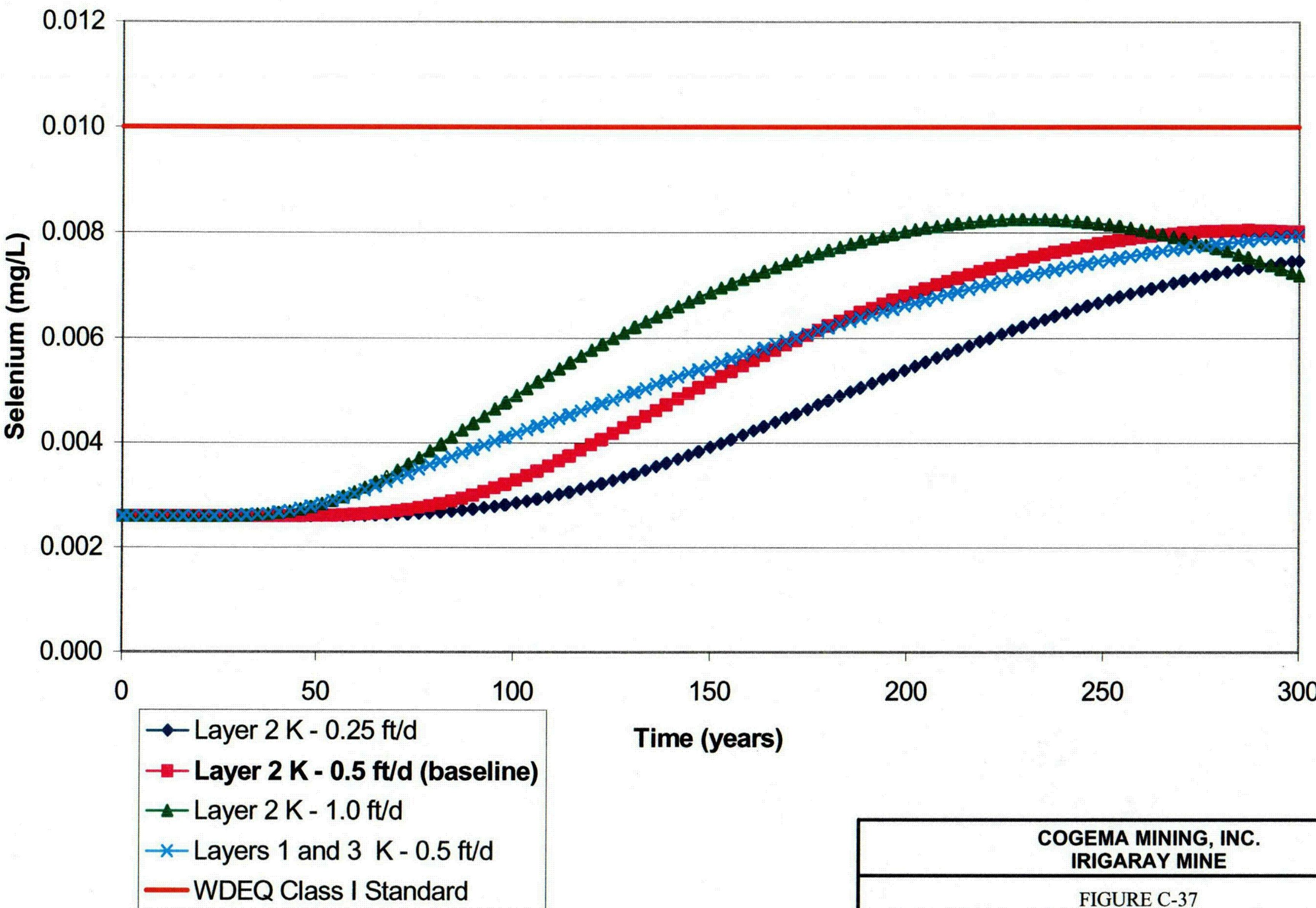
C92



COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-37
SENSITIVITY ANALYSIS-HYDRAULIC CONDUCTIVITY
SELENIUM AT OBSERVATION POINT OP5

PROJECT: CMI/IRIGARAY	DATE: JUNE 2002	
DWG: COGEMAFIGC37r.srf	BY: EPL	CHECKED: HPD

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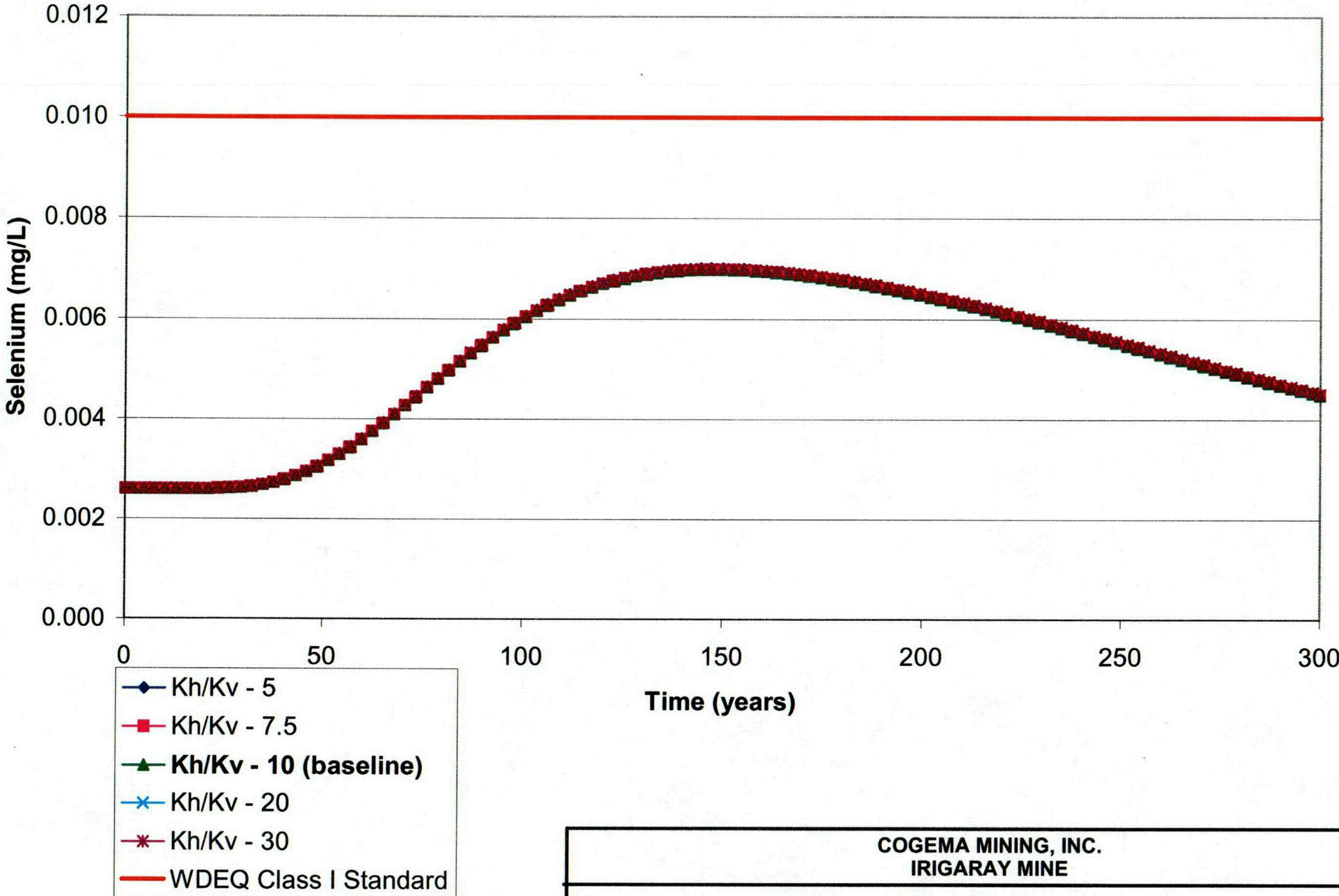

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-38
SENSITIVITY ANALYSIS-HORIZONTAL/VERTICAL HYDRAULIC CONDUCTIVITY RATIO
SELENIUM AT OBSERVATION POINT OP3

PROJECT: CMI/IRIGARAY	DATE: JUNE 2002	
DWG: COGEMAFIGC38r.srf	BY: EPL	CHECKED: HPD

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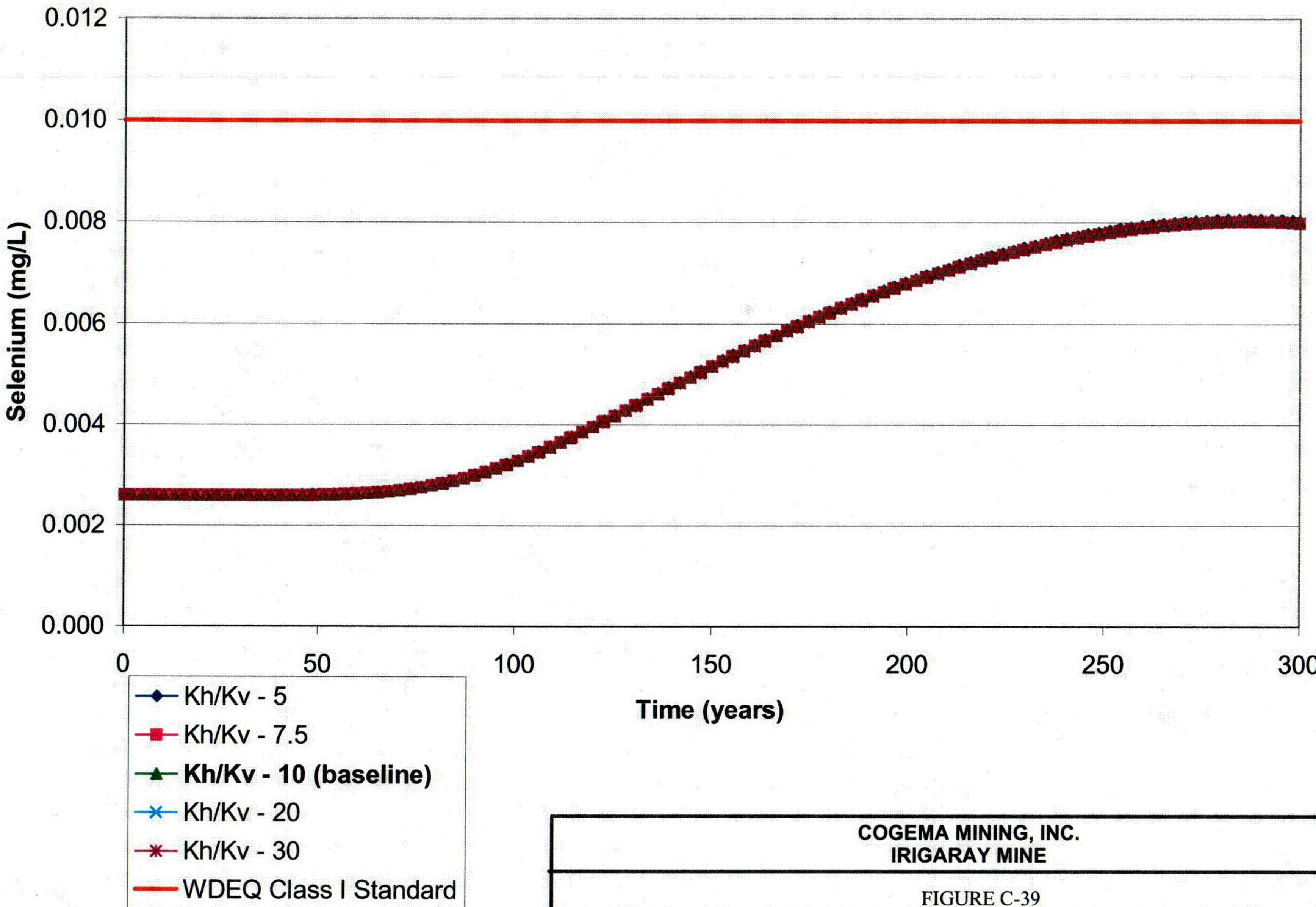

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-39
SENSITIVITY ANALYSIS-HORIZONTAL/VERTICAL HYDRAULIC CONDUCTIVITY RATIO
SELENIUM AT OBSERVATION POINT OP5

PROJECT: CMI/IRIGARAY	DATE: JUNE 2002
DWG: COGEMAFIGC39r.srf	BY: EPL CHECKED: HPD

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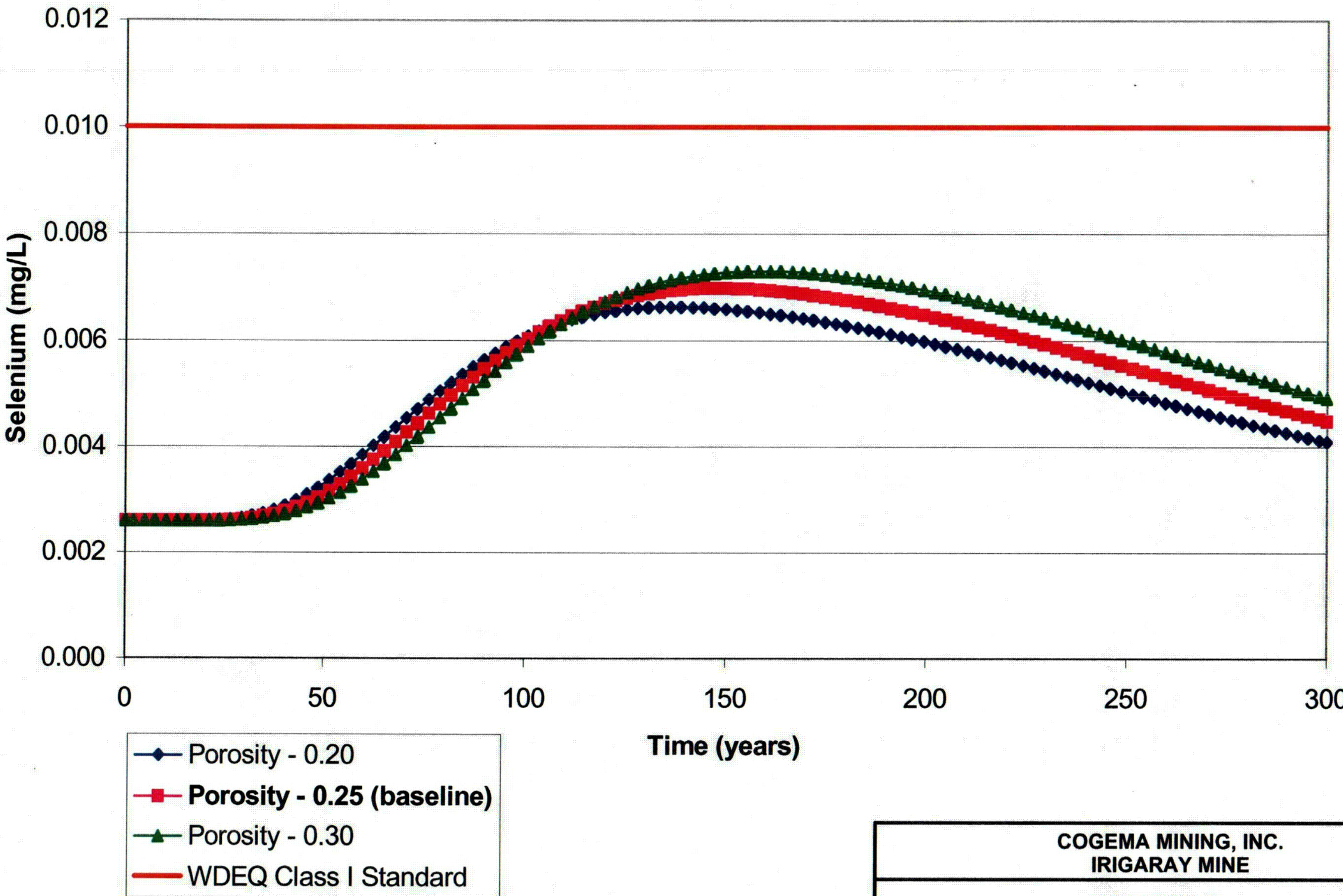

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-40
SENSITIVITY ANALYSIS-POROSITY (LAYER 2)
SELENIUM AT OBSERVATION POINT OP3

PROJECT: CMI/IRIGARAY	DATE: JUNE 2002
DWG: COGEMAFIGC40.srf	BY: EPL CHECKED: HPD

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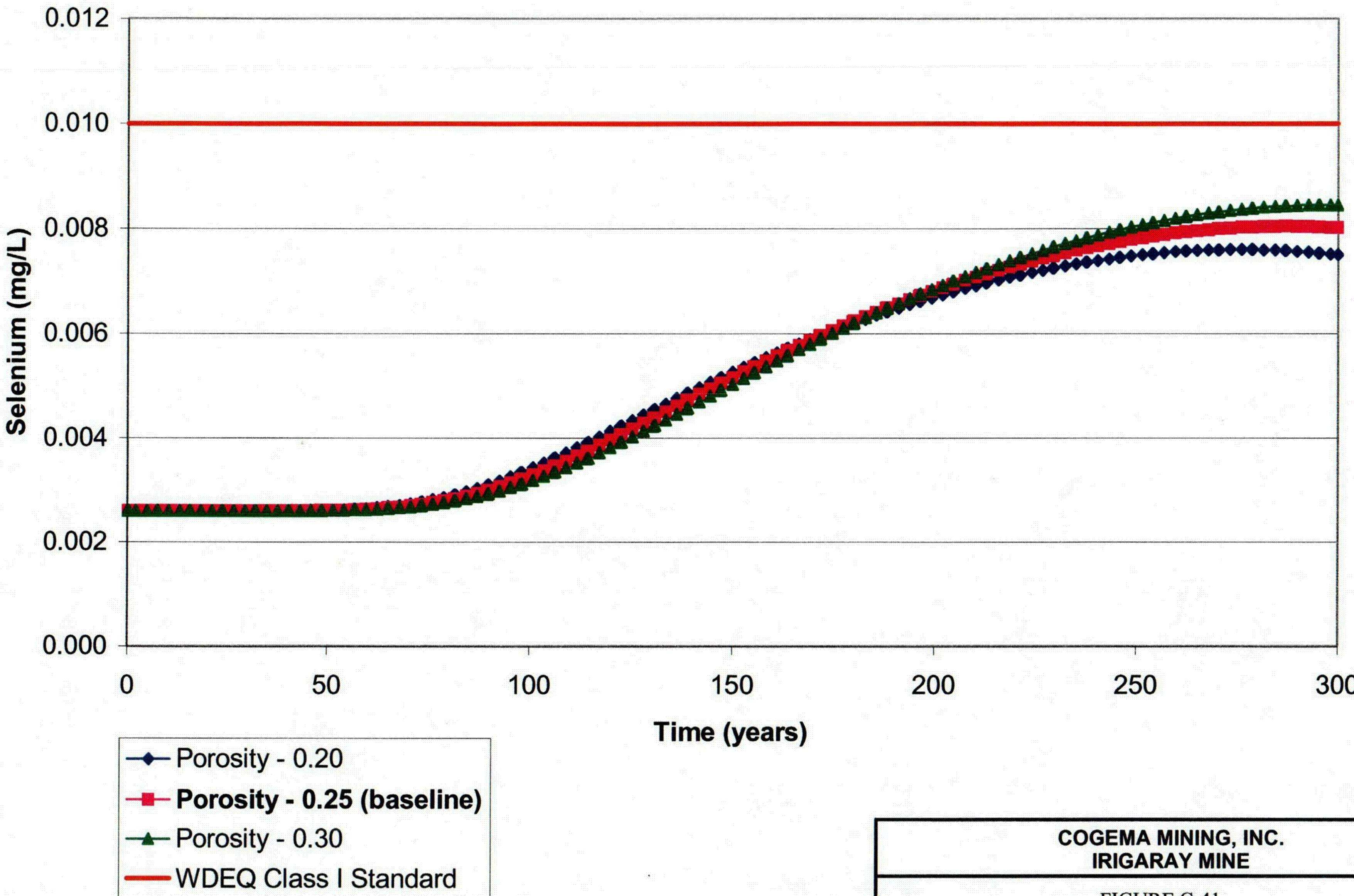

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-41
SENSITIVITY ANALYSIS-POROSITY (LAYER 2)
SELENIUM AT OBSERVATION POINT OP5

PROJECT: CMI/IRIGARAY	DATE: JUNE 2002	
DWG: COGEMAFIGC41r.srf	BY: EPL	CHECKED: HPD

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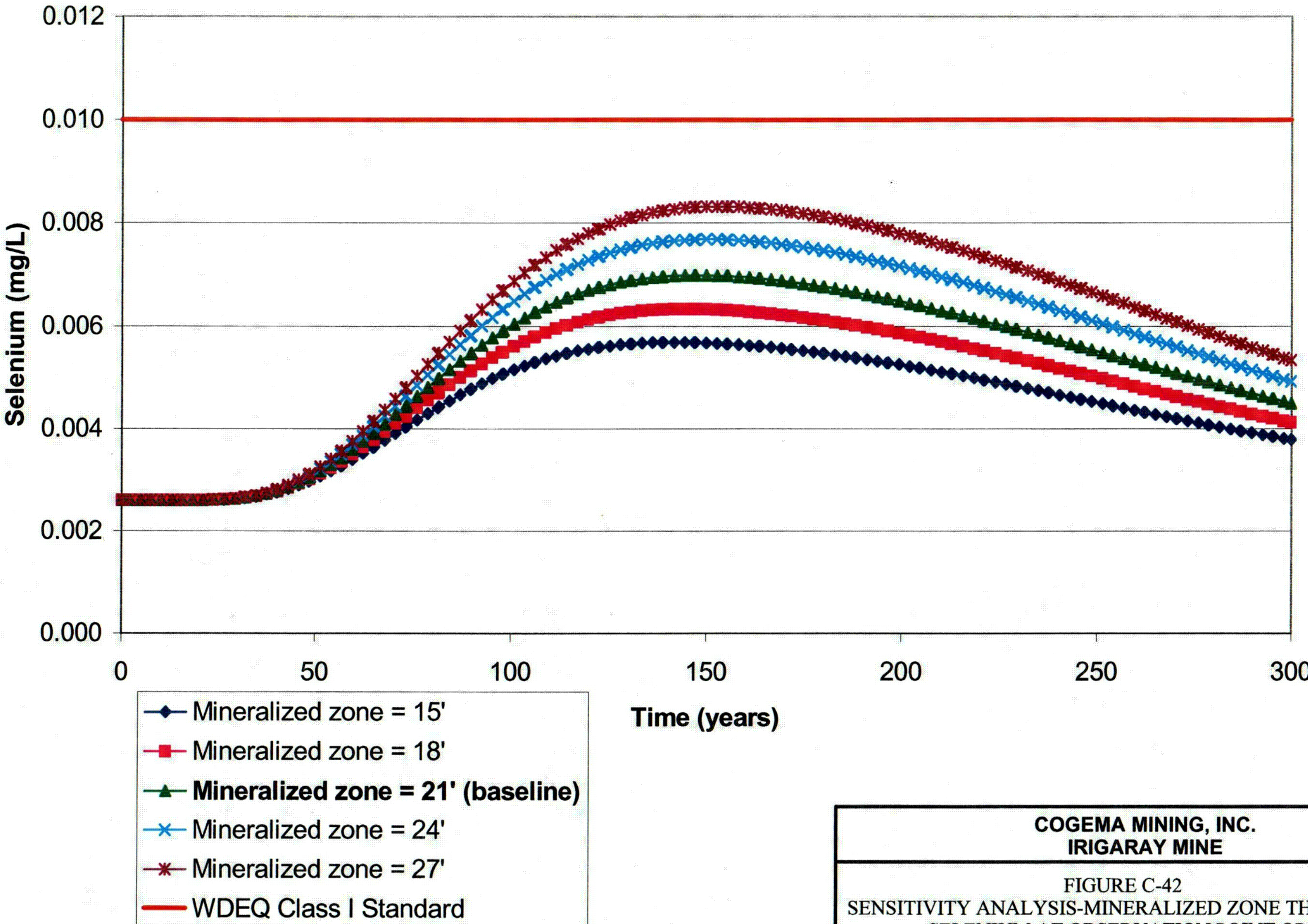

COGEMA MINING, INC. IRIGARAY MINE	
FIGURE C-42 SENSITIVITY ANALYSIS-MINERALIZED ZONE THICKNESS SELENIUM AT OBSERVATION POINT OP3	
PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC42r.srf	BY: EPL CHECKED: HPD
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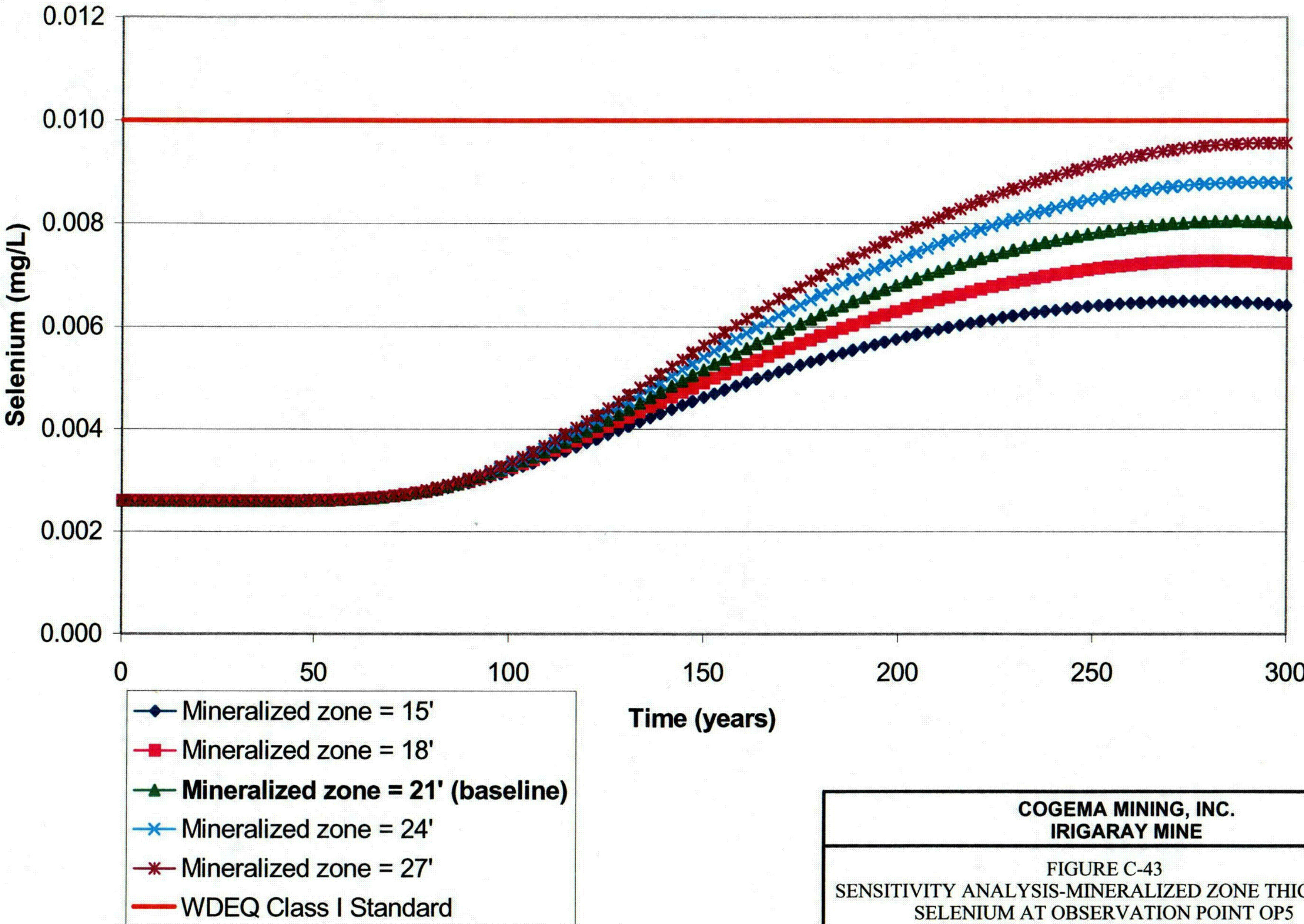
C98



COGEMA MINING, INC. IRIGARAY MINE	
FIGURE C-43 SENSITIVITY ANALYSIS-MINERALIZED ZONE THICKNESS SELENIUM AT OBSERVATION POINT OP5	
PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC43r.srf	BY: EPL CHECKED: HPD
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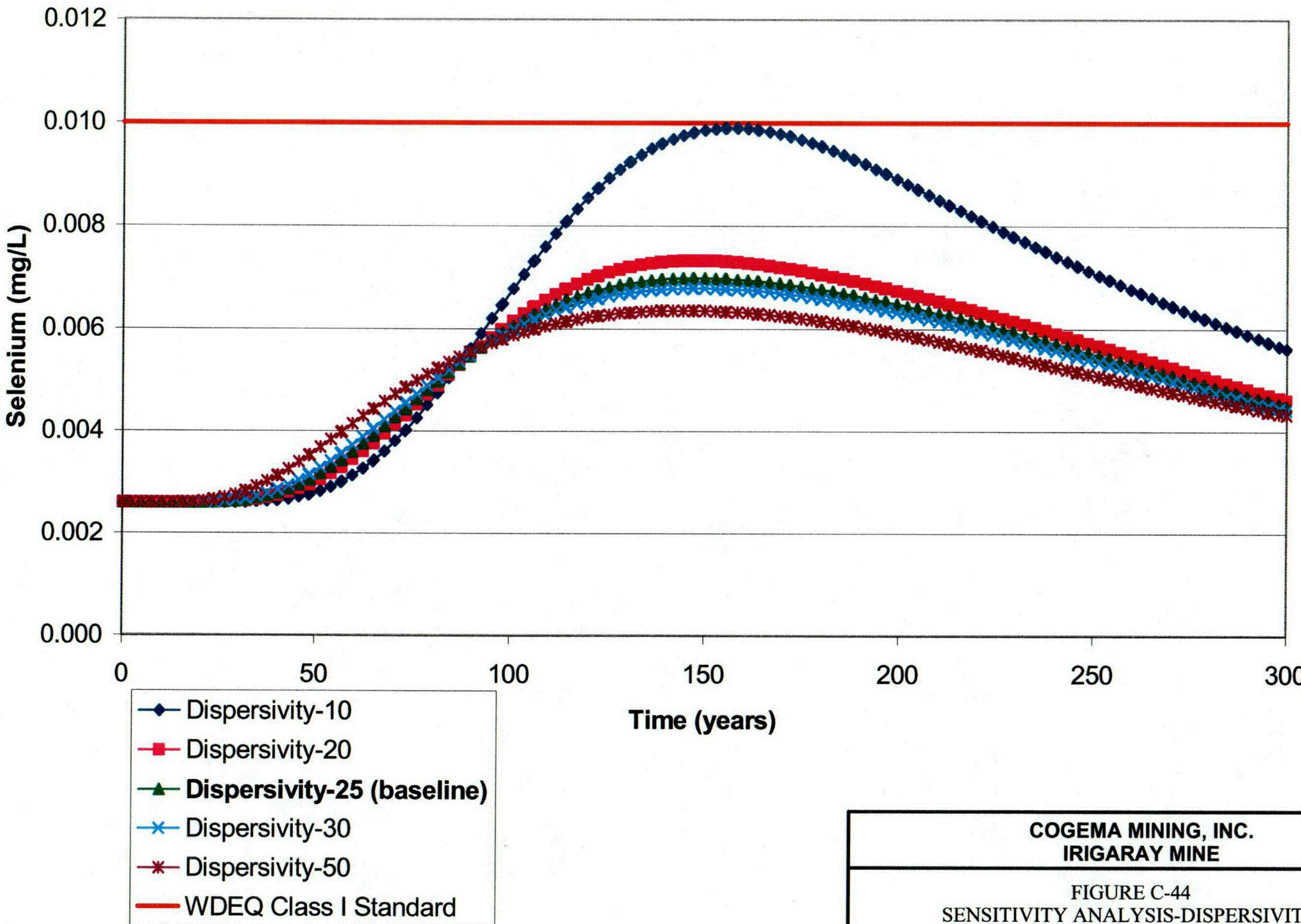
C99



COGEMA MINING, INC. IRIGARAY MINE	
FIGURE C-44 SENSITIVITY ANALYSIS-DISPERSIVITY SELENIUM AT OBSERVATION POINT OP3	
PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC44r.srf	BY: EPL CHECKED: HPD
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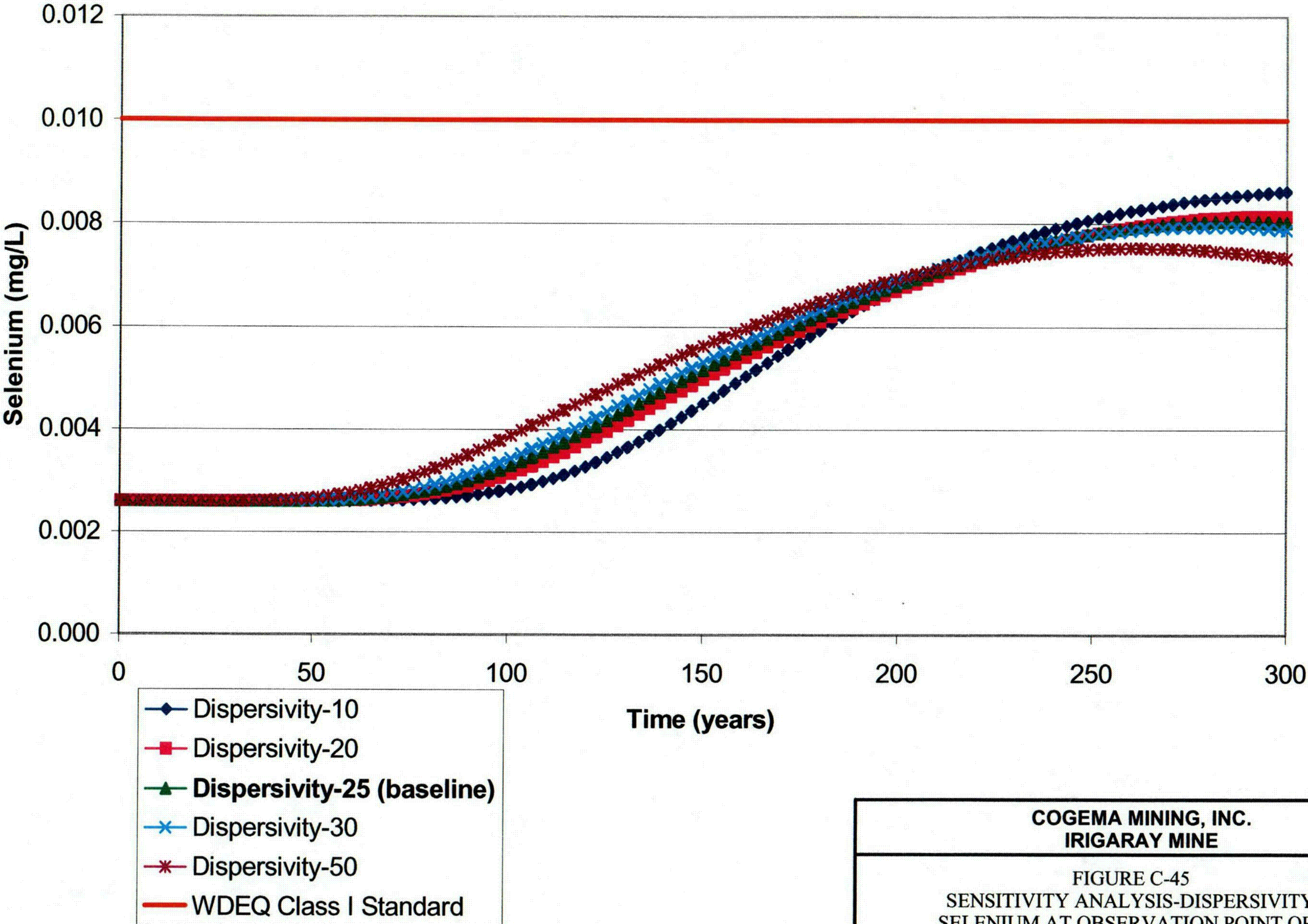
C100



COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-45
SENSITIVITY ANALYSIS-DISPERSIVITY
SELENIUM AT OBSERVATION POINT OP5

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC45r.srf	BY: EPL CHECKED: HPD

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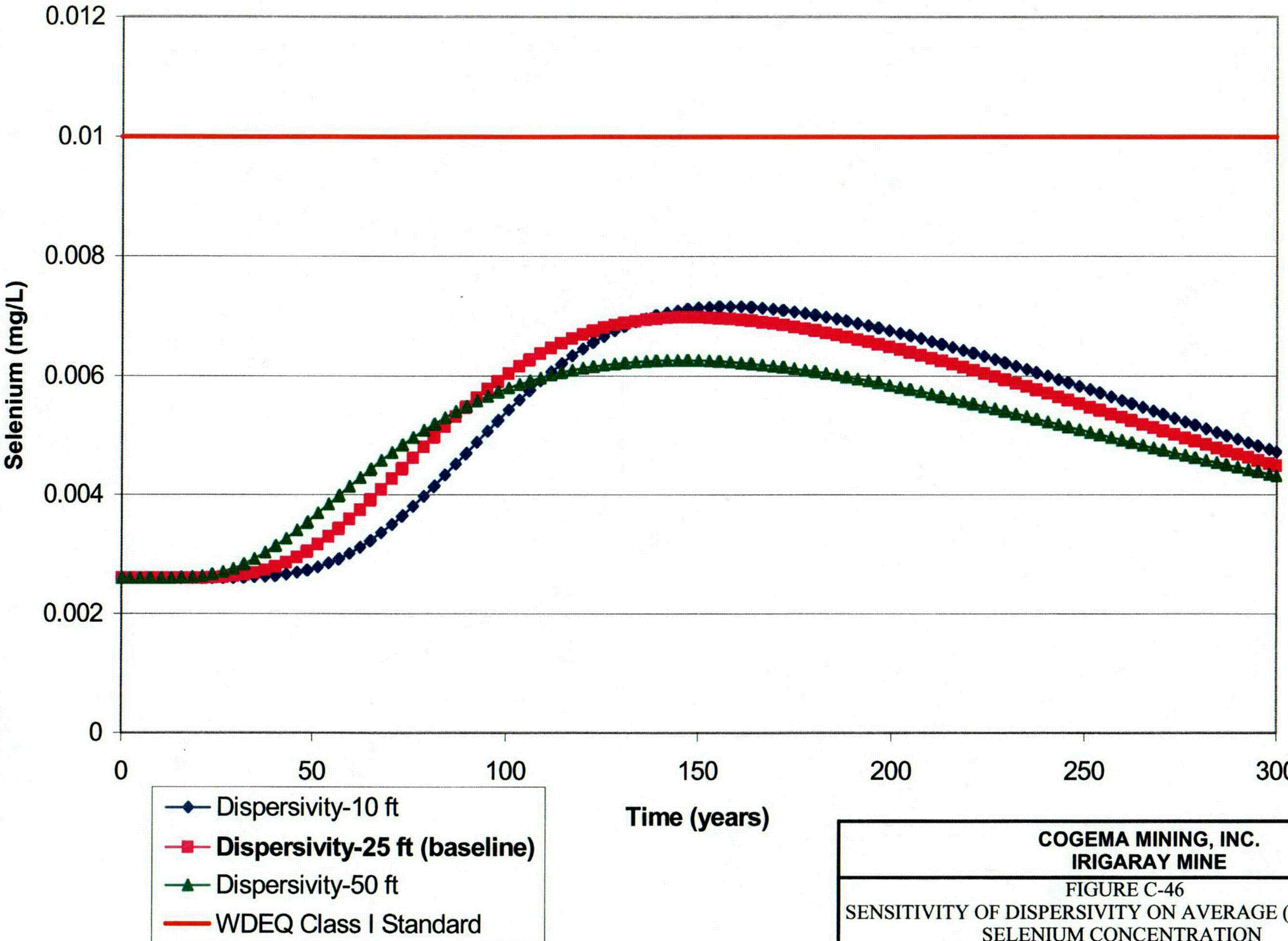
C101



COGEMA MINING, INC. IRIGARAY MINE	
FIGURE C-46 SENSITIVITY OF DISPERSIVITY ON AVERAGE (WEIGHTED) SELENIUM CONCENTRATION MODELED AQUIFER AT OBSERVATION POINT OP3	
PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC46r.srf	BY: EPL CHECKED: HPD
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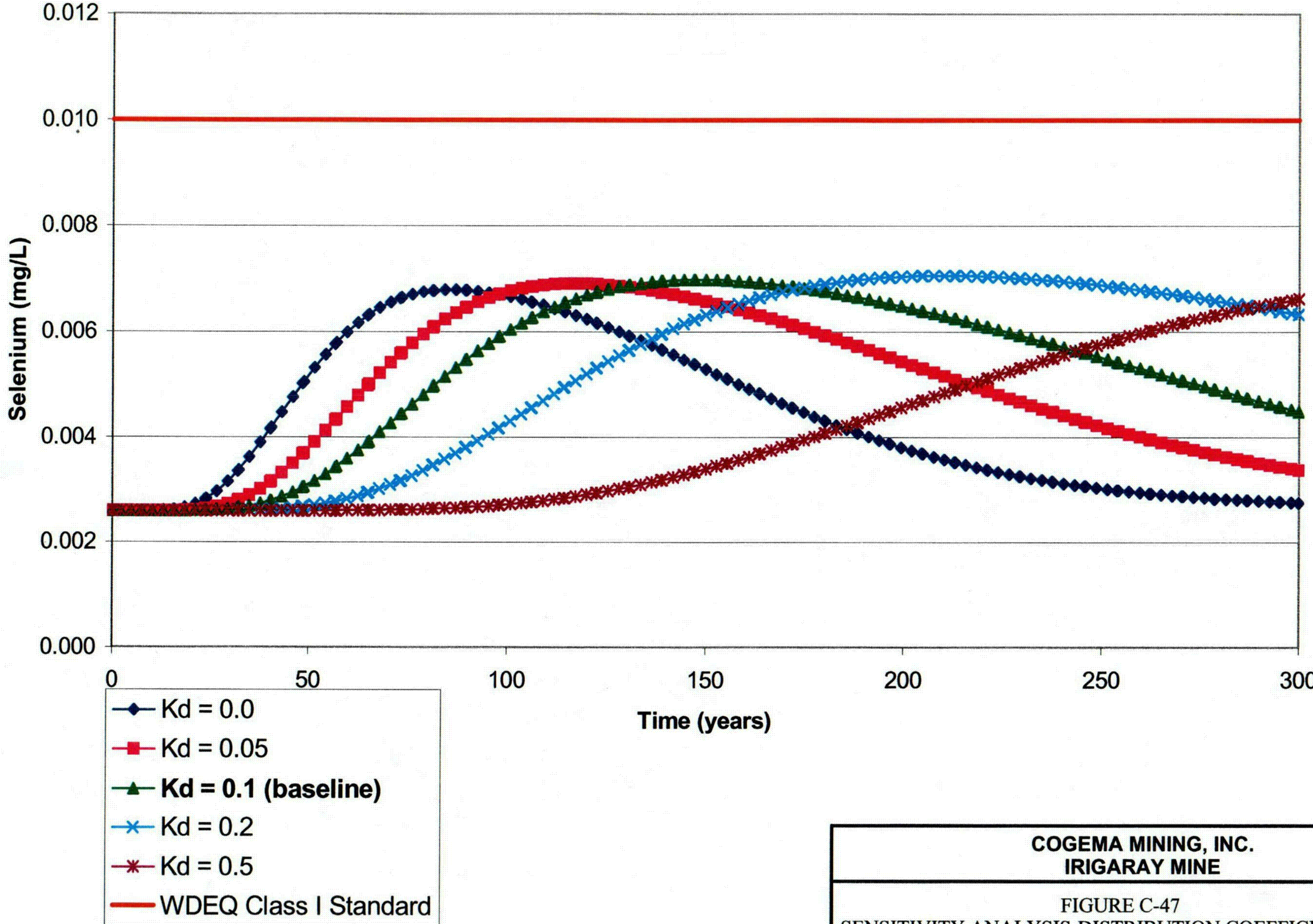

COGEMA MINING, INC.
IRIGARAY MINE

FIGURE C-47
SENSITIVITY ANALYSIS-DISTRIBUTION COEFFICIENT (Kd)
SELENIUM AT OBSERVATION POINT OP3

PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC47r.srf	BY: EPL CHECKED: HPD

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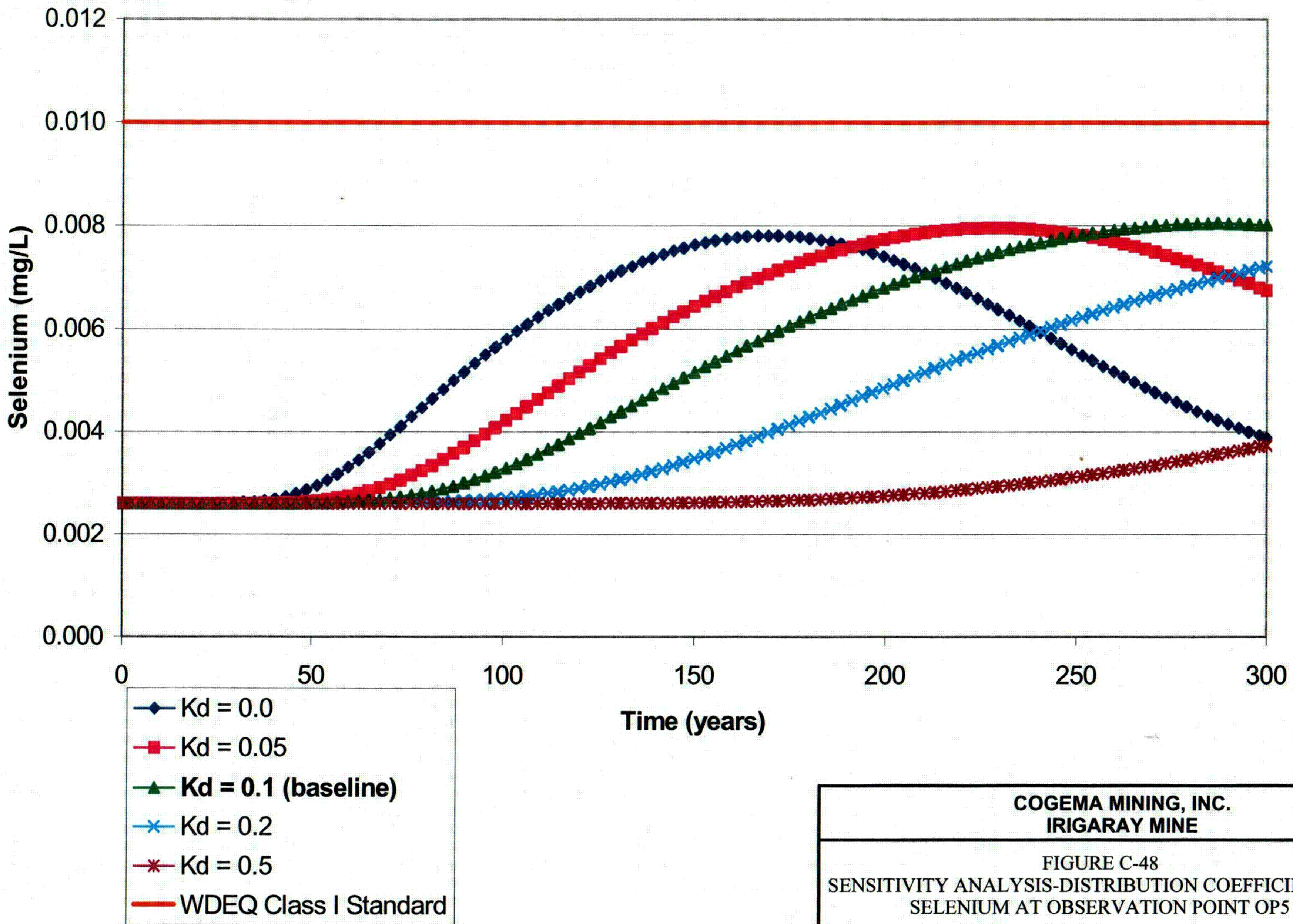

COGEMA MINING, INC. IRIGARAY MINE	
FIGURE C-48 SENSITIVITY ANALYSIS-DISTRIBUTION COEFFICIENT (Kd) SELENIUM AT OBSERVATION POINT OP5	
PROJECT: CMI/IRIGARAY	DATE: MAY 2002
DWG: COGEMAFIGC48r.srf	BY: EPL CHECKED: HPD
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c/04

Table Summary of Pumping Test Results, Irigaray ISL Wellfiel ɔming

Testing Performed By	Report Date	Test Date	Mine Units	Rate (gpm)	Duration (hours)	No. of Obs. Wells	Obs. Well Dist. (ft)	Average H (ft)	Average T (ft^2/d)	Average K (ft/d)	Average S
D'Appolonia	02/01/1982	Jun-80	8-9	10	48	4	250-430	92	38.6	0.42	1.60E-04
Hydro Eng.	Dec-87	Jul-87	7-8	7.6	2.5	9	40-147	100	53.4	0.53	4.00E-04
Hydro Eng.	Sep-87	Jul-87	6-9	12.5	96	27	50-540	100	50.8	0.51	7.00E-04
Cannonie	Sep-86	Jul-87	2-3	13.8	96	9	40-800	112	120.3	1.07	2.00E-04
Cannonie	1987	Feb-87	Sec. 5	16.2	50	3	59-107	111	41.4	0.37	1.60E-04
D'Appolonia	02/01/1982	Feb-77	A	10	15	3	40-90	100	66.8	0.67	8.00E-05
D'Appolonia	02/01/1982	Oct-77	B	17	5	4	160-170	100	91.4	0.91	2.70E-04
D'Appolonia	02/01/1982	Aug-77	C & D	15	23	4	70-130	100	58.7	0.59	2.30E-04
Hyd. Assoc	02/21/1979	May-79	E	20	24	4	70-170	100	40.1	0.40	1.70E-04
Hyd Assoc	??	Mar-79	G (5)	16	48	5	48-340	100	136	1.36	3.70E-05

gpm- gallons per minute
Obs.- observation
H -aquifer thickness
T - transmissivity
K - hydraulic conductivity
S- storativity

Table C arison of Hydraulic Gradients During Post Restoration Recovery, Irigaray ISL Wellfield, Wy

Transect & Well ID		Water Level on 1/22/2002 (feet amsl)	Water Level on 5/14/2002 (feet amsl)	Difference in Water Levels (feet)	X_EAST (feet)	Y_NORTH (feet)	Distance Along Transect (feet)	Hydraulic Gradient 5/14/2002 (feet/foot)	Hydraulic Gradient 1/22/2002 (feet/foot)	Difference in Hydraulic Gradient (feet/foot)	Percent Difference (%)
Transect A-1											
	M32	4306.7	4315.3	8.6	821,002	1,172,095					
	M29	4298.2	4307.5	9.3	819,656	1,173,213	1,750	0.0045	0.0049	-0.0004	-9.0
Transect A-2											
	M32	4306.7	4315.3	8.6	821,002	1,172,095					
	M25	4291.2	4299.5	8.3	819,321	1,174,368	2,827	0.0056	0.0055	0.0001	1.9
Transect B-1											
	M28	4300.8	4309.9	9.1	820,858	1,173,301					
	M25	4291.2	4299.5	8.3	819,321	1,174,368	1,871	0.0056	0.0051	0.0004	7.7
Transect B-2											
	M28	4300.8	4309.9	9.1	820,858	1,173,301					
	M15	4291.9	4300.4	8.5	819,409	1,174,798	2,083	0.0046	0.0043	0.0003	6.3
Transect C-1											
	M24	4298.7	4307.0	8.3	820,773	1,174,420					
	M15	4291.9	4300.4	8.5	819,409	1,174,798	1,415	0.0047	0.0048	-0.0001	-3.0
Transect C-2											
	M24	4298.7	4307.0	8.3	820,773	1,174,420					
	T3	4289.5	4297.3	7.8	819,202	1,175,948	2,192	0.0044	0.0042	0.0002	5.2
Transect D-1											
	M19	4295.3	4303.6	8.3	820,230	1,175,315					
	T3	4289.5	4297.3	7.8	819,202	1,175,948	1,207	0.0052	0.0048	0.0004	7.9
Transect D-2											
	M19	4295.3	4303.6	8.3	820,230	1,175,315					
	M1	4290.7	4298.6	7.9	819,557	1,176,424	1,297	0.0039	0.0035	0.0003	8.0

shown on Figure C-4

Table C-3. Calibration Targets and Residuals for the Irigaray Groundwater Flow Model, Wyoming

Calibration Target	Observed Head (ft)	Computed Head (ft)	Residual (ft)
M1	4295.8	4295.50	0.30
T3	4294.4	4294.19	0.21
M4	4299.9	4298.79	1.11
M12	4302.5	4302.40	0.10
M15	4296.9	4297.06	-0.16
M19	4300.3	4300.39	-0.09
M24	4304.0	4303.71	0.29
T39	4300.2	4300.12	0.08
M29	4303.6	4302.84	0.76
M30	4309.4	4309.18	0.22
M31	4305.7	4306.09	-0.39
M32	4311.8	4311.56	0.24
T51	4305.4	4305.42	-0.02
T8	4295.2	4294.18	1.02
T12	4290.5	4292.28	-1.78
T24	4295.8	4294.41	1.39
T25	4292.4	4293.23	-0.83
T36	4297.7	4298.79	-1.09
M10	4292.5	4293.74	-1.24
M25	4296.4	4297.51	-1.11
M28	4305.9	4306.61	-0.71
DI40	4294.2	4295.64	-1.44
RS26	4296.3	4295.80	0.50
RS27	4296.8	4295.47	1.33

Residual is calculated by subtracting the computed head from the observed head

Table C-4. Calibration Statistics, Irigaray Groundwater Flow Model, Wyoming

Statistical Parameter	Value (feet)
Residual Mean	-0.06
Residual Standard Deviation	0.86
Sum of Squares	17.71
Absolute Residual Mean	0.68
Minimum Residual	-1.78
Maximum Residual	1.39
Head Range	21.3
Standard Deviation/Head Range	0.04

Table (.overy Rates for the Irigaray Groundwater Flow Model Validation Simulation

Model Time Step	Observation Period Represented	Days	Net Recovery (gpm)	Net Recovery (ft3/d)	Distribution Mine Unit/Percent	Model Cells MU-6	Model Cells MU-7	Recovery Rate per cell-MU-6 (ft3/d)	Recovery Rate per cell-MU-7 (ft3/d)
1	Jul-00/Sep-00	92	52	10074	MU-6/50%-MU-7/50%	418	348	12.05	14.47
2	Oct-00/Dec-00	92	43	8276	MU-6/50%-MU-7/50%	418	348	9.90	11.89
3	Jan-01/Jun-01	180	31	5943	MU-6/50%-MU-7/50%	418	348	7.11	8.54
4	Jul-01/Aug-01	31	120	23154	MU-6/50%-MU-7/50%	418	348	27.70	33.27
5	Aug-01/Sep-01	31	73	14094	MU-6/50%-MU-7/50%	418	348	16.86	20.25
6	Sep-01/Oct-01	30	50	9595	MU-6/100%-MU-7/0%	418	348	22.95	0
7	Oct-01/Nov-01	31	130	24969	MU-6/100%-MU-7/0%	418	348	59.73	0
8	Nov-01-Feb-02	113	0	0	MU-6/0%-MU-7/0%	418	348	0	0

MU-Mine Unit
Net Recovery-Difference between total injection and total recovery for the specified observation period
MU-6/50%-MU-7/50%-indicates that 50% of the net recovery was distributed across MU6
and 50% of the net recovery was distributed across MU7
Model Cells-Indicates the total number of cells representing the specified mine unit.
Recovery Rate per cell-MU-6 (ft3/d)-Calculated by multiplying the net recovery by the distribution percentage and dividing by the number of model cells

Table Summary of Model Input Concentrations and Maximum Simul Concentrations vs. WDEQ Class-1 Standards

	Selenium (mg/l)	Manganese (mg/l)	Uranium (mg/l)	Radium (pCi/l)	TDS (mg/l)
Initial Model Concentration inside Wellfield	0.04	0.18	2.1	139.9	650
Initial Model Concentration outside Wellfield	0.0026	0.0106	0.0165	0.9026	379
Maximum Total Simulated Concentration[1]	0.008	0.034	0.24	2.2	420
WDEQ Class 1 Regulatory Standard	0.01	0.05	5.0	5.0	500

1 - Maximum level at any observation point 400 feet downgradient of the wellfield (base case conditions)

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED: "PLATE 1 IRIGARAY MINE REGIONAL LOCATION/ FACILITIES MAP"

WITHIN THIS PACKAGE

D-01

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

"PLATE 2
GEOLOGIC CROSS SECTION
9 H - H'
FROM RESISTIVITY LOGS"

WITHIN THIS PACKAGE

D-02