AR TARGET SHEET

The following document was too large to scan as one unit, therefore it has been broken down into sections.

DOCUMENT # DOE/EIS-0189

EDMC # 0045013

SECTION 3 **OF** 4

- **Recent deposits.** Recent alluvial and eolian deposits, primarily reworked Hanford Formation sediments.

F.2.4.1.2 Hydrology

In general, the unconfined aquifer is located within the Ringold and Hanford formations, in consolidated to semi-consolidated sediments overlying the Columbia River Basalt. Because of deposition in a structural depression, the Ringold Formation is up to 366 m (1,200 ft) thick within the Pasco Basin. The Ringold formation is up to 38 m (125 ft) thick at the 200 East Area and up to 84 m (274 ft) thick at the 200 West Area. In addition, the upper portion of the aquifer is more transmissive than the finer-grained lower portion.

Historically, the unconfined aquifer was located almost exclusively in the Ringold Formation, except for a few areas near the Columbia River. A confining bed at the base of the Ringold Formation serves as an aquitard and inhibits the vertical migration of contaminants downward from the unconfined aquifer. However, wastewater discharges occurring since 1944 (Kincaid et al. 1993) have raised the water table, causing water levels to enter the Hanford Formation in the 200 East Area and in a wider area near the Columbia River (Wurstner-Devary 1993). Because of the increase in groundwater elevation, the water table is now in the Hanford Formation over much of the eastern portion of the Hanford Site (Thorne-Newcomer 1992). In general, water levels have increased at least 15 m (49 ft) in the vicinity of the 200 West Area and 5 m (16 ft) in the vicinity of the 200 East Area. The groundwater mounding created a vertical downward gradient in the areas of wastewater discharge. However, this downward gradient does not extend to the area between Gable Butte and Gable Mountain where there is an erosional window in the aquitard.

The change of the water table elevation is important to the modeling effort because the Hanford Formation is 10 to 100 times more permeable than the Ringold Formation (Wurstner-Devary 1993). Groundwater mounds of approximately 28 and 9 m (90 and 30 ft) have developed under wastewater discharge areas at the 200 Areas. Although more water has been discharged at the 200 East Area, the mound is higher at the 200 West Area because of a lower aquifer hydraulic conductivity.

F.2.4.1.3 Flow Properties

Groundwater in the unconfined aquifer generally flows from recharge areas on the western boundary of the region east and north towards the Columbia River. Groundwater recharge occurs primarily in the Cold Creek, Dry Creek, and Yakima River valleys and in wastewater discharge areas. Groundwater discharge occurs along the Columbia River.

For the modeling effort it was assumed that no interaction exists between the unconfined aquifer and the underlying confined aquifer. There is a potential for leakage between these systems in areas of increased vertical hydraulic conductivity, such as the area northeast of the 200 East Area (Wurstner-Devary 1993). Although limited quantitative information exists on these areas, adequate flow system calibration was obtained without including these areas in the model (Wurstner-Devary 1993). Flow in the Columbia River Basalts is not considered in this study because the basalts are hydraulically isolated

from the Ringold Formation in areas where downward hydraulic gradients would have the potential to cause contaminants to move into the basalts. The vertical gradients resulting from groundwater mounds in the wastewater discharge areas will dissipate within a short period compared to the time frame of interest.

The modeling effort for all TWRS alternatives assumed steady-state flow conditions for December 1979, consistent with the CFEST modeling effort. The CFEST modeling effort generated water elevation contours as part of a steady-state 2-D model run. This information is presented in Figure F.2.4.2. Water elevation contours in Figure F.2.4.2 are based on conditions observed in December 1979 (Wurstner-Devary 1993).

Although fluid flux volumes (based on infiltration) change at the eight source sites in accordance with Hanford Site activities for each alternative, these changes in infiltration are not important to groundwater elevations and flow velocities at the Site. For example, a steady-state run based on an infiltration of 0.5 cm/year (0.2 in./year) at the tank source areas locally affected groundwater elevations by approximately 1.0E-05 m (3.2E-05 ft), compared with no infiltration at the source areas.

Transmissivity and saturated water content were based on values used for the CFEST modeling effort. Transmissivity values ranged from 5.5 to 6.5E+03 m/day (18 to 2.1E+04 ft/day). Transmissivity values used for CFEST are presented in Figure 4.2.8 of the CFEST model document (Wurstner-Devary 1993). Saturated water content was set at 0.5.

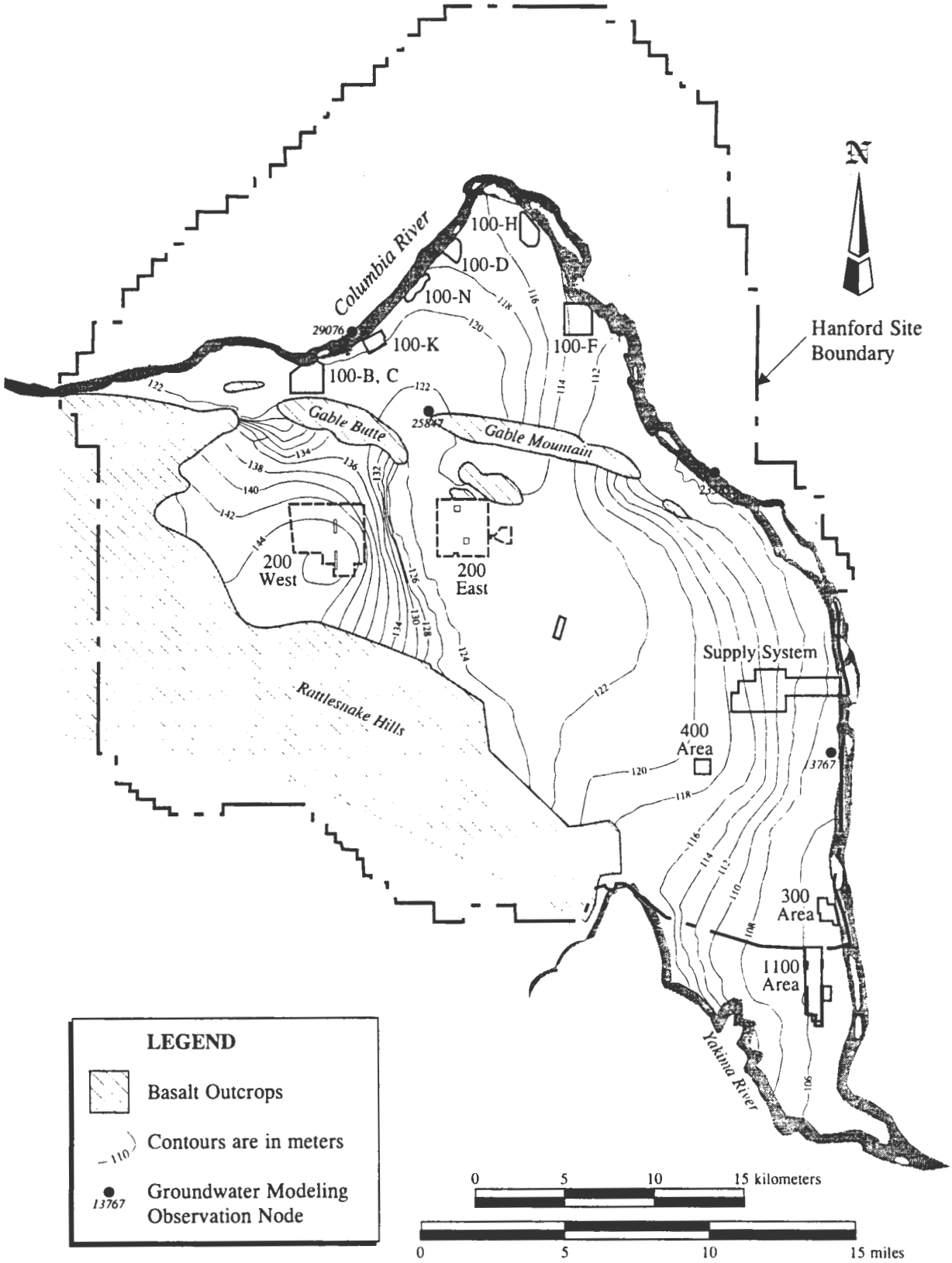
Boundary Conditions

The conceptual flow model includes several areas defined as no flow, fixed head, and fixed flux boundaries. These conditions reflect the physical conditions at the Site affecting flow. Physical boundaries include the Rattlesnake Hills, Yakima Ridge, Umtanum Ridge, and the Columbia and Yakima rivers. The boundary conditions for the modeling effort are consistent with previously published groundwater modeling efforts performed by PNL (Wurstner-Devary 1993).

The Rattlesnake Hills, Yakima Ridge, and Umtanum Ridge are outcrop areas of the Columbia River Basalt. These three features follow the axes of anticlines (the Rattlesnake Hills Structure, Yakima Ridge Structure, and Gable Mountain Structure, respectively, see Volume Five, Appendix I). The Columbia River Basalt where it occurs as an outcrop or subcrop acts as a flow barrier. Consequently, the model boundary adjacent to these features is defined as a no-flow boundary. The two synclinal areas between these structures, known as the Cold Creek and Dry Creek valleys (Kincaid et al. 1993), recharge the aquifer. To achieve model calibration with the CFEST model, the Cold Creek drainage was defined as a constant head boundary, and the Dry Creek drainage was defined as a fixed flux boundary.

The Yakima River recharges the unconfined aquifer in the southern part of the AOI, creating a hydraulic gradient in this area from west to east (Wurstner-Devary 1993). The model boundary adjacent to this river is set as a constant head boundary. The Columbia River, located along the

Figure F.2.4.2 Results of CFEST Steady-State Simulations for December 1979



SOURCE: Wurstner and Devary, 1993

northern and eastern perimeter of the AOI, drains the unconfined aquifer and is set as a constant head boundary.

Four interior boundaries are defined by outcrops of the Columbia River Basalt. These consist of Gable Butte, Gable Mountain, and two unnamed basalt outcrop areas south of Gable Mountain. These areas are defined as no flow boundaries.

The average wastewater discharge quantities for 1979 were used as part of the flow conceptual model. These discharges influence flow conditions in the 200 Areas. Wastewater discharge areas are defined as fixed flux boundaries. Fluid flux quantities are summarized in Table F.2.4.1.

Table F.2.4.1 Summary of Fixed Flux Boundaries from CFEST Model

Flux Site Name	Flux (m^3/day)
216-B-3 (B Pond)	6.94E+03
216-B-63	8.81E+02
216-S-19	1.48E+02
216-U-10 (U Pond)	1.20E+04
216-A-10	7.0E+01
216-A-30	4.31E+02
216-A-37-1	5.4E+01
216-B-55	1.8E+02
216-B-62	4.4E+01
216-S-25	6.3E+01
West Area Ash Pit	4.7E+01
216-T-1	1.1E+01
216-T-4-2	1.4E+01
Rattlesnake Mountain Springs	1.33E+03

Additional fixed flux boundary conditions were established to allow contaminant input from the source areas. Although these boundary conditions are not defined as part of the CFEST model, their effect on groundwater elevations is inconsequential. The source area boundary conditions assumed an infiltration rate of 0.5 cm/year (0.20 in./year) would originate from the tank areas. The volumetric fluid fluxes were calculated in m^3/day by multiplying the infiltration rate by the area of the source. Fluid flux quantities of the source areas are summarized in Table F.2.4.2.

F.2.4.1.4 Saturated Zone Contaminant Transport Properties

Once contaminants move through the vadose zone and enter the unconfined aquifer, they migrate in the groundwater until they are intercepted by a well or discharged to the Columbia River. Generally, contaminants will move from source locations at the 200 East Area towards the east, and from source locations at the 200 West Area towards the north and east, eventually discharging to the Columbia River or one of the springs located adjacent to the river.

Table F.2.4.2 Source Area Fixed Flux Boundaries

Flux Site Name	Flux (m^3/day)
1WSS	4.08E-02
2WSS	4.44E-02
3WDS	3.37E-03
1ESS	4.08E-02
2ESS	1.38E-02
3EDS	1.24E-02
4ESS	1.12E-02
5EDS	3.37E-03

Previous simulations of contaminant transport in the unsaturated zone and unconfined aquifer have shown the time of travel within the vadose zone is much greater than in the aquifer (Kincaid et al. 1993). Existing tritium contaminant plumes originating in the 200 East Area reached the Columbia River in 25 to 30 years.

Saturated zone contaminant transport parameters required by VAM2D for the modeling effort include:

- Free water molecular diffusion coefficient, D_m;
- Longitudinal and transverse dispersivity, α_L and α_T;
- Effective porosity, ϕ_e;
- Bulk density, ρ_B;
- Distribution coefficient, K_d;
- Darcy velocity components of the fluid phase considered, v_1 and v_2; and
- Prescribed values of solute flux at boundary nodes, q_c.

Contaminant concentrations were adjusted in post processing (Section F.2.4.2) to account for radioactive decay. A brief description of each of the above parameters is provided in the following text.

Free Water Molecular Diffusion Coefficient

Groundwater flow across the Hanford Site is sufficient to make a molecular diffusion coefficient value in the range of 2E-9 to 1E-11 m^2/second insignificant to contaminant transport simulation. Therefore, this value was set to 0.0 for the saturated zone model runs. A more detailed discussion of the molecular diffusion coefficient is provided in Section F.2.3.1.3.

Dispersion Parameters

A discussion of longitudinal and transverse dispersivity in the saturated zone is presented in the environmental setting data document (Schramke et al. 1994). If no value is available from the site data, the recommended estimate to be used for longitudinal dispersivity is based on the following equation (Walton 1985):

$$\alpha_L = 0.1\ (Tr)$$

Where:

Tr is the length of the travel path (plan view) from the center of the waste site to the receptor point.

Transverse dispersivity should be calculated as 1/5 of the longitudinal dispersivity (Walton 1985):

$$\alpha_T = 0.2\ (\alpha_L)$$

Walton (Walton 1985) states that the equation for α_L applies to mean travel distances less than about 305 m (1,000 ft). However, the actual relationship is not linear. Consequently, the equation may not be valid for transport simulation across the Hanford Site and should only be considered an upper bound to dispersivity.

In the field, dispersivity approaches a maximum asymptotic value (Walton 1985), and the equation used to estimate longitudinal dispersivity is:

$$\propto_L = A_d \left[1 - \frac{B_a}{L_d + B_a} \right]$$

Where:

A_d = asymptotic or maximum dispersivity (L)
B_a = mean travel distance corresponding to $A_d/2$ (L)
L_d = mean travel distance (L).

Walton (Walton 1985) also presents a graph depicting field measurements of α_L versus the mean travel distance of the plume (Figure F.2.4.3). In this graph, the maximum dispersivity value approaches approximately 125 m (400 ft). Due to the large travel distances modeled at this site, the maximum dispersivity value presented by Walton (Walton 1985) was selected for the groundwater modeling effort.

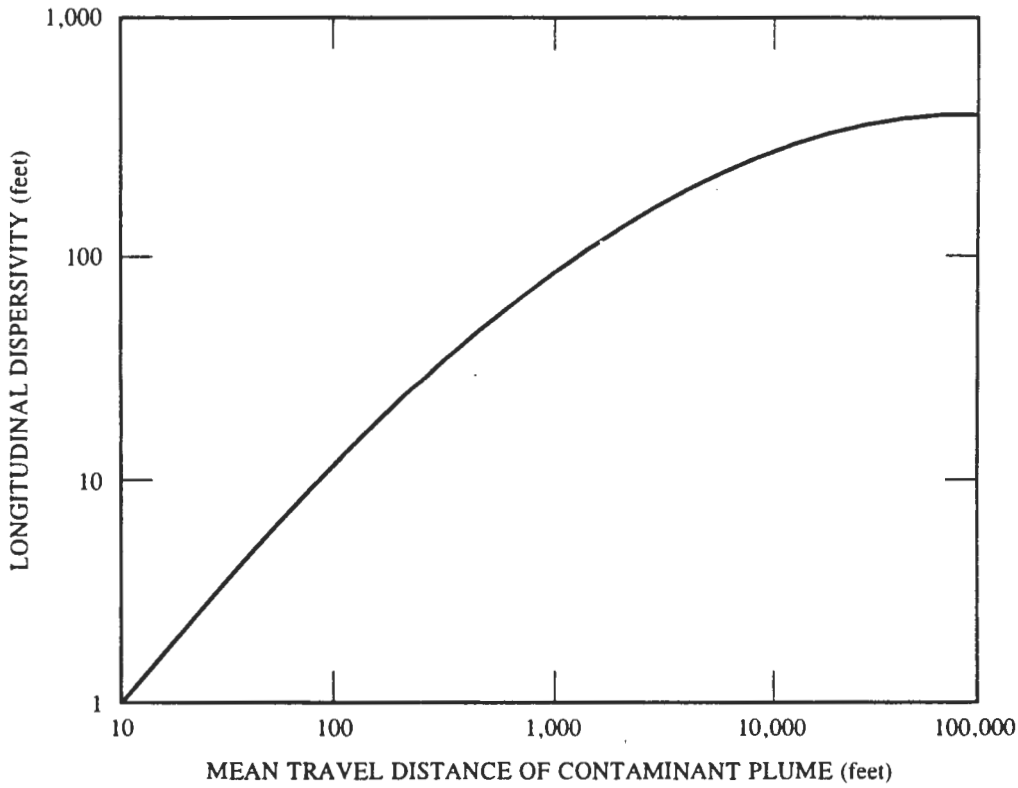
A second factor affected by the value used for dispersivity is the Peclet number, which is defined as:

$$P_e = \frac{\Delta_x}{\propto}$$

Where $\propto$ = (longitudinal) dispersivity
Δ_x = largest grid dimension in model

In groundwater modeling, the local Peclet number criterion should not exceed a value of 4, or, in cases where the flow is steady-state, it should not exceed 2 or 3 (Huyakorn et al. 1985). Applying this formula to fix the Peclet number at 2 and the longitudinal dispersivity at 125 m (400 ft) yields a

Figure F.2.4.3 Longitudinal Dispersivity Values Observed in the Field



SOURCE: Modified from Walton 1985

maximum grid of 250 m (820 ft). Thus, the selected value of 125 m (410 ft) satisfies the Peclet number and is consistent with values observed in the field.

Effective Porosity

Effective porosity values estimated for the Hanford Site were presented in the environmental settings data document (Schramke et al. 1994). These values are presented by environmental setting areas, (Figure F.2.4.4) defined within the document. Table F.2.4.3 presents effective and total porosity values reported in a number of tables within Appendix B of the environmental settings data document. These data were recommended by Schramke (Schramke et al. 1994) to be used for the saturated zone at each area.

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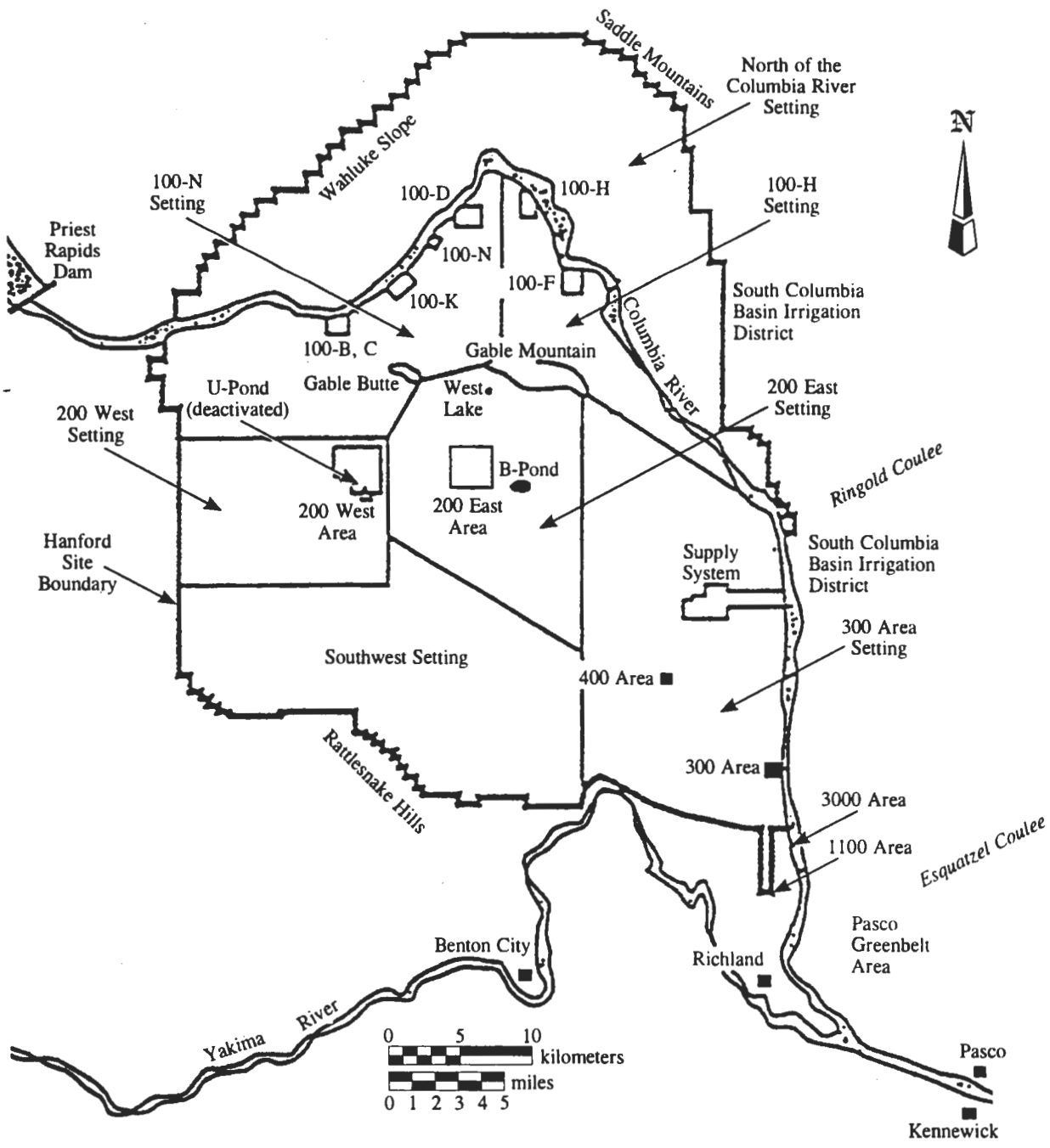
Figure F.2.4.4 Hanford Environmental Settings Areas



SOURCE: Schramke et al. 1994

Table F.2.4.3 Effective Porosity Values Recommended for the Hanford Site

Source Area	Effective Porosity	Total Porosity	Soil Classification	Percent Sand/silt/clay organics	(pH)
100-N [1]	11.0	30.0	Loamy Sand	87/11/2/0	7.7
100-H [2]	26.0	38.0	Sand	91/6/3/0	7.5
200-East [1]	10.0	18.0	Loamy Sand	86/12/2/0	7.7
200-West [3]	11.0	36.0	Loamy Sand	87/11/2/0	7.1
300 [2]	23.2	26.0	Sand	92/6/2/0	7.1
SW setting[1]	11.0	36.0	Loamy Sand	87/11/2/0	7.64

Source: Schramke et al. 1994.
Notes:
[1] Saturated zone is reported as Ringold Formation.
[2] Saturated zone is reported as Hanford Formation - Gravels.
[3] Saturated zone is reported as Middle Ringold Formation

Bulk Density

Bulk density values estimated for the Hanford Site were presented in the environmental setting data document (Schramke et al. 1994). These values are presented by environmental setting areas, defined within the document and shown in Figure F.2.4.4. Table F.2.4.4 presents bulk density values reported in a number of tables within Appendix B of the environmental settings data document. These data were recommended by Schramke (Schramke et al. 1994) to be used for the saturated zone at each area.

Table F.2.4.4 Bulk Density Values Recommended for the Hanford Site

Source Area	Bulk Density (g/m^3)
100-N	1.90E+06
100-H	1.64E+06
200-East	1.64E+06
200-West	1.76E+06
300	2.06E+06
SW setting	1.76E+06

Source: Schramke et al. 1994.

Distribution Coefficient

To limit the number of modeling runs, radionuclides and nonradiologic tank constituents were grouped according to mobility (represented by the distribution coefficient [K_d]). These contaminant groups are summarized in Section F.2.2.2.

Darcy Velocity Components of the Fluid Phase

The Darcy velocity refers to the rate of groundwater flow through a cross-sectional area of a porous medium (the aquifer) in response to differences in hydraulic head. The designations of v_1 and v_2 correspond to the Darcy velocities in the x and y dimensions, respectively. For the groundwater modeling effort, the orientation can be thought of as an areal view, with the x component of flow

oriented in an east to west direction and the y component of flow oriented north to south. This orientation differs from the vadose zone model, where the y component of flow represented vertical flow and the x component (representing lateral flow) was not used.

For the groundwater modeling effort, the flow was modeled as steady-state; therefore Darcy velocity remains constant over time. These values were obtained by performing a steady-state flow simulation of the unconfined aquifer using VAM2D. The values of Darcy velocity are written to an output file from the steady-state flow. This output file is subsequently used as input for the transient transport model.

Prescribed Values of Solute Flux at Boundary Nodes

Input for solute flux for the groundwater model was developed from the vadose zone model results at each source area for each alternative model. Section F.2.3.2, Post-Processing for Groundwater Model Input, discusses the development of the source term for groundwater.

F.2.4.2 Post-Processing Groundwater Results for Risk Assessment

The contaminants were grouped based on their mobility as represented by K_ds in the vadose zone and underlying unconfined aquifer. The contaminant groups were used rather than the individual mobility of each contaminant primarily because of the uncertainty involved in determining the mobility of individual contaminants. Where there was ambiguity, contaminants were placed within the more mobile group.

This approach required post-processing to determine contaminant concentrations for each constituent in the group, perform other adjustments as appropriate, and combine the results of each source area. The approach is conservative in that it will result in a somewhat higher overall estimation of concentration and mobility compared to an approach that uses each contaminant's estimated K_d values.

In summary, post-processing was performed in two phases. The first phase entailed reducing the data from multiple files (generally eight) at a 250-m (820-ft) grid spacing, into one file representing the desired 1-km (0.62-mi) grid spacing, for each time step of interest and K_d group. One file for each time of interest was input into the ARC/INFO geographic information system (GIS). An INFO program was written to enable GIS to perform the second phase of post-processing.

The second phase of post-processing for each of these values included adjusting the eight raw concentration data values for aquifer thickness, initial calculated concentration for each constituent, and radioactive decay. The eight adjusted values were then added to predict a single concentration value for each constituent within the K_d group at each 1-km (0.62-mi) grid node. The results of the ARC/INFO post-processing program were exported into Surfer format files for each constituent at each time of interest. Additional details for each phase are provided in the following subsections.

F.2.4.2.1 Reducing Data Results to 1-km (0.62-mi) Grid

The VAM2D model stores all predicted contaminant concentrations for each grid node for each time period of interest consecutively in one file. Thus, each output file would contain up to six data arrays, each representing one of the specified time periods of interest (e.g., 300, 500, 1,000, 2,500, 5,000, and 10,000 years from the model initiation time). Each data array contained 32,768 lines, 1 for each node of the groundwater model. Each line contained the x-coordinate, y-coordinate, and calculated concentration value. The output file for each source area was split into separate data files, each representing a concentration data array for one time period of interest. These matrix files were given a name representing the appropriate source area and time.

For each time period of interest, the eight data matrix files (one for each source area, which include 1WSS, 2WSS, 3WDS, 1ESS, 2ESS, 3EDS, 4ESS, and 5EDS) were combined into one file containing the x-coordinate, y-coordinate, and eight consecutive concentration values. Additionally, the data were reduced from the 250-m (820-ft) model grid spacing to the desired (1-km [0.62-mi]) grid spacing. This reduced the number of concentration values representing each source area from 32,768 to 2,173.

A FORTRAN program was written to address combining the eight files (one for each source area) into one file. The program performed the following tasks:

- First, the program read in the x-coordinate and y-coordinate and calculated concentration value for the first site (1WSS) and stored these into three data arrays. Next, the program read the remaining seven files and stored only the concentration values into data arrays.
- Once all of the data were stored into arrays, the program determined if there were any negative concentration values at 1-km (0.62-mi) node points. (Negative concentration values are caused by numeric dispersion within the model. This usually only occurs early in time and at the leading edge of the contaminant plume where concentration values are low.) Negative concentration values were adjusted as follows: The program looked for two nodes on either side of the negative node that were both positive concentration values and adjusted the negative value to be the average of the two. The program looked at orthogonal values (i.e., east to west, or north to south), followed by diagonal values. If the negative value could not be resolved in this manner, it was changed to its absolute value.
- Next, values reported in the model below 1.0E-12 were changed to zero values. The VAM2D model numerically estimates concentrations at all node points for each timestep; consequently, even at the beginning timesteps of the model, nodes tens of kilometers away show minuscule numbers such as 1.23E-370. These numbers obviously are not valid predictions of contaminant concentrations; therefore, a determination was made as to where the concentration should be considered "zero." The value 1.0E-12 was chosen because it was more than 20 orders of magnitude less than the initial concentration.
- Finally, the program wrote an output file for import into the GIS. Every fourth node on the finer grid corresponded directly to the 1-km grid spacing. Therefore, only

every fourth grid point and corresponding concentration was output to the GIS file. This output file contained 2,173 lines of data, each representing a 1-km (0.62-mi) node. Each line contained the x-coordinate, y-coordinate, and eight consecutive calculated concentration values corresponding to the eight sites, respectively.

F.2.4.2.2 Adjusting Raw Data to Constituent Concentrations

Once the data were reduced to a more manageable number of values, the resulting file was imported as a raw data table into ARC/INFO for additional post-processing. Each raw data table generally contained eight values (one for each tank source area) for each 1-km (0.62-mi) grid node. The steps used for this process are described in the following text.

Step One - Adjust Raw Data for Aquifer Thickness for Each Site

Two-dimensional contaminant transport modeling results in predictions of contaminants distributed uniformly throughout the thickness of the aquifer. However, Hanford Site data indicated that the majority of contaminants are concentrated within the upper portion (approximately 6 m [20 ft]) of the aquifer. The unadjusted results from the 2-D model effectively diluted concentration predictions.

To compensate for the dilution of calculated contaminant concentrations throughout the aquifer, the model code was modified by HydroGeoLogic to track cumulative mass per unit thickness (meter) as well as the cumulative mass retained within the aquifer. From this information, the average thickness of the aquifer within the area of the contaminant plume was determined and a corresponding concentration factor was calculated. The raw value at each 1-km (0.62-mi) grid node was multiplied by the concentration factor to re-distribute the contaminant into the upper 6 m (20 ft) of the aquifer.

Step Two - Adjust Results for the Initial Concentration of Each Constituent in the K_d Group

Within any one of the K_d groups, the calculated concentration of each waste constituent at any location and time within the aquifer is scalable from the concentration used in the transport simulation.

A linear relationship exists between the unit concentration used in the transport simulation and the resulting calculated concentration in groundwater for all other constituents within any K_d group. For example, if an initial concentration of 100 g/L at the source results in a concentration of 25 g/L at a given node and time, then a contaminant with an initial concentration of 10 g/L will result in a concentration of 2.5 g/L at that node and time. This relationship allows the model results for one contaminant to be post-processed for all of the other contaminants within the K_d group.

Step two entailed adjusting the raw data values at each node by the ratio of the concentration of the contaminant of interest to the concentration modeled. This step resulted in a matrix of concentration values for each constituent for the particular K_d group. For example, the concentration simulated for the No Action alternative for the K_d group 1 (K_d = 0) was based on nitrate and set at 400 g/L. For this alternative, the initial concentration of U-238 was 70.036 g/L. Initial concentration values for each of the constituents for the various alternatives are provided in Section F.2.2.3. To predict the

concentration values of U-238 (also in K_d group 1) at site 1WSS, the result at each node was adjusted by multiplying the calculated concentration by 70.036/400 = 0.17509.

Step Three - Adjust Radionuclide Constituents for Decay at the Time of Interest

The concentration of each radioisotope was then adjusted for decay for each time of interest. The relationship used for this adjustment is $A(t) = A(0)e^{-kt}$, where k = ln 2/ half-life of the radioisotope of interest in days, and t = the time of interest (days), A(t) is the decayed concentration value at time t, and A(0) is raw data concentration value prior to decay.

For example, the half-life of U-238 is 2.34E+07 years, or 8.55E+09 days. To determine the adjustment factor for decay at 27.4 years (10,000 days) the following calculations were performed:

- k = ln 2 / 8.55E+09 days = 8.11E-11/day
- kt = 8.11E-11/day · 10,000 days = 8.11E-7
- $e^{-kt} = e^{-8.11E-07}$ = 9.999E-01

To determine the concentration at each node, the raw data concentration would then be multiplied by 9.999E-01 to determine the final result at each node as follows, assuming an initial concentration value of 5.500 mg/L.

- A(t) = 5.500 mg/L (9.999E-01)
- A(t) = 5.499 mg/L

Ingrowth of progeny was not calculated.

Step Four - Combine Results for Each Constituent

The first three steps determined calculated concentrations in groundwater for discrete source areas at each 1-km (0.62-mi) node for each constituent at each time of interest. Once this information was obtained, the eight concentration values at each node (associated with each tank source) were added to provide a single calculated concentration in groundwater from all sources. This information was stored in the INFO database and exported to an ASCII text file for final processing. Each file was then run through a program to change the format of the file so that it could be read directly into Surfer for the risk assessment task. The ASCII file contained a list of the concentration values sorted by grid location. The Surfer file was required to be in the following format:

Line 1: id (4 characters)

Line 2: nx,ny (where nx=number of grid lines along X axis, ny=number of grid lines along Y axis)

Line 3: xlo,xhi (where xlo=minimum x-coordinate of grid, xhi=maximum x-coordinate of grid)

Line 4: ylo,yhi (where ylo=minimum y-coordinate of grid, yhi=maximum y-coordinate of grid)

Line 5: grid row 1 (concentration values organized in row order)

Line 6: grid row 2
Line 7: grid row 3
.
.
.
Line 57: grid row 53

F.3.0 PREDICTED CONTAMINANT CONCENTRATIONS

This section describes the potential impacts to the groundwater aquifer from the TWRS alternatives. The discussion includes the calculated movement of contaminants through the vadose zone and unconfined aquifer. Results are presented for five time periods; 300, 500, 2,500, 5,000, and 10,000 years from the present for the primary contributor to human health risk, C-14, I-129, Tc-99, U-238, and nitrate.

F.3.1 NO ACTION ALTERNATIVE (TANK WASTE)

The No Action alternative would result in the release of the total waste inventory from the 177 tanks into the vadose zone. The contaminants in K_d groups 1 and 2, modeled as K_d equals zero and one, respectively, ultimately pass through the vadose zone and reach groundwater in the underlying unconfined aquifer, within the 10,000-year period of interest. Once in the aquifer, the contaminants in K_d group 1 move relatively quickly through the aquifer and discharge to the Columbia River.
The results of contaminant transport modeling through the vadose zone and groundwater are discussed in the following sections.

F.3.1.1 Vadose Zone

The scenario for this alterative includes the following major assumptions:

- Infiltration is 5.0 cm/year (1.36E-04 m/day) initially and throughout the period of interest;
- Contaminant release for the five SST source areas and the three DST source areas is assumed to begin at the end of institutional control in the year 2095; and
- The initial unit concentration assumed in modeling for K_d groups 1 and 2 (K_d equals zero and one) is 400,000 mg/L.

For K_d equals zero, the vadose modeling results predict contaminant first arrival at the vadose zone/groundwater interface at approximately 130 to 150 years (Figure F.3.1.1). (Note: All figures and tables follow the text.) Peak concentration at the vadose zone/groundwater interface is reached at times varying from approximately 210 to 260 years.

Contaminant concentrations from four of the five SST source areas (1WSS, 2WSS, 1ESS, and 4ESS) reach or nearly reach steady-state and the maximum possible (400,000 mg/L) concentration.
The vadose zone in the 200 West Area is generally thinner by 5 to 20 m (16 to 65 ft), compared to that in the 200 East Area. The flatter shape of the peak of the time/concentration curves for the 200 West Area sites compared to the 200 East Area sites indicates that peak concentrations calculated at the

groundwater-vadose zone interface are relatively sensitive to vadose zone thickness. The fifth SST source area, 2ESS, is located in 200 East. First arrival of contaminants at the water table from this source area is similar to that from the other SST sources but the peak concentration is much lower, at approximately 28,000 mg/L. This occurs because the contaminant mass and corresponding release period (Table F.2.2.10) for the 2ESS source area is generally one or more orders of magnitude less than the other source areas.

For K_d equals one, contaminant first arrival at the groundwater varies from approximately 1,020 to 1,380 years (Figure F.3.1.2).

For contaminant groups 3 and 4 (K_d equals 10 and 50), first arrival occurs very late (i.e., beyond the 10,000 period of interest). For this reason, modeling results are not reported for these K_d groups.

F.3.1.2 Groundwater

Contaminants in K_d groups 1 and 2, modeled as K_d equals zero and one, respectively, are calculated to reach the groundwater of the unconfined aquifer within the period of interest. Two time frames were selected to illustrate the contaminant distribution in the unconfined aquifer. Figure F.3.1.3 presents the calculated nitrate distribution in the groundwater at 300 years from the present. Nitrate has assumed K_d equal to zero and thus moves at the velocity of groundwater. The time versus calculated concentration of nitrate at selected locations within the aquifer is provided in Figure F.3.1.4. Figure F.3.1.4 indicates that nitrate has moved completely through the groundwater system (i.e., nitrate concentrations in groundwater have fallen to approximately zero) prior to approximately 900 years from the present. The nitrate concentrations shown in Figures F.3.1.3 and F.3.1.4 have been adjusted for an assumed initial source concentration of 360,000 mg/L of nitrate and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer.

Figure F.3.1.5 provides the calculated distribution of bismuth in the groundwater at 5,000 years from the present. Bismuth is representative of elements in K_d group 2 (modeled as K_d equals one). Bismuth moves through the groundwater system at a much slower velocity than water, as illustrated in Figure F.3.1.6. This figure shows that for the selected observation nodes within the aquifer, it takes bismuth over 8,000 years from first arrival until its concentration drops back to near zero. Time versus concentration for observation nodes 13767 and 23585 exhibit a bimodal pattern (Figure F.3.1.6). These two observation points are located along the Columbia River approximately due east of the 200 Areas, and southeast of the 200 Areas, respectively. Both of these locations receive contaminants from tank sources in both 200 East and 200 West Areas. The bimodal pattern is due to contaminants reaching the Columbia River from the 200 East Area sources first, followed by contaminants from 200 West Area sources. The other two observation nodes (25647 and 29076) do not exhibit the bimodal pattern because the primary source of contaminants to these points originates only from 200 West Area sources. These two observation nodes are located between Gable Butte and Gable Mountain and along the Columbia River near the B Reactor, respectively. The bismuth concentrations shown in Figures F.3.1.5 and F.3.1.6 have been adjusted for their initial source concentrations shown in Table F.2.2.11, and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer. Also provided in Table

F.3.1.1 are the calculated maximum concentrations of the contaminants in K_d groups 1 and 2 in groundwater at five periods of interest ranging from 300 to 10,000 years from the present. The values presented in this table have been adjusted for their initial source concentration and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer. Figures F.3.1.7 through F.3.1.20 are provided to illustrate the distribution of Tc-99, I-129, C-14, U-238, and nitrate in the unconfined aquifer at time frames from 300 through 2,500 years from the present. These figures represent calculated concentrations in the upper 6 m (20 ft) of the aquifer.

F.3.2 LONG-TERM MANAGEMENT ALTERNATIVE

The Long-Term Management alternative would result in the release of the total waste inventory from the 177 tanks into the vadose zone. The contaminants in K_d groups 1 and 2, modeled as K_d equals zero and one, respectively, ultimately pass through the vadose zone and reach the groundwater in the underlying unconfined aquifer within the 10,000-year period of interest. Once in the aquifer, the contaminants in K_d group 1 move relatively quickly through the aquifer and discharge to the Columbia River. The results of contaminant transport modeling through the vadose zone and groundwater are discussed in the following sections.

F.3.2.1 Vadose Zone

The scenario for this alternative includes the following major assumptions:

- Infiltration is 5.0 cm/year (1.36E-04 m/day) initially and throughout the period of interest;
- Contaminant release for the five SST source areas is assumed to begin at the end of institutional control in the year 2095;
- Contaminant releases from the three DST source areas are assumed to begin 100 years after the end of institutional control in the year 2195; and
- The initial unit concentration assumed in modeling for K_d groups 1 and 2 (K_d equals zero and one) is 400,000 mg/L.

For K_d equals zero, the vadose modeling results predict contaminant first arrival at the vadose zone/groundwater interface at times varying from approximately 140 to 150 years for the SSTs and from approximately 230 to 250 years for the DSTs (Figure F.3.2.1). The difference between the first arrival times for the two tank types corresponds well to the release scenario assumed for SSTs and DSTs. Peak concentration at the vadose zone/groundwater interface is reached at times varying from approximately 210 to 350 years.

Contaminant concentrations from four of the five SST source areas (1WSS, 2WSS, 1ESS, and 4ESS) reach or nearly reach steady-state and the maximum possible (400,000 mg/L) concentration.
The vadose zone in the 200 West Area is generally thinner by 5 to 20 m (16 to 66 ft), compared to that in the 200 East Area. The flatter shape of the peak of the time and concentration curves for the 200 West Area sites compared to the 200 East Area sites indicate that peak concentrations calculated at the groundwater-vadose zone interface are relatively sensitive to vadose-zone thickness. The fifth SST source area, 2ESS, is located in the 200 East Area. First arrival of contaminants at the water table

from this source area is similar to that from the other SST sources, but the peak concentration is much lower at approximately 28,000 mg/L. This occurs because the contaminant mass and corresponding release period (Table F.2.2.12) for the 2ESS source area is generally one or more orders of magnitude less than the other source areas.

For K_d equals one, the vadose modeling results predict contaminant first arrival at the groundwater at times varying from approximately 1,020 to 1,470 years (Figure F.3.2.2). The time lag between first arrival of contaminants from SST source areas compared to DST source areas that was observed for K_d equals zero is not apparent for the K_d equals one simulations. This lack of contrast occurs because as the K_d increases, contaminant transport becomes increasingly more sensitive to the distance of travel (i.e., vadose zone thickness). This is illustrated by comparing the average time of first arrival at the groundwater between sources in the 200 Areas. The average time of first arrival to groundwater for the three source areas in the 200 West Area is approximately 1,290 years while the average time of first arrival for the five source areas in the 200 East Area is approximately 1,180 years. The longer average time to first arrival to groundwater for source areas in the 200 West Area is consistent with the thicker vadose zone in the 200 West Area. Another observation apparent from the vadose modeling is that as the K_d increases, peak concentrations in groundwater decrease and duration increases for the period from first arrival until contaminant concentrations decrease back to zero. This is readily observed by comparing Figures F.3.2.1 and F.3.2.2.

For contaminant groups three and four (K_d equals 10 and 50), first arrival occurs beyond the 10,000-year period of interest. For this reason, modeling results are not reported for these K_d groups.

F.3.2.2 Groundwater

Contaminants in K_d groups 1 and 2, modeled as K_d equals zero and one, respectively, are calculated to reach the groundwater in the unconfined aquifer within the period of interest. In the following discussion, nitrate representing a contaminant with a K_d equal to zero, and bismuth, representing a contaminant with a K_d equal to one, are used to illustrate general groundwater flow and contaminant transport in the unconfined aquifer. At the end of this subsection, additional isoconcentration maps are provided for Tc-99, I-129, C-14, U-238, and nitrate for 300 to 2,500 years from the present. These maps are provided because these contaminants exceed drinking water standards or human health advisories or have the potential to create substantial human health risk from groundwater use onsite.

Figure F.3.2.3 presents the calculated nitrate distribution in the groundwater at 300 years from the present. Nitrate has an assumed value of K_d equal to zero and thus moves at the velocity of groundwater. The time versus calculated concentration of nitrate at selected locations within the aquifer are provided in Figure F.3.2.4. Figure F.3.2.4 indicates that nitrate has moved through the groundwater system (i.e., nitrate concentrations in groundwater have fallen to approximately zero) prior to approximately 900 years from the present. The nitrate concentrations shown in Figures F.3.2.3 and F.3.2.4 have been adjusted for an assumed initial source concentration of 360,000 mg/L of nitrate and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer.

Figure F.3.2.5 provides the calculated distribution of bismuth in the groundwater at 5,000 years from present. Bismuth is in K_d group 2 (modeled at K_d equals one). Bismuth moves through the groundwater system at a much slower velocity than nitrate, as illustrated in Figure F.3.2.6. This figure shows that for the selected observation nodes within the aquifer, it takes bismuth approximately 7,500 years from first arrival until its concentration drops back to nearly zero. Time versus concentration for observation nodes 13767 and 23585 on Figure F.3.2.6 exhibit a bimodal pattern. Observation nodes 13767 and 23585 are located along the Columbia River approximately due east of the 200 Areas and southeast of the 200 Areas, respectively (Figure F.3.2.5). Both of these locations receive contaminants from tank sources in the 200 Areas. The bimodal pattern is due to contaminants first reaching the Columbia River from the 200 East Area sources and then followed by contaminants from the 200 West Area sources. The other two observation nodes (25647 and 29076) do not exhibit the bimodal pattern because the primary source of contaminants to these points originates from the 200 West Area sources only. Observation nodes 25647 and 29076 are located between Gable Butte and Gable Mountain and along the Columbia River near the 100 North Area, respectively. The bismuth concentrations shown in Figures F.3.2.5 and F.3.2.6 have been adjusted for their initial source concentrations shown on Table F.2.2.11 and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer.

Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d groups one and two are provided in Table F.3.2.1 for 300, 500, 2,500, 5,000, and 10,000 years from 1995. The values presented in this table have been adjusted for their initial source concentration and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer. These selected times represent the times of concern for the risk assessment (Volume Three, Appendix D). Figures F.3.2.7 through F.3.2.20 are provided to illustrate the distribution of Tc-99, I-129, C-14, U-238, and nitrate in the unconfined aquifer at time frames from 300 through 2,500 years from the present.

F.3.3 IN SITU FILL AND CAP ALTERNATIVE

Under the In Situ Fill and Cap alternative, the complete inventory from the 177 tanks would be released into the vadose zone. Only the most mobile contaminants, those modeled as K_d equals zero, are calculated to reach the groundwater within the period of interest. The contaminant source is the same as for the No Action and Long-Term Management alternatives. The major difference between these alternatives is that a Hanford Barrier would be constructed over the tanks in the In Situ Fill and Cap alternative, which would result in a lower infiltration rate and mass flux to the vadose zone. Also, the tanks would be filled with sand and gravel to structurally stabilize the domes. Once in the aquifer, the contaminants move relatively quickly and then discharge to the Columbia River. Peak groundwater concentrations in the aquifer would be at least an order of magnitude lower than those calculated for the Long-Term Management alternative, primarily as a result of a lower infiltration rate due to the Hanford Barrier. The results of contaminant transport modeling through the vadose zone and groundwater are discussed in the following sections.

F.3.3.1 Vadose Zone

The scenario for this alternative includes the following major assumptions:

- The initial vadose zone flow field is based on an infiltration rate of 5.0 cm/year(1.36E-04 m/day);
- The infiltration rate is assumed to decrease to 0.5 cm/year (1.36E-05 m/day)in response to Hanford Site activities and decreases again to 0.05 cm/year (1.36E-06 m/day)after the Hanford Barrier is installed; the Hanford Barrier is assumed to lose integrity 1,000 years later, causing infiltration to increase to 0.1 cm/year (2.74E-06 m/day) throughout the remainder of the 10,000-year period of interest;
- Contaminant release for the eight tank source areas is assumed to begin 500 years after the Hanford Barrier is installed (NRC 1994);
- The initial unit concentration assumed in modeling is 400,000 mg/L; and
- The initial contaminant inventory and concentrations are the same as for the No Action alternative.

Contaminant first arrival at the vadose zone and groundwater interface is calculated to occur at times varying from approximately 2,330 to 3,380 years (Figure F.3.3.1). Peak concentration at the vadose zone and groundwater interface is reached at times varying from approximately 4,080 to 6,300 years. This alternative, compared to the No Action and Long-Term Management alternatives, has a much longer calculated time to first arrival and peak concentration at the vadose zone and groundwater interface due to the lower infiltration rate through the Hanford Barrier. The calculated peak concentration for each of the eight source areas at the vadose zone and groundwater interface is of a similar magnitude to that calculated for the Long-Term Management alternative. As with the No Action alternative, contaminant levels reach or nearly reach steady-state conditions with maximum concentrations of 400,000 mg/L for all source areas except site 2ESS.

F.3.3.2 Groundwater

Contaminants in K_d group 1 are calculated to reach the groundwater of the unconfined aquifer within the period of interest. In the following discussion, nitrate representing a contaminant with a K_d equal to zero is used to illustrate general groundwater flow and contaminant transport in the unconfined aquifer. At the end of this subsection, addition isoconcentration maps are provided for Tc-99, I-129, C-14, U-238, and nitrate at 2,500 through 10,000 years from the present.

Figure F.3.3.2 presents the calculated nitrate distribution in the groundwater at 5,000 years from the present. Nitrate has an assumed value of K_d equal to zero and thus moves at the velocity of groundwater. The time versus concentration of nitrate at selected observation nodes is provided in Figure F.3.3.3. Figure F.3.3.3 indicates that nitrate concentrations reach peak concentration at approximately 5,500 years and continue at those concentration levels for approximately 1,500 years for nodes 13767 and 23585. For nodes 25647 and 29076, peak concentration is reached at about 5,000 years and continues for approximately 3,000 years. This is because nodes 25647 and 29076 would receive contaminants in groundwater from the 200 West Area sources only, and the average longevity of contaminant release into the vadose zone is approximately twice as long for the 200 West Area sites.

Table F.2.2.13 provides release duration and mass for this alternative. The nitrate concentrations shown in Figures F.3.3.2 and F.3.3.3 have been adjusted for an assumed initial source concentration of 360,000 mg/L of nitrate and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer.

Contaminants have not yet reached groundwater from the sources from earlier time periods of interest (e.g., 300 and 500 years from the present). Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d group 1 are provided in Table F.3.3.1 for 2,500, 5,000, and 10,000 years from 1995. Figures F.3.3.4 through F.3.3.17 are provided to illustrate the distribution of Tc-99, I-129, C-14, U-238, and nitrate in the unconfined aquifer at time frames from 2,500 through 10,000 years from the present.

The sensitivity of the In Situ Fill and Cap alternative to changing the operating infiltration rate through the Hanford Barrier from 0.05 to 0.1 cm/year (1.36E-06 to 2.74E-06 m/day) after 500 rather than 1,000 years was evaluated. This assumes that the Hanford Barrier degrades after 500 years. Results of this parameter sensitivity analysis suggest that peak concentrations of contaminants in groundwater remains the same but occur slightly earlier for the 500 year Hanford Barrier. Additional discussion of the parameter sensitivity is provided in Section F.4.3.5.

F.3.4 IN SITU VITRIFICATION ALTERNATIVE

The In Situ Vitrification alternative results in the partial release of the initial inventory from the 177 tanks into the vadose zone over the period of interest. Not all of the tank waste is released over the 10,000 year period of interest because of the low glass corrosion rate coupled with a cap over the tanks. Only the most mobile contaminants, those modeled as K_d equal to zero, are calculated to reach the groundwater within the period of interest. Because the source is relatively large and the release rates are relatively low, contaminants are released at a constant concentration for thousands of years from each source area.

Once in the aquifer, the contaminants move relatively quickly and discharge to the Columbia River. Contaminant concentrations in the aquifer reach a constant level for much of the period of interest because of the long, constant concentration discharge of contaminants from the vadose zone.

F.3.4.1 Vadose Zone

The scenario for this alternative includes the following major assumptions:

- The initial vadose zone flow field is based on an infiltration rate of 5.0 cm/year (1.36E-04 m/day);
- In response to Hanford Site activities, the infiltration rate is assumed to decrease to 0.5 cm/year (1.36E-05 m/day) and then 0.05 cm/year (1.36E-06 m/day) after the Hanford Barrier has been installed. The Hanford Barrier is assumed to lose some integrity 1,000 years later, which would cause infiltration to increase to 0.1 cm/year (2.74E-06 m/day) throughout the remainder of the 10,000-year period of interest;
- Contaminant release for the eight tank source areas is assumed to begin 500 years after the Hanford Barrier is installed; and

- The initial unit concentration assumed in modeling is 400 mg/L.

Contaminant first arrival at the vadose zone and groundwater interface is calculated to occur at times varying from approximately 2,350 to 3,410 years (Figure F.3.4.1). Peak concentration at the vadose zone and groundwater interface reach steady-state conditions with a concentration of 400 mg/L between approximately 6,250 to 7,500 years from the present and remain at that concentration for the remainder of the period of interest. This alternative, compared to the No Action and Long-Term Management alternatives, has a longer calculated time to first arrival and peak concentration at the vadose zone and groundwater interface primarily because of the lower infiltration rate through the Hanford Barrier. The calculated peak concentration for each of the eight source areas at the vadose zone and groundwater interface would be lower. This is because the initial source concentrations are three orders of magnitude less than the source concentrations for the No Action and Long-Term Management alternatives.

F.3.4.2 Groundwater

Contaminants in K_d group one are calculated to reach the groundwater of the unconfined aquifer within the period of interest. The distribution of two contaminants, Tc-99 and U-238, in groundwater at selected time frames are provided to illustrate the impact of this alternative. Figures F.3.4.2 and F.3.4.3 provide the predicted distribution of Tc-99 and U-238 respectively for 5,000 years from the present. Variations in the distribution are due to variations in the inventory of each contaminant at the eight source areas. The time versus concentration of U-238 in the unconfined aquifer at selected locations is provided in Figure F.3.4.4 where U-238 can be observed to reach steady-state conditions at approximately 6,000 years. The U-238 concentrations actually drop slightly after approximately 6,000 years because of radioactive decay. A stable contaminant such as sodium would continue at its peak or steady-state concentrations beyond the 10,000 year period of interest.

Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d group 1 ($K_d = 0$) are provided in Table F.3.4.1 for 5,000 and 10,000 years from 1995. Contaminants for earlier time periods (e.g., 300, 500, and 2,500 years) are not presented because they would not have reached groundwater within this time period. The predicted distribution of U-238 in the unconfined aquifer 10,000 years from the present is provided in Figure F.3.4.5. The U-238 and Tc-99 concentrations shown in Figures F.3.4.2 through F.3.4.5 have been adjusted for their assumed initial source concentration and represent the calculated concentrations in the upper 6 m (20 ft) of the unconfined aquifer.

F.3.5 EX SITU INTERMEDIATE SEPARATIONS ALTERNATIVE

The Ex Situ Intermediate Separations alternative would release contaminants to the vadose zone from the 177 tanks associated with retrieval operations (from SSTs only), residual waste left in the tanks (for all tanks), and releases from the LAW disposal facility. Only the most mobile contaminants, those modeled as K_d equal to zero, are calculated to reach the groundwater within the period of interest. Compared to the No Action and Long-Term Management alternatives, the mass of contaminants released from the tanks would be relatively small.

Once in the aquifer, the contaminants would move relatively quickly and discharge to the Columbia River. Contaminant concentrations from the tank source areas have a relatively sharp peak. Contaminant concentrations from the LAW disposal facility would reach peak concentrations in the groundwater approximately 6,610 years from the present and remain at their peak concentration for the remainder of the period of interest. The peak concentrations in the groundwater from the LAW facility are over two orders of magnitude less than the peaks associated with contaminants from the tank sources.

F.3.5.1 Vadose Zone

The scenario for this alternative includes the following major assumptions:

- The initial vadose zone flow field is based on an infiltration rate of 5.0 cm/year (1.36E-04 m/day) for tank source areas and the LAW source area;
- In response to remediation activities, the infiltration rate is assumed to decrease to 0.5 cm/year (1.36E-05 m/day)when retrieval activities start and to 0.05 cm/year (1.36E-06 m/day) after the Hanford Barrier is installed at tank source areas and the LAW source area. The Hanford Barrier is assumed to lose some integrity 1,000 years later, which would cause infiltration to increase to 0.1 cm/year (2.74E-06 m/day) throughout the remainder of the 10,000-year period of interest for tank sources, and the LAW disposal facility.
- Contaminant release for the five SST source areas is assumed to occur during two periods: first during retrieval when the infiltration rate is 0.5 cm/yr and then from residual materials 500 years after Hanford Barrier construction when the infiltration rate is 0.05 cm/yr (1.36E-06 m/day) (NRC 1994).
- Contaminant release for the three DST source areas is assumed to result from releases from residual material 500 years after barrier construction.
- Contaminant release for the LAW facility is assumed to begin 500 years after the Hanford Barrier is constructed over the vaults (NRC 1994).
- For the tank source areas the initial unit concentration calculated is 400,000 mg/L.
- For the LAW source area the initial unit concentration calculated is 100,000 mg/L.
- For the tank source areas the initial contaminant concentrations would be the same as for the No Action and Long-Term Management alternatives. For the LAW disposal facility the initial concentrations are provided in Table F.2.2.17.

Contaminant first arrival at the groundwater is calculated to occur at times varying from approximately 1,070 to 3,420 years from the tank source areas and 3,320 years from the LAW facility.
The comparatively early arrival time of over 1,000 years is related to vadose zone migration of contaminants released during retrieval when the infiltration rate is relatively high (0.5 cm/ year [1.36E-05 m/day]). Concentration versus time at the vadose zone and groundwater interface for the unit contaminant releases from the eight source areas and the LAW facility are illustrated in Figure F.3.5.1. The initial source concentration for the eight source areas and the LAW facility are 400,000 and 100,000 mg/L, respectively. It was necessary to use a different constituent to represent vadose

zone concentrations for the LAW disposal facility because nitrate is not present in the vitrified waste source.

Peak contaminant concentrations at the vadose zone and groundwater interface for the tank source areas would be reached at times varying from 3,630 to 5,110 years. Peak contaminant concentrations at the vadose zone and groundwater interface for the LAW facility would be reached at approximately 6,610 years and remain at that concentration for the remainder of the period of interest. Compared to the Long-Term Management alternative, this alternative has a much longer time to first arrival and peak contaminant concentrations at the vadose zone and groundwater interface primarily because of the lower infiltration rate through the Hanford Barrier and the low corrosion rate of the vitrified waste in the LAW facility.

The calculated peak concentration for each of the eight source areas at the vadose zone and groundwater interface is lower that for the No Action and Long-Term Management alternatives for K_d equals zero by approximately an order of magnitude. Contaminants in K_d groups 2 through 4, modeled as K_d equals 1.0, 10.0, and 50.0 mL/g, did not reach the groundwater within the period of interest.

F.3.5.2 Groundwater

Contaminants in K_d group 1 are calculated to reach the groundwater of the unconfined aquifer within the period of interest. Figure F.3.5.2 presents the calculated nitrate distribution in the groundwater from the tank sources 5,000 years from the present. Nitrate has an assumed K_d equal to zero and thus moves at the velocity of groundwater.

The time versus concentration of nitrate from the tank sources at selected observation nodes are provided in Figure F.3.5.3. Time versus concentration for observation nodes 13767 and 23585 on Figure F.3.5.3 exhibit a bimodal pattern. Both of these locations receive contaminants from tank sources in the 200 Areas. The bimodal pattern is due to contaminants reaching the Columbia River first from the 200 East Area sources followed by contaminants from the 200 West Area sources. The other two observation nodes (25647 and 29076) do not exhibit the bimodal pattern because the primary source of contaminants to these points originate only from the 200 West Area sources. Figure F.3.5.3 indicates that nitrate has moved completely through the groundwater system (i.e., nitrate concentrations in groundwater have fallen to approximately zero) prior to approximately 7,000 years from the present. The nitrate concentrations shown in Figures F.3.5.2 and F.3.5.3 have been adjusted for an assumed initial source concentration of 360,000 mg/L of nitrate and represent calculated concentrations in the upper 6 m (20 feet) of the aquifer.

The calculated concentrations of U-238 versus time in the unconfined aquifer for tank sources only and the LAW vault source at selected observation nodes are provided in Figures F.3.5.4 and F.3.5.5, respectively. Time versus concentration for observation nodes 13767 and 23585 on Figure F.3.5.5 indicates that U-238 concentrations reach steady-state conditions at approximately 7,000 years and continue at those concentration levels throughout the remainder of the time period of interest. Because the LAW burial facility is located in the 200 East Area, observation nodes 25647 and 29076 remain at

a concentration of zero throughout the time period of interest. This is because groundwater does not flow from the 200 East Area towards these nodes. Figure F.3.5.6 provides the predicted distribution of U-238 in the unconfined aquifer at 5,000 years from the present from both tank and LAW vault sources combined. The distribution of this contaminant is much the same as calculated for nitrate at the same time frame. The contaminant concentrations have been adjusted for their assumed initial source concentrations, radioactive decay where applicable, and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer.

Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d group one from the tank sources are provided in Table F.3.5.1 for 2,500, 5,000, and 10,000 years from the present. Contaminants have not yet reached groundwater from the tank sources at earlier time periods of interest (e.g., 300, 500, and 2,500 years from the present). Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d group 1 from the LAW disposal site are provided in Table F.3.5.2 for 5,000 and 10,000 years from the present. Contaminants have not yet reached groundwater from the LAW disposal sources at earlier time periods of interest.

F.3.6 EX SITU NO SEPARATIONS ALTERNATIVE

Under this alternative, waste would be retrieved from the tanks, vitrified or calcined, and shipped to the potential geologic repository for disposal. A Hanford Barrier would be placed over the tanks. Groundwater impacts would result from potential releases to the groundwater system associated with releases 1) during retrieval from the waste tanks; and 2) from residuals remaining in the tanks. The vitrified or calcined waste would not have a potential groundwater impact because they would be shipped offsite for disposal. The groundwater impacts for this alternative would be the same as those estimated for the retrieval and residual releases for Ex Situ Intermediate Separations alternative. The calculated distribution of nitrate in the unconfined aquifer 5,000 years from the present is illustrated in Figure F.3.5.2. The calculated U-238 concentrations in groundwater from the tank sources at 5,000 years is illustrated in Figure F.3.6.1.

F.3.7 EX SITU EXTENSIVE SEPARATIONS ALTERNATIVE

This alternative is similar to the Ex Situ Intermediate Separations alternative, with the only difference being that a more extensive separations process would be used. Under this alternative, waste would be retrieved from the tanks, HLW would be separated from the LAW, and both HLW and LAW would be vitrified. The extensive separations process would result in a smaller amount of contaminant source associated with the LAW vaults. A Hanford Barrier would be placed over the tanks and LAW vaults. Potential groundwater impacts would result from contaminant releases to the groundwater system 1) during tank waste retrieval; 2) from residuals in the tanks; and 3) from the LAW vaults. Groundwater impacts associated with retrieval and residual releases would be the same as for the Ex Situ Intermediate Separations alternative. This alternative would include extensive waste separation processes, but there would still be some contribution of U-238 from releases associated with the LAW vaults. Figure F.3.7.1 shows the calculated U-238 concentrations in groundwater 5,000 years from the present for both tank and vault sources.

F.3.8 EX SITU/IN SITU COMBINATION 1 ALTERNATIVE

The tank waste Ex Situ/In Situ Combination alternative would remediate 107 tanks in situ by filling and capping the tanks using the methods described under the In Situ Fill and Cap alternative. The waste in the remaining 70 tanks (60 SSTs and 10 DSTs) would be retrieved and treated using methods described under the Ex Situ Intermediate Separations alternative. The LAW from these tanks would be disposed of in a LAW vault. The HLW would be shipped to a potential geologic repository. As with both the In Situ Fill and Cap and Ex Situ Intermediate Separations alternatives, only the most mobile contaminants, those modeled as K_d equal to zero, are calculated to reach groundwater within the period of interest.

Once in the aquifer, the contaminants move relatively quickly through the aquifer and discharge to the Columbia River. Peak groundwater concentrations in the aquifer would be at least an order of magnitude lower than those calculated for the No Action alternative, primarily as a result of a lower infiltration rate due to the Hanford Barrier, which is constructed over the tanks remediated in situ and the LAW vault. The results of contaminant transport modeling through the vadose zone and groundwater are discussed in the following sections.

F.3.8.1 Vadose Zone

The two major components resulting in releases to the vadose zone are 1) tank sources from retrieval releases and releases from tanks remediated in situ; and 2) releases from the LAW vault. The scenarios for these components include all of the assumptions stated for the In Situ Fill and Cap and Ex Situ Intermediate Separations alternatives. For purposed of analysis, the residual that may be left in the tanks after retrieval (assumed to be 1 percent of the initial inventory from the retrieved tanks) is assumed to be additive to the inventory of tanks that are remediated in situ.

F.3.8.2 Groundwater

One of the objectives of this alterative is to reduce the number of tanks in which the waste is processed ex situ and yet achieve low calculated groundwater concentrations of the high-risk contaminants Tc-99, C-14, I-129, and uranium. These contaminants are all mobile and are in K_d group 1. They, along with several other contaminants in K_d group 1, are calculated to reach the groundwater in the unconfined aquifer within the period of interest. The distributions of Tc-99, C-14, I-129, and U-238 in the unconfined aquifer (U-238 being the most abundant of the tank waste uranium isotopes) are presented in this section for 5,000 and 10,000 years from the present. Although contaminant first arrival for tank sources occurs before 2,500 years, concentrations are approximately one order of magnitude lower than those predicted at 5,000 years. Therefore, contaminant distribution maps were not prepared for the 2,500-year period of interest.

Figures F.3.8.1 through F.3.8.3 present the calculated distributions of Tc-99, I-129, and U-238 in the groundwater at 5,000 years from the present from the tank sources remediated in situ. These calculated concentrations are from approximately 5 to 10 times lower than the concentrations calculated for the In Situ Fill and Cap alternatives. Concentrations of Tc-99 and U-238 for the LAW vault source at 5,000 years from the present are shown on Figures F.3.8.4 and F.3.8.5, respectively. Contaminant

concentrations from the LAW vault source are 100 to 1,000 times lower than from tank sources. I-129 is not shown for the LAW vaults because it is not in the vault inventory.

Figures F.3.8.6 through F.3.8.8 present the calculated distributions of Tc-99, I-129, and U-238 in the groundwater at 10,000 years from the present for the tank sources remediated in situ. These calculated concentrations are from approximately 5 to 1,000 times lower than the concentrations calculated for the In Situ Fill and Cap alternative. Concentrations of Tc-99 and U-238 for the LAW vault source at 10,000 years from the present are shown on Figures F.3.8.9 and F.3.8.10, respectively. As with the 5,000 year time frame, contaminant concentrations from the LAW vault source are 100 to 1,000 times lower than from the tank sources. Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d group 1 are provided in Tables F.3.8.1 through F.3.8.3 for the tank retrieval, in situ tank remediation, and LAW vaults contributions, respectively. The maximums calculated in these tables are not additive on a one-to-one basis because the maximums for the three components of the alternative occur at a different location within the unconfined aquifer.

F.3.9 EX SITU/IN SITU COMBINATION 2 ALTERNATIVE

One objective of this alternative is to further reduce the number of tanks in which the waste is processed ex situ and yet achieve a high retrieval of the long-term contributors to risk (i.e., C-14, I-129, Tc-99, and U-238). These contaminants are all mobile and are in K_d group 1.

F.3.9.1 Vadose Zone

Only the most mobile contaminants, those in K_d group 1 ($K_d = 0$) and include C-14, I-129, Tc-99, and U-238 are calculated to reach the groundwater in the unconfined aquifer within the period of interest. The distributions of Tc-99, I-129, and U-238 in the unconfined aquifer are presented in this section for 5,000 and 10,000 years from the present. Although contaminant first arrival for tank sources occurs before 2,500 years, concentrations are approximately one order of magnitude lower than those predicted at 5,000 years. Therefore, contaminant distribution maps were not prepared for the 2,500-year period of interest.

F.3.9.2 Groundwater

Figures F.3.9.1 through F.3.9.3 present the calculated distributions of Tc-99, I-129, and U-238 in the groundwater at 5,000 years from the present from the tank sources. These calculated concentrations would be at or slightly greater than those calculated for the Ex Situ/In Situ Combination 1 Alternative. As indicated by the note on these figures, the contaminants contributed by retrieval (ex situ) are very small. By retrieving from fewer (as compared to the Ex Situ/In Situ Combination 1 alternative) tanks in the Ex Situ/In Situ Combination 2 alternative, the retrieval contribution becomes less while the residual portion actually becomes greater. Concentrations of Tc-99 and U-238 for the LAW vault source at 5,000 years from the present shown on Figures F.3.9.4 and F.3.9.5, respectively. contaminant concentrations from the LAW vault source are 100 to 1,000 times lower than from tank sources. I-129 is not shown for the LAW vaults because it is not in the vault inventory.

Figures F.3.9.6 through F.3.9.8 present the calculated distributions of Tc-99, I-129, and U-238 in the groundwater at 10,000 years from the present for the tank sources. Similar to the situation at 5,000 years, the most significant portion of the contamination results from the tank remediated in Situ. Contributions from retrieval are minimal. Concentrations of Tc-99 and U-238 for the LAW vault source at 10,000 years from the present are shown on Figure F.3.9.9 and F.3.9.10, respectively.

Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d group 1 are provided in Tables F.3.9.1 through F.3.9.3 for the tank retrieval, in situ tank remediation, and LAW vaults components, respectively.

F.3.10 PHASED IMPLEMENTATION ALTERNATIVE

Phase 1

There are no groundwater impacts associated with the first phase of this alternative. Waste retrieval only occurs in the DSTs, and there are no releases assumed to come from these tanks. The retrieved waste is vitrified and shipped to an onsite repository.

Total Alternative

The contaminant concentrations for this alternative would be the same as those for the Ex Situ Intermediate Separations alternative, discussed in Section F.3.5. Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d Group 1 from the tank sources are provided in Table 3.10.1 for 2,500, 5,000, and 10,000 years from the present. Contaminants have not yet reached groundwater from the tank sources at earlier time periods. Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d Group 1 from the LAW disposal site are provided in Table F.3.10.2 for 5,000 and 10,000 years from the present. Contaminants have not yet reached groundwater from the LAW sources at earlier time periods.

F.3.11 EFFLUENT TREATMENT FACILITY

The effects of disposal on groundwater were simulated as entering the uppermost aquifer beneath the SALDS at a projected rate of 568 L/min (150 gal/min) over an area of 8,350 m^2 (90,000 ft^2) for 125 years. Tritium concentrations in the treated effluent entering the groundwater system were assumed to be 2.1E-05 Ci/L (21μCi/L) with a half-life of 12.3 years. The simulation results indicated that disposal of treated effluent would have little effect on the local direction for groundwater movement beneath the SALDS. Groundwater flow directions resume their northeasterly regional flow direction at a point approximately 300 m (980 ft) downgradient of the disposal site. A residence time of 100 years for tritium in the uppermost aquifer was obtained as the travel time for tritium between the disposal site and the Columbia River. Maximum tritium concentrations at the riverbank prior to dilution in the Columbia River are calculated to be 1.4E-08 Ci/L, which is below the Federal drinking water standard of 2.0E-08 Ci/L (20,000 pCi/L) (Jacobs 1996).

F.3.12 SUMMARY OF RESULTS

F.3.12.1 Observed Contamination Concentrations

Currently, hazardous chemicals and radionuclides at levels that exceed Federal drinking water standards are present in groundwater beneath the 200 Areas and in plumes emanating from the 200 Areas that are moving toward the Columbia River. Hazardous chemical contaminants observed to exceed drinking water standards include nitrates, cyanide, fluoride, Cr, chloroform, carbon tetrachloride, trichloroethylene, and tetrachloroethylene (Dresel et al. 1994). Radiological contaminants include I-129, tritium, Cs-137, Pu-239 and 240, Tc-99, and Sr-90. Generally, the groundwater beneath the 200 Areas is severely contaminated at levels that substantially exceed drinking water standards. For example, I-129 is present at levels that exceed standards by up to 20 times (Dresel et al. 1994). Groundwater-use restrictions have been implemented to prevent current and future uses of contaminated groundwater. Implementing any of the TWRS alternatives would add contaminants to the groundwater. However, peak concentrations from the alternatives would result in less risk than that derived from existing contaminant distributions in groundwater.

F.3.12.2 Calculated Contaminant Concentrations

Table F.3.12.1 compares the maximum calculated contaminant concentration in the groundwater for the alternatives. These calculated contaminant concentrations are for five representative contaminants at five selected times within the unconfined aquifer beneath the Hanford Site. Federal drinking water standards are provided as a basis of comparison. The contaminants shown on Table F.3.12.1 were selected as indicators, based on the criteria of 1) mobility in the environment; 2) persistence (e.g., long half-life); and 3) high human toxicity. Many other contaminants are calculated to be released for each alternative and this information is carried forward to the human health risk assessment (Section 5.11). The following observations are based on data presented in Table F.3.12.1.

Calculated contaminant concentrations would be highest at 300 and 500 years for the No Action and Long-Term Management alternatives compared to other alternatives. The tank inventory would be released faster than any of the other alternatives because there would be no engineered barriers such as the Hanford Barrier to reduce infiltration, nor would there be any effort to stabilize the waste. For the these two alternatives, the maximum calculated contaminant concentrations would drop several orders of magnitude by 2,500 years because all K_d group 1 contaminants would have passed through the groundwater system. The contaminant concentrations would be lowest for these two alternatives at 5,000- and 10,000-years because most of the mass released from the tanks would have currently passed through the groundwater system and discharged into the Columbia River prior to 5,000 years from the present.

At 2,500 years from the present, contaminants in the groundwater associated with the all of the alternatives, except the Phased Implementation alternative, would be evident but at lower maximum calculated concentration (e.g., by at least by a factor of 100 for nitrate) compared to the No Action alternative and Long-Term Management alternative. At this point in time, the concentration of all of the contaminants in the K_d group 2 for the No Action and Long-Term Management alternatives would have peaked in groundwater, and contaminant concentrations would be dropping. Conversely, source

concentrations from the In Situ Fill and Cap and the Ex Situ Intermediate Separations alternatives would still be increasing and would peak between 2,500 and 5,000 years from the present.

The earliest arrival of contaminants in the groundwater associated with the In Situ Vitrification alternative would be 2,500 years from the present, and would peak between 2,500 and 5,000 years from the present.

The levels of contaminant concentrations for all of the Ex Situ alternatives would be low at all times. There would be only slight exceedances of drinking water standards. Under all of the alternatives that include placing waste in onsite LAW vaults, the concentrations of contaminants in the groundwater would be within drinking water standards for the contaminants of concern.

F.4.0 FLOW AND TRANSPORT MODEL

The vadose zone and groundwater modeling effort used VAM2D to predict contaminant migration through the vadose zone and groundwater. VAM2D has been previously used for flow and transport assessments at the Hanford Site. The model formulation used in the code is a descendant of that used in the SATURN code presented by Huyakorn et al. (Huyakorn et al. 1984, 1985) and was developed by HydroGeoLogic Inc. (Huyakorn et al. 1991).

The approach used for this modeling effort relies as much as possible on extensive previous work completed at the Hanford Site (e.g., hydrogeological investigations and modeling studies). Understanding and being able to predict changes in the hydraulic head of the unconfined aquifer is in an advanced stage at the Hanford Site. However, contaminant transport in the unconfined aquifer and flow and contaminant transport in the vadose zone are still in relatively early stages of understanding and development. The modeling approach was as follows:

- A combined groundwater flow and transport code (VAM2D) was used.
- Hydrogeologic and contaminant transport parameters from previous studies, including Wood et al. (Wood et al. 1995), Kincaid et al. (Kincaid et al. 1993), and Wurstner and Devary (Wurstner-Devary 1993) were used in this modeling effort.
- The VAM2D flow model of the unconfined aquifer at the Hanford Site was developed based on a previously published Sitewide calibrated groundwater flow model developed with the CFEST code (Wurstner-Devary 1993). The VAM2D flow model of the unconfined aquifer was then benchmarked against these results.

Details of the approach used to test the model are provided in the following sections.

F.4.1 FEATURES OF THE VAM2D FLOW AND TRANSPORT CODE

VAM2D is a 2-D, finite element model developed for simulating saturated and unsaturated flow and transport. Using a single model code for both vadose zone and groundwater modeling simplified the combined modeling effort. VAM2D is capable of performing flow and transport simulations in vertical cross-sections as well as horizontal orientations.

The capabilities of VAM2D applicable to the TWRS EIS modeling effort include the following:

- Simulates flow and transport in saturated and unsaturated zones;
- Solves flow and transport simultaneously or sequentially;
- Accommodates a wide range of field conditions;
- Computes hysteretic effects on flow because of wetting and drying cycles; and
- Computes the effects of variable anisotropic hydraulic conductivities on flow in stratified media.

F.4.2 LIMITATIONS OF THE TRANSPORT MODEL

Limitations of VAM2D specified in the user's manual (Huyakorn et al. 1991) include the following:

- Does not simulate three-dimensional flow. However, a 2-D analysis is appropriate for the site in that there is a lower confirming bed in the Ringold Formation, and sufficient data to develop a three-dimensional flow and transport model may not be available;
- In performing variably saturated flow, the code handles only single-phase flow (i.e., water) and ignores the flow of a second phase (i.e., air or other nonaqueous phase). This is not a concern as aqueous phase liquids are not reported in site inventory;
- The code does not address kinetic sorption effects and/or reversible chemical reactions; and
- The groundwater flow portion of the model was executed for steady-state conditions. This did not allow simulation of the decay of the groundwater mounds associated with waste disposal activities.

F.4.3 RELIABILITY TESTING OF CALCULATED RESULTS

Several tests may be performed to demonstrate a model's ability to reasonably predict flow and contaminant transport. These include:

- Verification - Comparing the numerical solutions generated by the model with one or more analytical solution or with other solutions.
- Benchmarking - Testing the model solution against the solution of other models for the same problem.
- Calibration - Establishing that the model can reproduce field-measured conditions.
- Validation - Comparing model results with detailed field data.
- Parameter Sensitivity - Quantifying the uncertainty in the calibrated model caused by uncertainty in the estimates of the parameters used.

The following sections describe reliability testing performed on VAM2D for the Hanford Site.

F.4.3.1 Verification

A number of tests were performed to ensure reliability of the code on the computer platform used for the modeling effort (IBM RS/6000 workstation) and to compare results with known analytical solutions. These included the following:

- Initially verifying the model against sample problem 1 in the VAM2D User's Manual;

- Verifying results for saturated flow against an analytical solution (Dupuit solution) (Fetter 1994); and
- Verifying results for saturated transport against an analytical solution (Domenico solution [Domenico 1985]).

The sample problem results matched the results published in the VAM2D User's Manual for head, saturated value, and x-velocity. Y-velocity values differed slightly, however the differences were less than 2.0E-13. The results published in the user's manual were for VAM2D Version 5.2; Version 5.3 was used for this modeling effort.

For the flow problem to be solved with the Dupuit solution, a simple model was constructed and solved for unconfined flow with fixed head boundaries at each end and fixed across a transect. The analytical solution was calculated for several points and compared to the model results. VAM2D model results very closely matched the Dupuit solution. Results calculated by VAM2D compared to the analytical solution are provided as follows.

Distance from Left Boundry	Head Calculated by VAM2D	Head Calculated by Dupuit Solutions
12.5 m	5.844 m	5.846 m
37.5 m	4.90 m	4.981 m

For the transport problem to be solved with the Domenico solution, a simple 2-D model was constructed and solved for transient transport. A contaminant was input at one grid node and a transient model run was performed to predict contaminant concentrations for several node points at a specified point in time (300,000 days). Concentrations based on the Domenico solution were calculated for several points and compared to the model results. VAM2D model results very closely matched the Domenico solution. Results calculated by VAM2D compared to the analytical solution are provided as follows.

Grid Location		Concentration Calculated	Concentration Calculated
Delta X	Delta Y	by VAM2D	by Domenico Solution
10 m	0 m	453.3 mg/L	455.71mg/L
20 m	5 m	85.08 mg/L	83.15 mg/L
30 m	0 m	270.5 mg/L	273.71mg/L
40 m	10 m	14.60 mg/L	13.73 mg/L

F.4.3.2 Benchmarking

The groundwater flow model effort was developed and benchmarked as follows:

- Unconfined aquifer flow parameters and boundary conditions used to set up the VAM2D model were developed from published groundwater flow modeling work using

CFEST (Wurstner-Devary 1993). This effort has undergone verification, calibration, and quasi-validation efforts, which were initiated in the mid-1960's.

- VAM2D predictions of hydraulic head were compared to these published CFEST results (Wurstner-Devary 1993). Basic differences in the model input requirements and the grid used required minor adjustments, primarily to boundary discretization, to obtain a closer match.

Figure F.4.3.1 shows both the published results from prior model development and the hydraulic heads calculated with the VAM2D model. As expected, this figure indicates good agreement between the VAM2D results and the previously published results.

F.4.3.3 Calibration

Calibration of a groundwater model consists of comparing its results to an independent standard. Changing flow conditions at the Hanford Site make an absolute calibration infeasible. However, a qualitative calibration can be performed. This qualitative calibration begins by examining the geometry of a tritium plume that is present on the Hanford Site and estimating tritium travel times from the 200 East Area to the Columbia River. Contaminants originating from the 200 East Area are estimated to take approximately 20 to 25 years to reach the Columbia River. The estimated travel time is based on site operations beginning in the 1940's and detection of contaminants in springs and groundwater in the 1970's.

In this qualitative calibration effort, the VAM2D model was used to simulate a contaminant concentration of 200,000 mg/L source originating from B Pond in the 200 East Area. Discharge fluid fluxes were based on 1979 data, and the transient transport simulation was based on the steady-state field (also based on 1979 data). Figure F.4.3.2 provides estimates of tritium levels observed in groundwater based on 1977 environmental monitoring (Meyers 1978). Figure F.4.3.3 provides the 300 mg/L isoconcentration lines for tritium at 10, 20, and 30 years, assuming this constant discharge rate. Figure F.4.3.3 demonstrates that the travel times calculated by VAM2D correspond well with the assumed 20- to 25-year travel time. Additionally, the plume geometry for the tritium plume originating from the 200 East Area (Figure F.4.3.2) is similar to the predicted plume geometry (Figure F.4.3.3). An exact match between these two plumes should be not expected because discharge amounts varied substantially over time, and the observed tritium plume (Figure F.4.3.2) was created by multiple sources. However, similarities between the two plume geometries indicate that the VAM2D results are reasonable.

F.4.3.4 Validation

Validating a groundwater model consists of comparing model results with detailed field data. However, rigorous validation requires accurate historic data on effluent discharges as a function of time.

Although data are available on flow and transport within the unconfined aquifer, the data set is not sufficient to perform a detailed model validation. Flow conditions have changed dramatically since the

early 1940's, primarily as the result of changes in wastewater discharges. Historic records of effluent amounts and water quality have not been maintained since that time in sufficient detail to perform a rigorous validation of flow and transport in the unconfined aquifer.

F.4.3.5 Parameter Sensitivity

Parameter sensitivity was investigated for the following areas:

- The effect of higher glass surface areas for the In Situ Vitrification alternative;
- The effect of changing the performance period of the Hanford Barrier from 1,000 to 500 years;
- The effect of the decay of the potentiometric head resulting from groundwater mounding due to discharge to the Hanford Site ponds;
- The effect of variations in filtration rate; and
- The effect of variations in distribution coefficient (K_d).

The approach and conclusion from these investigations are provided in Volume Five, Appendix K.

F.4.4 MODELING ASSUMPTIONS AND UNCERTAINTIES

This appendix provides the basis of potential groundwater impacts associated with each of the TWRS alternatives. Developing the groundwater assessments provided in this appendix required several assumptions to uncertainties of some of the data. The major assumptions and uncertainties are related to either the natural system (i.e., an understanding and ability to assign vadose zone and aquifer parameter values) or uncertainties inherent to the assessment approach.

The most important assumptions and uncertainties are as follows:

- The rates of infiltration into natural ground and through a cap;
- Distribution coefficient (K_d) of contaminants;
- Uncertainty in future groundwater flow direction due to decay of groundwater mounds onsite;
- Uncertainty in future groundwater flow direction and vadose zone thickness due to climate change;
- Uncertainty in vadose zone transport due to use of one-dimensional flow and transport simulation; and
- Uncertainty due to calculation of releases during retrieval.

The basis for these assumptions and their potential impact on the alternatives is provided in Volume Five, Appendix K.

F.4.5 CONCEPTUAL GROUNDWATER CUMULATIVE IMPACTS

This section addresses potential cumulative groundwater impacts of other past and projected future waste disposal activities. The activities that may have a cumulative impact on the TWRS alternatives are as follows:

- Past-practice waste disposed of to the ground as liquid;
- Past leaks from waste tanks;
- Past-practice waste disposed of to the ground as solid;
- Solid low-level radioactive waste to be disposed of in the Environmental Restoration Disposal Facility (ERDF);
- Solid low-level radioactive waste to be disposed of in the 200 West Area burial grounds; and
- Solid low-level radioactive waste to be disposed of in the US Ecology burial grounds.

These activities result in both near-term and long-term groundwater impacts. The near-term impacts are in response to past-practice liquid waste disposal to the ground. Large volumes, over 1.29E+12 L (3.40E+11 gal) in the 200 Areas, containing radionuclides and hazardous chemicals have been discharged to the ground surface or subsurface since 1944 (Wodrich 1991). Long-term groundwater impacts are associated with 1) leaching of solid waste disposed of to the ground in the 200 Areas and on the Central Plateau (Wood et al. 1995), and with 2) the relatively low-volume leaks from the waste tanks, as compared with volumes discharged to cribs and ponds. It is assumed that all of these disposal activities, except for the past-practice liquid disposal, would have some cumulative impact with respect to the TWRS activities. Quantitative information, such as would be developed for a performance assessment, on the fate of current contaminant plumes resulting from past-practice liquid waste disposal is not available; however, the following discussion suggests these contaminants will not interact with groundwater contaminant plumes associated with the TWRS alternatives.

Potential cumulative impacts with respect to contaminants C-14, I-129, Tc-99, and uranium are provided in the following sections for each of the solid waste disposal facilities. These contaminants were chosen for comparison because they have high mobility in the Hanford vadose zone and groundwater, have been routinely monitored in the groundwater, and have been identified as contributing much of the tank waste-related risk.

F.4.5.1 Past-Practice Liquid Waste Disposal

Liquid waste disposal has resulted in extensive groundwater contamination in the 200 Areas as well as downgradient toward the Columbia River. Information on specific contaminants disposed of to ground surface or subsurface is limited to only a few key constituents including nitrate and radionuclides with half-lives greater than 10 years and in quantities large enough to be of concern in waste disposal and cleanup (Wodrich 1991). These radionuclides are Sr-90/Y-90, Cs-137, Tc-99, I-129, uranium, Am-241, and plutonium. Table F.4.5.1 provides a comparison of the inventories estimated for the past-practice liquid and solid waste disposal, past waste tank leaks, and TWRS tank waste. Quantitative estimates of contaminant concentration in groundwater with an acceptable degree of uncertainty from past-practice liquid waste disposal activities are not possible using available information. Key information that is not available includes definition of the multiple source terms (e.g., waste volume, contaminant concentration, release duration) and residual waste remaining in the vadose zone. A semi-quantitative approach coupled with some qualitative assumptions is used because of these limitations.

The past-practice liquid waste disposal impacts on groundwater are believed to be ongoing and would be greatly reduced by the time the TWRS alternatives would potentially impact groundwater. Thus, they are considered near-term impacts. These conclusions are based on several assumptions and on observations of groundwater contaminant concentration trends discussed later in this section. The assumptions are as follows:

- Present groundwater contaminants, concentration levels, and distribution in the 200 Areas and downgradient are a result of the past-practice liquid disposal in the 200 Areas.
- All liquid waste disposal to the ground at previously used waste disposal facilities (e.g., cribs, trenches, drains, and reverse wells) has been stopped or will be stopped by the year 2000.
- There will be no new ground disposal of radioactive or hazardous chemical-containing liquids, except for tritium.
- The remediation alternative for the past-practice liquid waste disposal sites will be installation of caps by the year 2005.
- Less mobile contaminants in the past-practice liquid waste may contribute to the cumulative impact but are not considered at this time.

Given these assumptions, the present concentrations of highly mobile contaminants in groundwater such as tritium, Tc-99, I-129, nitrate, and to a lesser extent, uranium currently would be experiencing a large reduction in concentration that would continue for less than 10 years, followed by many years where the contaminant concentration in groundwater diminishes at a much slower rate. Change in uranium concentrations in well 299-W19-18 is an example of this process. This well is located in the 200 West Area adjacent to the inactive 216-U-1 and 216-U-2 cribs. The uranium concentration in this well has reduced at a uniform rate of approximately 3,000 μg/L for a 2 to 3-year period since remediation of the cribs in 1988 (Woodruff-Hanf 1993). By the end of 1992, the uranium concentration in this well was approximately 750 μg/L and the rate of reduction had dropped to approximately 80 ug/L/yr. The rate of concentration reduction is expected to continue to decline but at a very slow rate such that the uranium concentration at this well would appear to become constant at some low level. This level is not known and is assumed to be inconsequential by the time contaminants from the tanks arrive at the groundwater. This early reduction in concentration also is observed for tritium in observation well 699-24-33 (Woodruff-Hanf 1993).

In the performance assessment for the low-level waste burial grounds in the 200 West Area (Wood et al. 1995), it is concluded that mixing of the present day plume with that from the burial grounds is unlikely. These burial grounds include disposal sites with and without caps, thus times to peak groundwater contaminant concentrations range from approximately 125 to 1,000 years from present. The performance assessment presents the following discussion to support this conclusion. First, the particle velocity in the unconfined aquifer, on the order of 10 m/yr, would result in the migration of the present plume a few hundred meters over a few decades (Wood et al. 1995). Secondly, additional plume generation is unlikely because liquid discharge nearly has ceased, and it is likely that only very small quantities of the mobile radionuclides such as Tc-99, C-14, and I-129 remain in the present soil

column. Other less mobile radionuclides are present in the soil column. They are believed to be short-lived (Wood et al. 1995) and would decay to inconsequential quantities before reaching the unconfined aquifer.

Of all the TWRS alternatives, the No Action and Long-Term Management alternatives have the earliest potential groundwater impact. First arrival of contaminants to the groundwater has been estimated to occur at about 140 years for these alternatives. Estimated first arrival of contaminants to groundwater for the other alternatives ranges from approximately 1,070 years for the ex situ alternatives to 2,330 years for the in situ alternatives. Cumulative impacts with respect to past-practice liquid disposal likely would be very low for the ex situ and in situ alternatives and, with a larger degree of uncertainty, is assumed to be very low for the No Action and Long-Term Management alternatives.

F.4.5.2 Past Leaks From the Single-Shell Tanks

Liquid waste from past tank leaks has resulted in vadose zone contamination beneath the leaking tanks and may be impacting the groundwater in the vicinity of the tanks. Potential groundwater impacts are currently being investigated as part of Resource Conservation and Recovery Act (RCRA) Groundwater Assessments for the T Farm Waste Management Area and will be ongoing soon for the S-SX and B-BX-BY Waste Management Areas.

Past SST tank leaks are considered to result in long-term groundwater impacts (compared to impacts from liquid waste disposal discussed in Section F.4.5.1) because the leak volume was, for the most part, insufficient to immediately flush the contaminants all the way through the vadose zone and into the underlying groundwater. Under current conditions (e.g., no cap over the tanks), impacts to the underlying groundwater are expected to occur over a period similar to that predicted for the No Action alternative, which is approximately 300 years. Groundwater impacts from past tank leaks would be expected to begin soon and may already be occurring because contaminants from the leaks are likely distributed vertically in the vadose zone from the tank bottoms to near the water table. A bounding approach is used to the extent practicable to estimate potential impacts from past waste tank leaks. The leak volume is taken as the upper range of the cumulative leak volume as provided in the inventory and surveillance reports (Hanlon 1996). The release to the groundwater is assumed to be analogous to release to the groundwater in the No Action alternative. Provided in the following discussion are the estimated leak volume, radioisotope content of the leaks, and the potential impact of the leaks on groundwater.

Leak monitoring is ongoing for the 177 waste tanks, and reports on waste inventory and surveillance are released monthly and quarterly. The report for the month ending February 29, 1996 (Hanlon 1996) indicates that 67 of the 149 SSTs are assumed leakers. There are no reported leaks from the 28 DSTs. The tank identification number, date tank was declared leaker, estimated leak volume, estimated activity of leak, and date the tank was stabilized are provided in Table F.4.5.2. The range of leak volume is from approximately 1,300 L (350 gal) from tank 241-C-204 in the 200 East Area to 436,000 L (115,000 gal) from tank 241-T-106 in the 200 West Area. Total leak volume from all 67 assumed

leakers ranges from 2.30E+06 to 3.4E+06 L (600,000 to 900,000 gal). Interim stabilization has been completed on all but five assumed leaking tanks.

The monthly tank waste and surveillance reports (Hanlon 1996) provide a estimated range of Cs-137 associated with the waste tank leaks. However, quantitative estimates of radioisotopes such as Tc-99, C-14, I-129, and U-238 in the liquids that leaked from the waste tanks are not available. The activities of Tc-99 and uranium (assumed to be U-238) isotopes that would have been released with the tank leaks were estimated based on the total and isotopic activity of liquid waste disposal in the 200 Areas (including waste tank leaks) (Wodrich 1991). These estimates, provided in Table F.4.5.2, include an upward adjustment to account for the upper bound of leak volume of 3.4E+06 L (900,000 gal). (Hanlon 1996). The amount or activity of nitrate and C-14, respectively, was estimated based on the 3.4E+06 L (900,000 gal) cumulative leak volume and the concentration of each contaminant in the tanks as shown on Table F.2.2.14. Nitrate is assumed to have a concentration of 3.6E+02 g/L in all the tanks. The concentration of C-14 varies from tank to tank, therefore, the maximum concentration in any one SST source area was used, which was 6.74E-05 g/L in source area 2ESS. The estimated past leak quantities for these constituents are provided in Table F.4.5.2.

The potential impacts to groundwater are provided for waste tank leaks in terms of maximum potential concentration of four critical isotopes. These estimated values are provided in Table F.4.5.3. The estimated maximum concentrations of the selected contaminants in groundwater range from approximately 1 percent (for nitrate) to 25 percent (for U-238) of the maximum predicted values for the No Action alternative.

F.4.5.3 Past-Practice Solid Waste Disposal

Quantitative estimates of contaminant concentration in groundwater with an acceptable degree of uncertainty from past-practice solid waste disposal activities is not possible with the present available information. As with past-practice liquid waste disposal, key information not available includes definition of the multiple source terms (e.g., waste volume, contaminant concentration, release duration). A semi-quantitative approach is used because of these limitations.

The approach is based on the premise that the potential impacts from the In Situ Fill and Cap alternative can be used as an analog for estimating impacts from past-practice solid waste disposal. This estimate is conservative given the following major assumptions.

- The remediation alternative for the past-practice solid waste disposal sites will be installation of caps by the year 2005.
- The inventory of past-practice solid waste is in proportion to the distribution of waste in the tanks.

Contaminants from past-practice solid waste disposal would be expected to reach the groundwater at approximately the same time as contaminants from the In Situ Fill and Cap alternative, given the previous assumptions. Based on the ratio of estimated past-practice solid waste disposed to waste in tanks for C-14 and uranium (Table F.4.5.2), a factor of 1.2 is used to adjust the calculated groundwater

concentrations upward from the In Situ Fill and Cap alternative. This is a semi-quantitative approximation of the potential impacts of the past-practice solid waste disposal. Table F.4.5.3 provides the potential maximum groundwater concentrations for Tc-99, I-129, C-14, and uranium. Maximum groundwater impacts of the past-practice solid waste disposal activities would occur at approximately 5,000 years based on the In Situ Fill and Cap alternative analog.

F.4.5.4 Solid Low-Level Radioactive Waste Disposal in the Environmental Restoration Disposal Facility

The proposed ERDF is a deep-lined trench disposal facility for the waste generated by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 cleanup activities. The ERDF will be located adjacent to the southwest corner of the 200 West Area. The waste will be disposed of primarily in bulk noncontainerized form and is anticipated to consist primarily of contaminated soils and concrete rubble (Wood et al. 1995a). There are currently two principal documents that provide calculated groundwater dose information: the Remedial Investigation and Feasibility Report for the Environmental Restoration Disposal Facility (DOE 1994h) and the Environmental Restoration Disposal Facility Performance Assessment (Wood et al. 1995a).
The performance assessment (PA) was used herein as the basis for potential ERDF inventory and groundwater contaminant concentrations because the approach taken in the PA is similar to that used to calculate groundwater impacts from the TWRS waste tanks.

The projected ERDF inventory for Tc-99, I-129, C-14, and uranium is provided in Table F.4.5.2 (Wood et al. 1995a). The PA provides calculated groundwater drinking dose estimates for these radionuclides based on consumption of 730 L/yr (193 gal/yr). The maximum groundwater concentration for these radionuclides is calculated from the maximum dose using the drinking water consumption rate assumed in the PA and the DOE internal dose factor (Wood et al. 1995a).

Using Tc-99 as an example, the maximum groundwater concentration is calculated as follows.
The reported maximum drinking water dose is 0.007 mrem/yr (Wood et al. 1995a) and the DOE internal dose factor for Tc-99 is 1.3E-06 mrem/pCi (Wood et al. 1995a). The maximum groundwater concentration of Tc-99 is calculated by dividing the reported maximum dose of 0.007 mrem/yr by the consumption rate of 730 L/yr (193 gal/yr) and the internal dose factor of 1.3E-06 mrem/pCi. This results in a maximum Tc-99 concentration in groundwater of 7.38 pCi/L. This maximum concentration would occur at approximately 1,500 years from present, assuming a K_d of zero and infiltration rate of 0.5 cm/yr (0.2 in./yr) (Wood et al. 1995a). Calculated maximum groundwater concentrations for Tc-99, I-129, C-14, and uranium are provided in Table F.4.5.3.

F.4.5.5 Solid Low-Level Radioactive Waste Disposal in the 200 West Burial Grounds

The 200 West low-level waste burial grounds consist of shallow (5 to 10 m deep [16 to 33 ft]), unlined trenches of variable widths (3 to 10 m wide [10 to 33 ft]), and lengths (50 to 100 m long [160 to 330 ft]). Potential groundwater impacts have been calculated in the Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds (Wood et al. 1995).
This performance assessment examines the potential groundwater impacts from disposal of waste in two

different facility types. The first, called a Category 1 waste facility, is assumed to have no functional barriers (e.g., cap) and is intended to contain very low concentrations of radionuclides. The other facility is called a Category 3 waste facility and is assumed to have a cap that controls infiltration to the same degree as the natural soil and vegetative system (Wood et al. 1995). Radionuclide inventory for each waste category is provided in Table F.4.5.2.

The maximum groundwater contaminant concentration for Tc-99, I-129, C-14, and uranium was calculated as described in Section F.4.5.3 and is provided in Table F.4.5.3.

F.4.5.6 Solid Low-Level Radioactive Waste Disposal in the US Ecology Burial Grounds

The US Ecology Burial Grounds is a commercial low-level waste disposal facility located on the Central Plateau just southwest of the 200 East Area and approximately 4 km (2.5 mi) east of the 200 West Area. Radionuclide inventory and maximum groundwater concentrations for Tc-99, I-129, C-14, and uranium were estimated for the US Ecology site at closure (Jacobs 1996). These values are based on preliminary estimates of future solid radioactive waste emplacement at the site. The estimates assume closure of the facility in about the year 2063. The inventory and maximum groundwater concentrations are provided in Tables F.4.5.2. and F.4.5.3, respectively.

F.4.6 Groundwater Impacts for Nominal Case

The preparation of the groundwater impacts assessment required numerous assumptions concerning not only the subsurface conditions that affect fate and transport through the vadose zone and unconfined aquifer but also the contents of the waste tanks and the release of waste during remediation. Bounding assumptions were used that would result in calculations of impacts than would be conservative compared to impact results based on average or nominal assumptions. This section provides calculated groundwater impacts for nominal estimates of waste tank releases for a scenario modified from the Ex Situ Intermediate Separations alternative. All other approaches and assumptions relative to fate and transport in the vadose zone and groundwater are the same as were used for calculating the groundwater impacts for the Ex Situ Intermediate Separation alternative summarized in Section F.3.5.

F.4.6.1 Nominal Case Source Term

The source term for this scenario is a result of releases from SSTs during waste retrieval, releases from the residuals in SSTs and DSTs, and releases from the LAW vaults. Only the long-term mobile risk contributing contaminants are considered for this scenario. These contaminants are I-129, C-14, Tc-99, and U-238. The grouping of these contaminants is the same for the base case Ex Situ Intermediate alternative scenario except for Np-237. The base-case Ex Situ Intermediate Separations alternative includes Np-237 with the above group of long-term mobile risk contributing contaminants. There is a large uncertainty surrounding the mobility of Np-237 in the Hanford Site vadose zone and unconfined aquifer and for the bounding impact analyses, it was conservatively placed in K_d group 1 ($K_d = 0$), which means that Np-237 would move at the same rate as the water in the vadose zone and underlying aquifer. For the nominal case scenario, Np-237 is assumed to have a K_d of 1 mL/g. In the following, a discussion of each of the three potential sources for the nominal case scenario is provided.

Released During Waste Retrieval

As with the bounding scenario for the Ex Situ Intermediate Separations alternative, retrieval releases only occur from the SSTs. The DSTs are assumed to have no releases during retrieval. Retrieval occurs over a 15-year period and the work is assumed to be ongoing at all eight of the source areas during this period. The infiltration scenario is the same as that assumed for the Ex Situ Intermediate Separations alternative, where it would decrease to 0.5 cm/yr (1.36E-05 m/day) for a 29-year period (15-year period of waste retrieval followed by a construction period or 14-years) from 5.0 cm/yr (1.36E-04 m/day). Infiltration through the Hanford Barrier at the end of construction is assumed to be 0.05 cm/yr (1.36E-06 m/day) for a 1,000-year period. It is assumed to double to 0.10 cm/yr (2.74E-06 m/day) after the 1,000-year period and remain at that level for the remainder of the period of interest.

The assumed release volume of 15,000 L (4,000 gal) per SST is retained for this scenario. For the nominal case, the contaminant concentration in the retrieval releases is two-thirds of the concentrations assumed for the Ex Situ Intermediate Separations alternative. The contaminants released during retrieval, their estimated mass and concentrations are provided in Tables F.4.6.1 and F.4.6.2. For this analysis, only the long-term risk contributors Tc-99, I-129, C-14, and U-238 are considered.

Releases from Waste Tank Residuals

The bounding scenario for the Ex Situ Intermediate Separations alternative incorporates an assumption that 1 percent of initial total tank waste remains after retrieval as a residual. This assumption does not account for recovery of the more soluble constituents during hydraulic retrieval. For the nominal case scenario, mobile soluble constituents in the residual inventory for the base case Ex Situ Intermediate Separations alternative are reduced, based on sludge wash factors reported in WHC-EP-0616. The residual inventory, concentration, and duration of release for the long-term risk contributors are provided in Table F.4.6.3, F.4.6.4, and F.4.6.5, respectively.

Releases from the LAW vaults

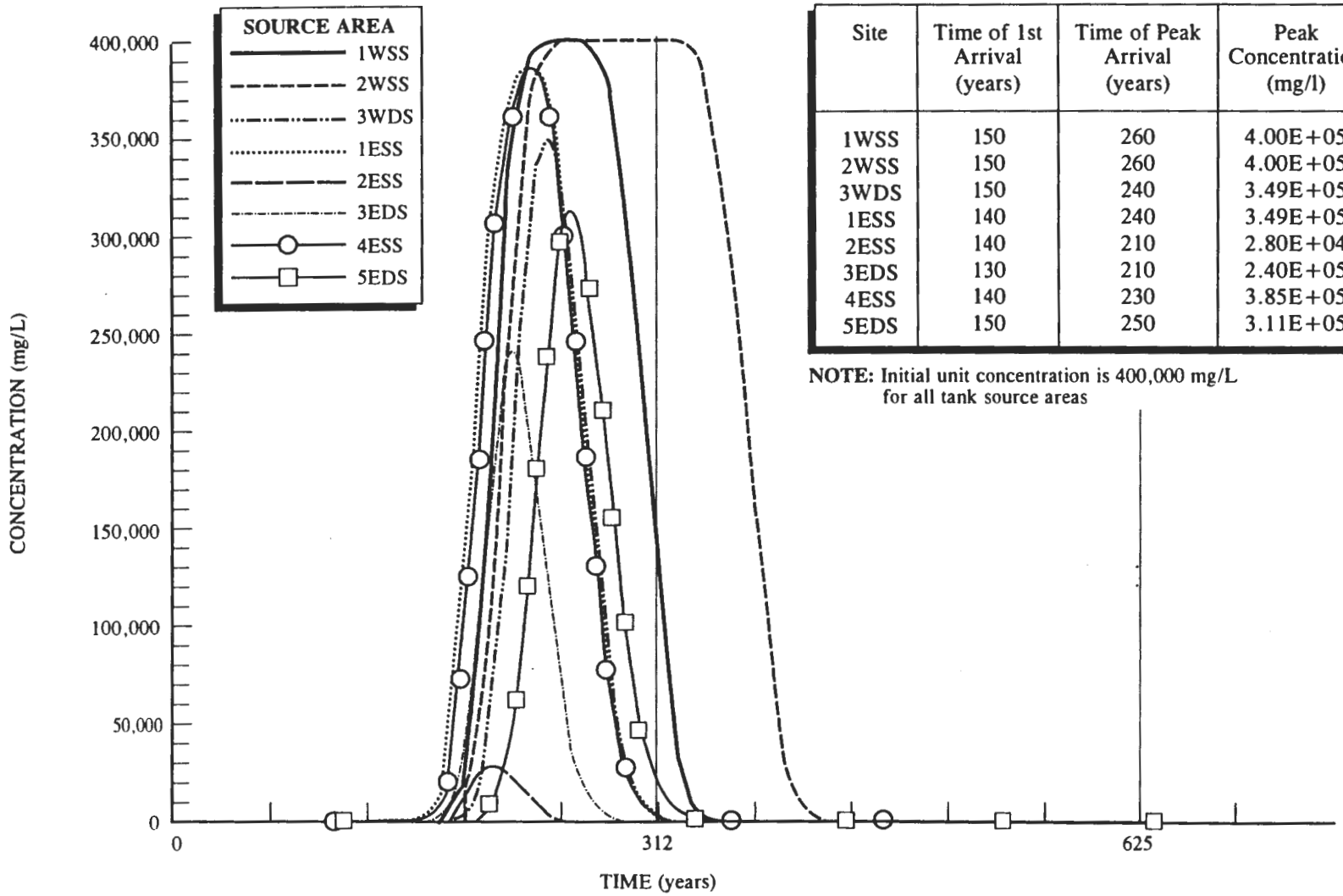
The releases from the LAW vaults for this scenario have not been modified from the bounding Ex Situ Intermediate Separations alternative because their contribution to overall risk in very small. The LAW vault inventory and initial contaminant concentrations are provided in Table F.2.2.6 and F.2.2.19, respectively.

F.4.6.2 Calculated Impacts for the Nominal Case Scenario

The calculated maximum contaminant concentrations from tank sources (i.e., waste released during retrieval from SSTs and residual waste released from SSTs and DSTs) are provided in Table F.4.6.5. Maximum calculated contaminant concentrations from the LAW vault sources are the same as were calculated for the Ex Situ Intermediate Separation Alternative LAW vault sources (Table 3.5.2).

The calculated concentrations from tank sources are lower than calculated concentrations for the Ex Situ Intermediate Separations alternative tank sources (Table F.3.5.1), as would be expected. Absent from this scenario is the impact of Np-237 because with a K_d of 1 mL/g, its movement in the vadose zone is sufficiently retarded such that it does not reach the unconfined aquifer within the 10,000-year period of interest. Provided in Volume Three, Appendix D, are the calculated risk values based on the nominal case groundwater concentrations.

Figure F.3.1.1 Predicted Contaminant Concentration for the No Action Alternative (K_d = 0) at the Vadose Zone/Groundwater Interface



Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Concentration (mg/l)
1WSS	150	260	4.00E+05
2WSS	150	260	4.00E+05
3WDS	150	240	3.49E+05
1ESS	140	240	3.49E+05
2ESS	140	210	2.80E+04
3EDS	130	210	2.40E+05
4ESS	140	230	3.85E+05
5EDS	150	250	3.11E+05

NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas

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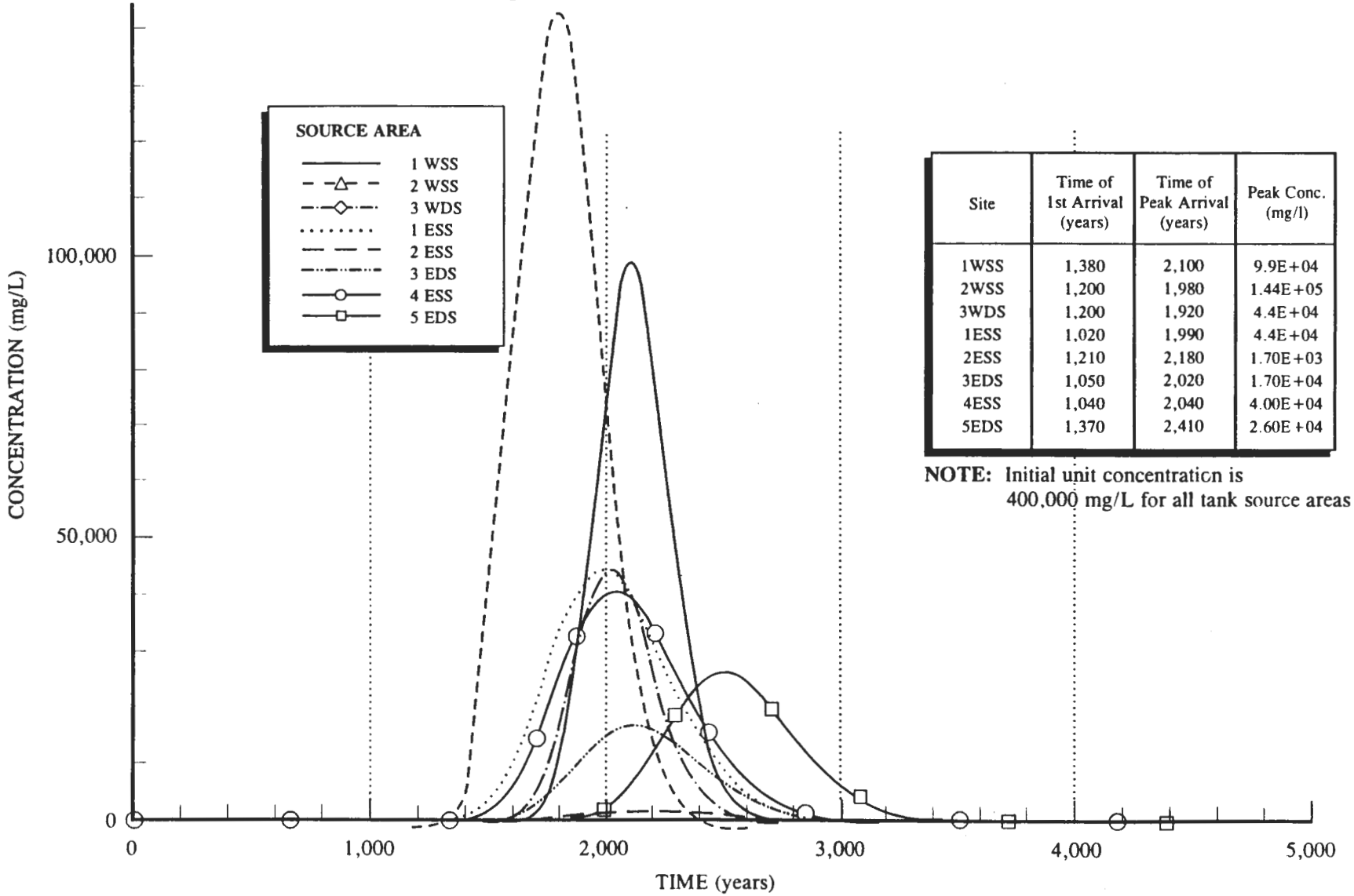
Figure F.3.1.2 Predicted Contaminant Concentration for the No Action Alternative (K_d=1) at the Vadose Zone/Groundwater Interface



Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Conc. (mg/l)
1WSS	1,380	2,100	9.9E+04
2WSS	1,200	1,980	1.44E+05
3WDS	1,200	1,920	4.4E+04
1ESS	1,020	1,990	4.4E+04
2ESS	1,210	2,180	1.70E+03
3EDS	1,050	2,020	1.70E+04
4ESS	1,040	2,040	4.00E+04
5EDS	1,370	2,410	2.60E+04

NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas

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Figure F.3.1.3 Predicted Nitrate Concentrations in Groundwater at 300 Years for the No Action Alternative

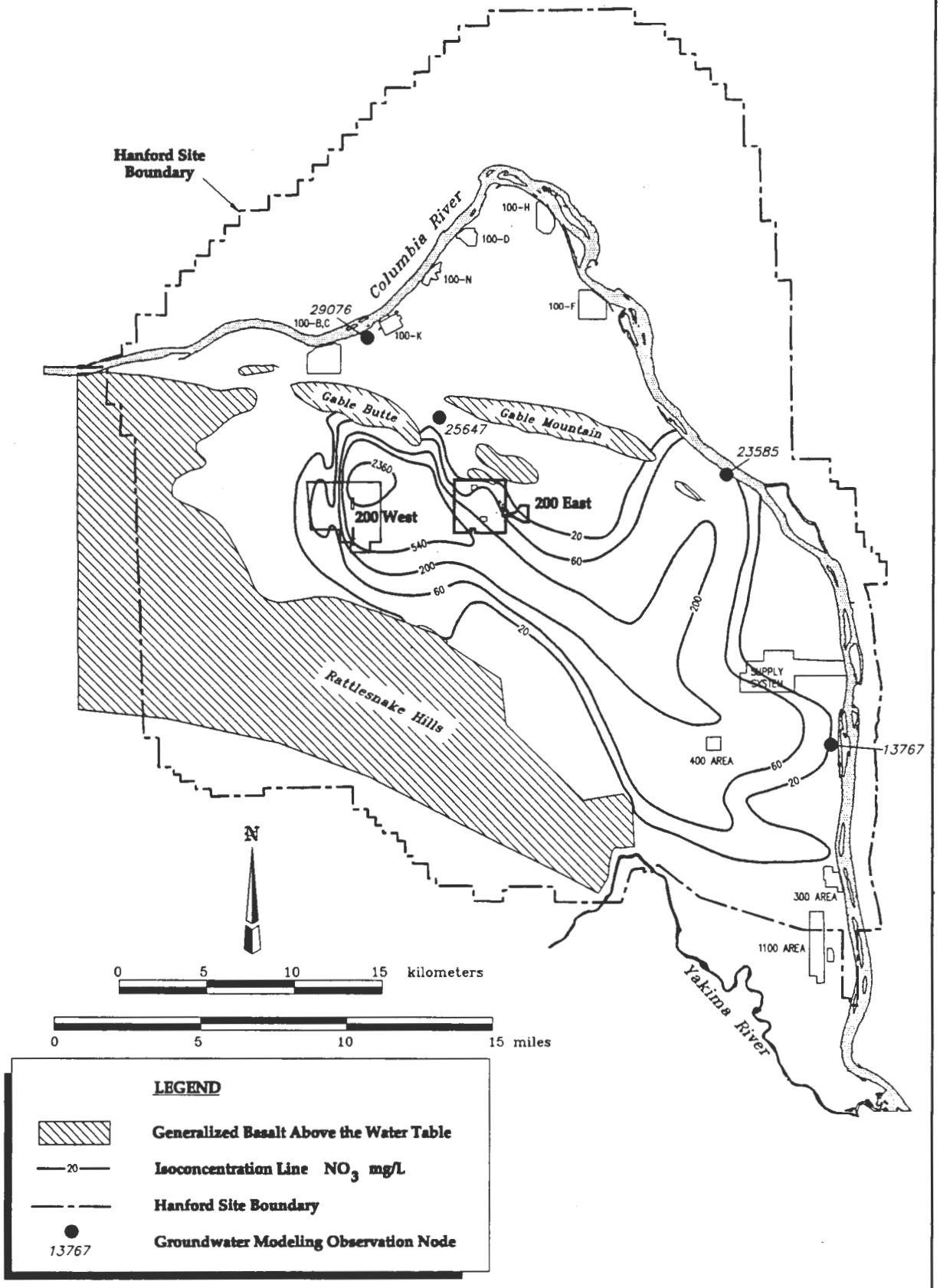
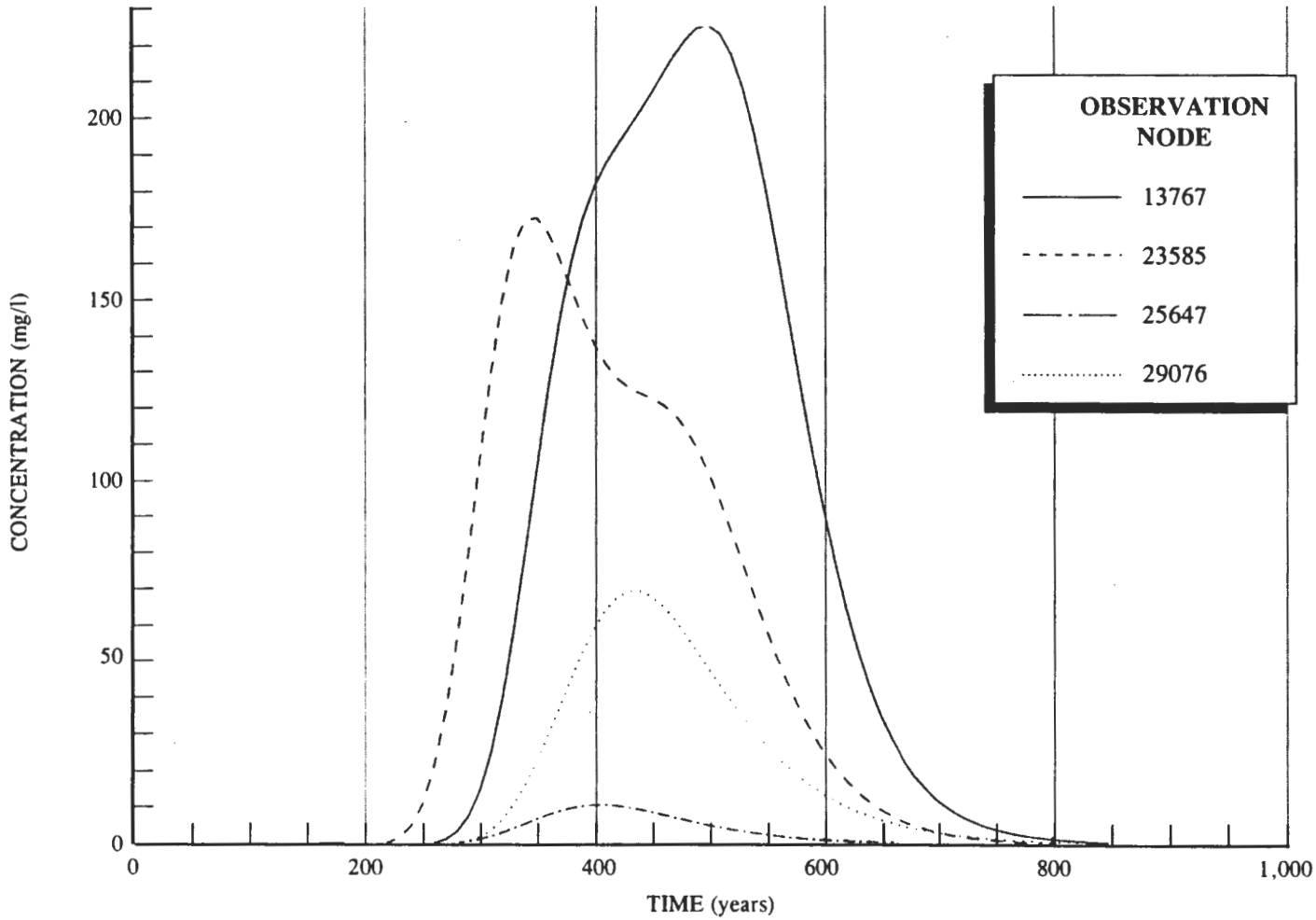


Figure F.3.1.4 Predicted Concentration of Nitrate in Groundwater at Selected Locations for the No Action Alternative (K_d = 0)



NOTE: See Figure F.3.1.3 for observation node locations

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Figure F.3.1.5 Predicted Bismuth Concentrations in Groundwater at 5,000 Years for the No Action Alternative

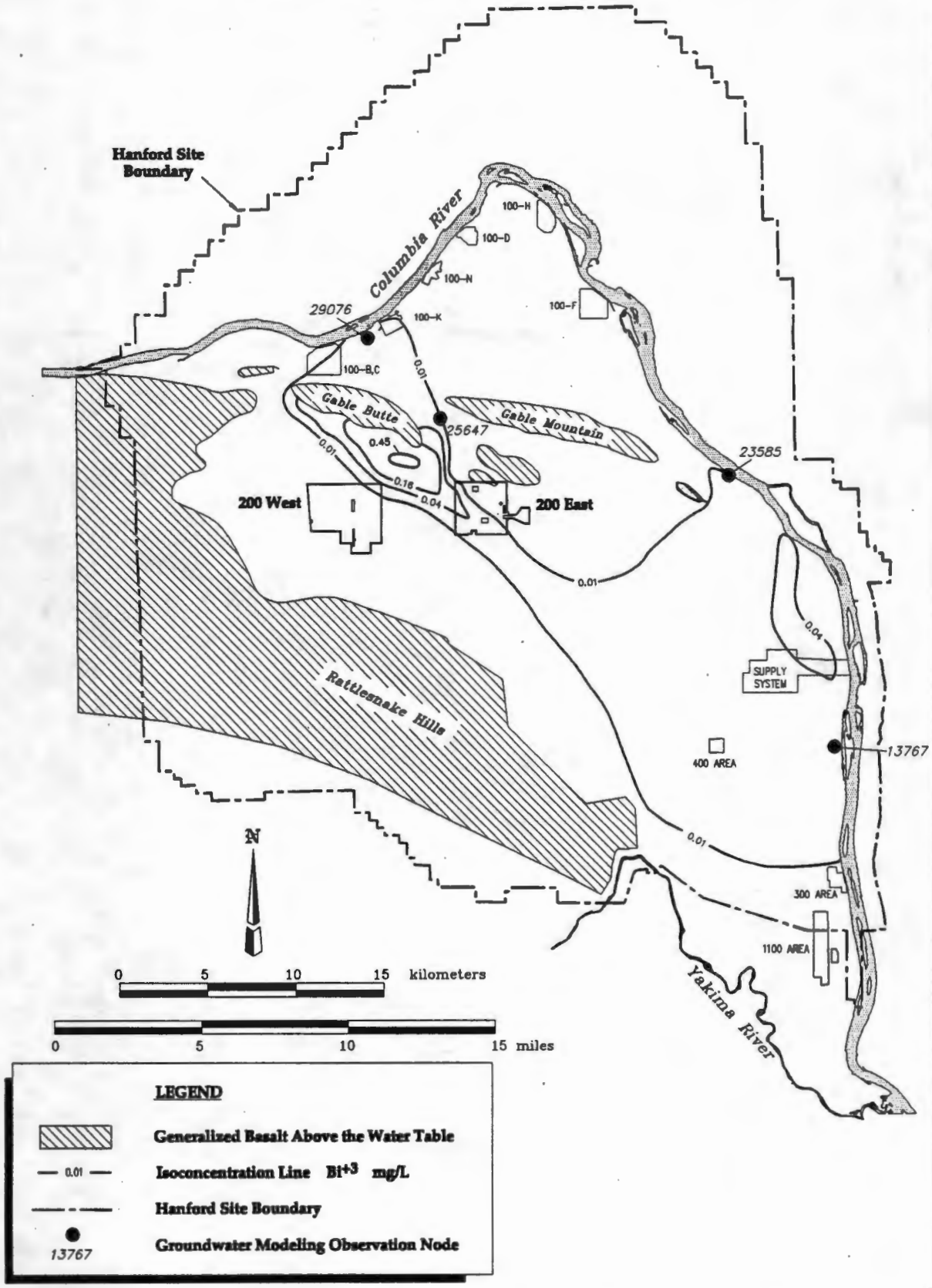
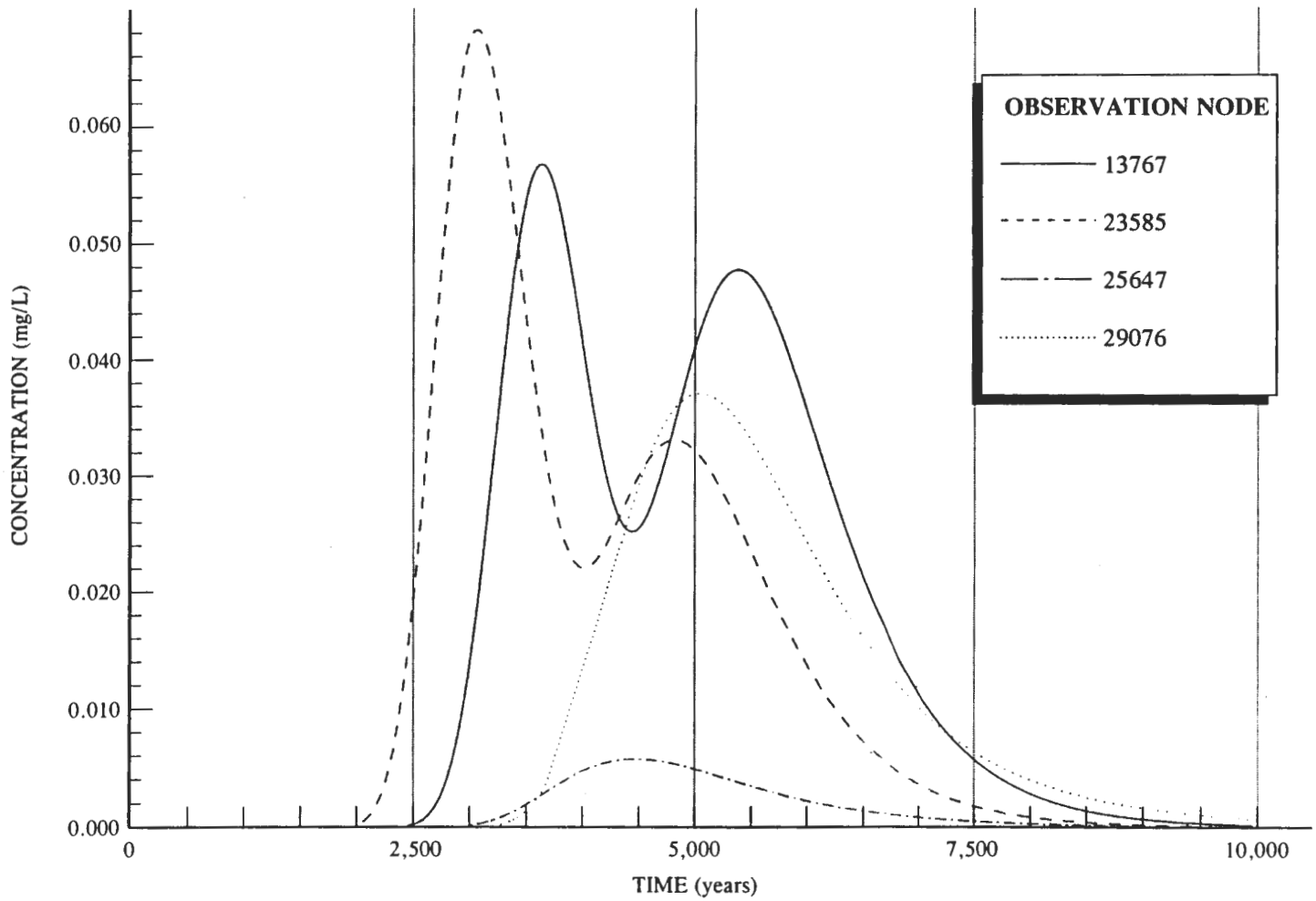


Figure F.3.1.6 Predicted Concentration of Bismuth in Groundwater at Selected Locations for the No Action Alternative (K_d = 1)



NOTE: See Figure F.3.1.5 for observation node locations

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Figure F.3.1.7 Predicted Technetium-99 Concentrations in Groundwater at 300 Years for the No Action Alternative

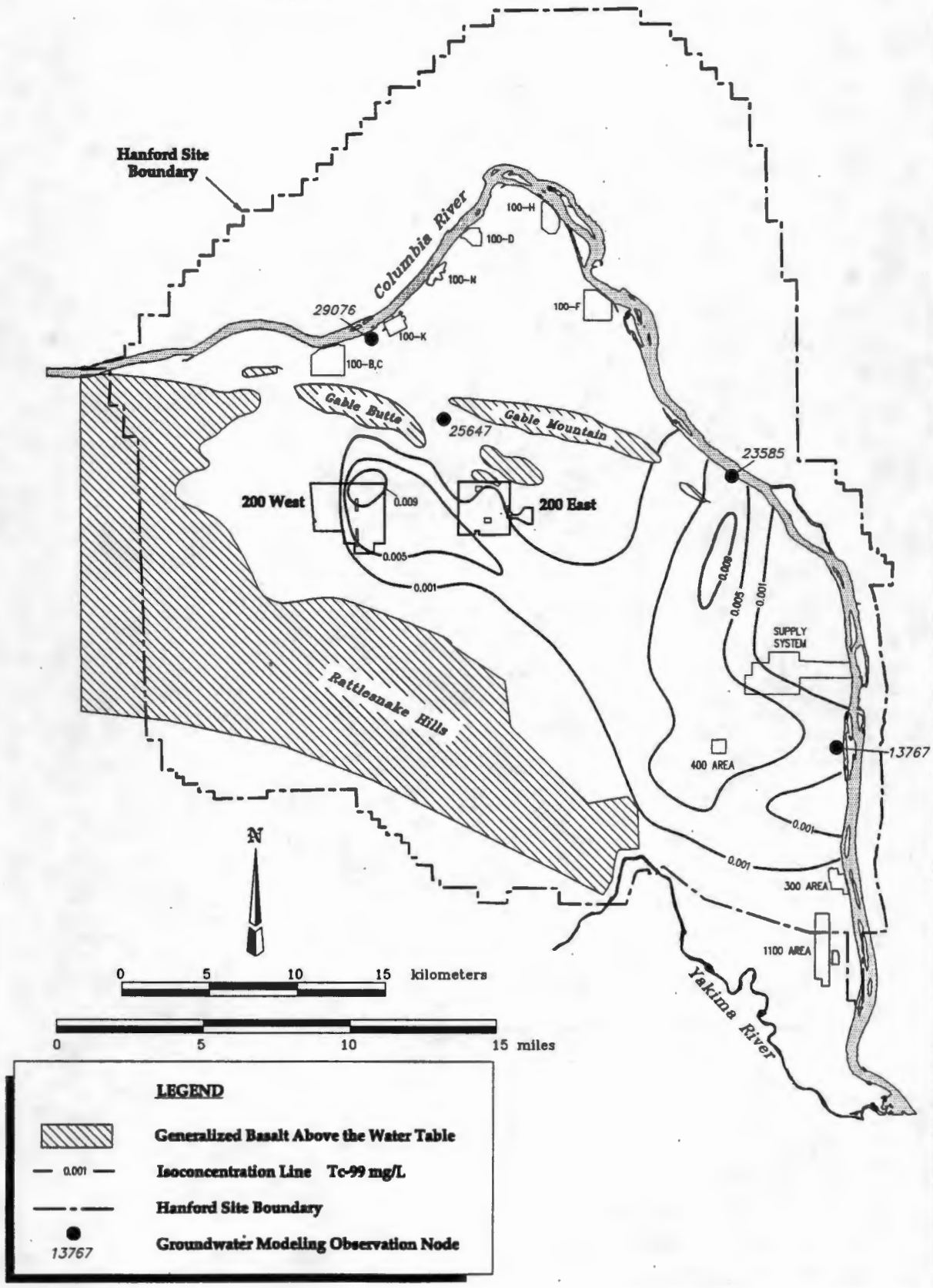

Figure F.3.1.8 Predicted Iodine-129 Concentrations in Groundwater at 300 Years for the No Action Alternative

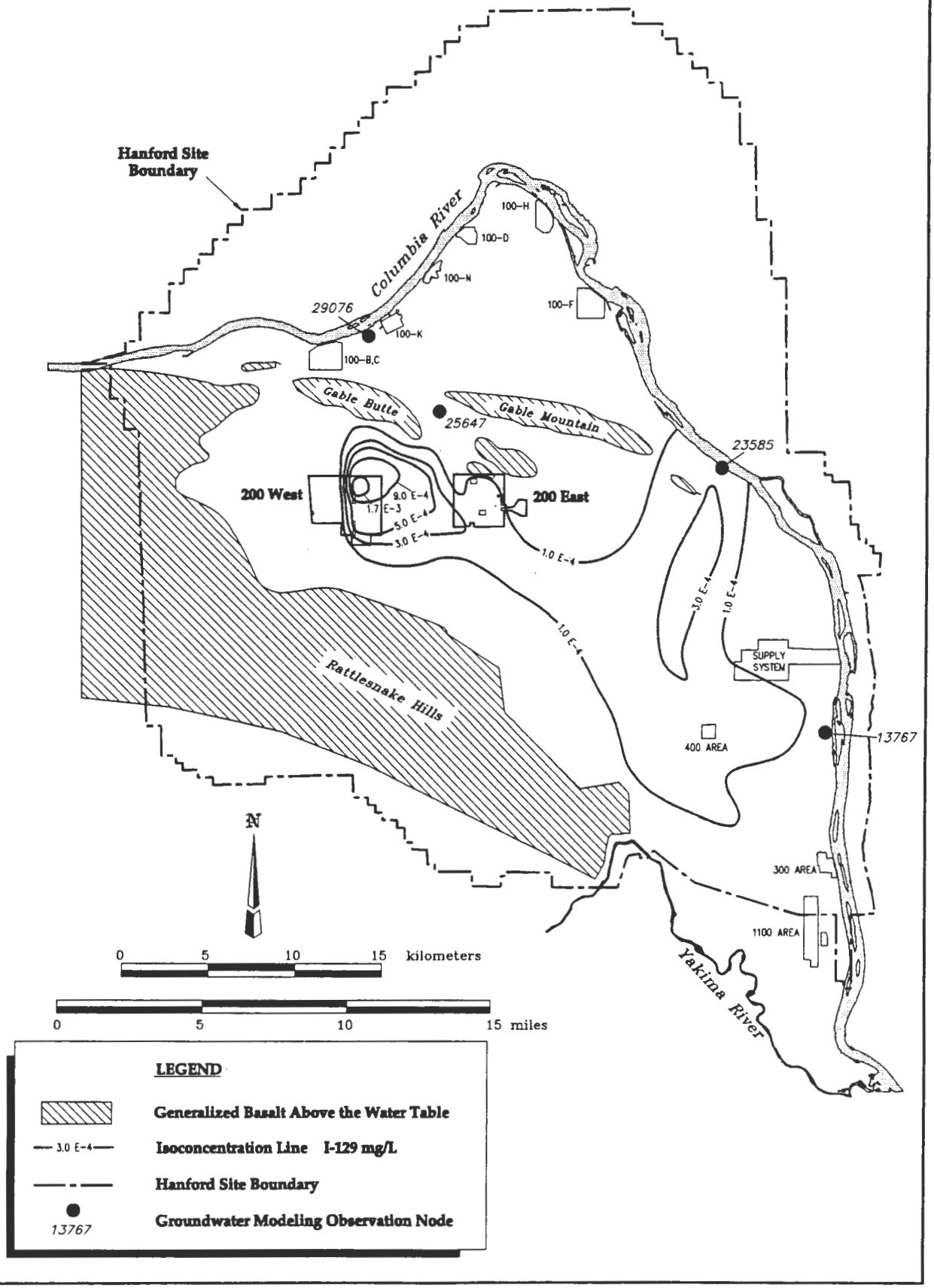

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Figure F.3.1.9 Predicted Carbon-14 Concentrations in Groundwater at 300 Years for the No Action Alternative

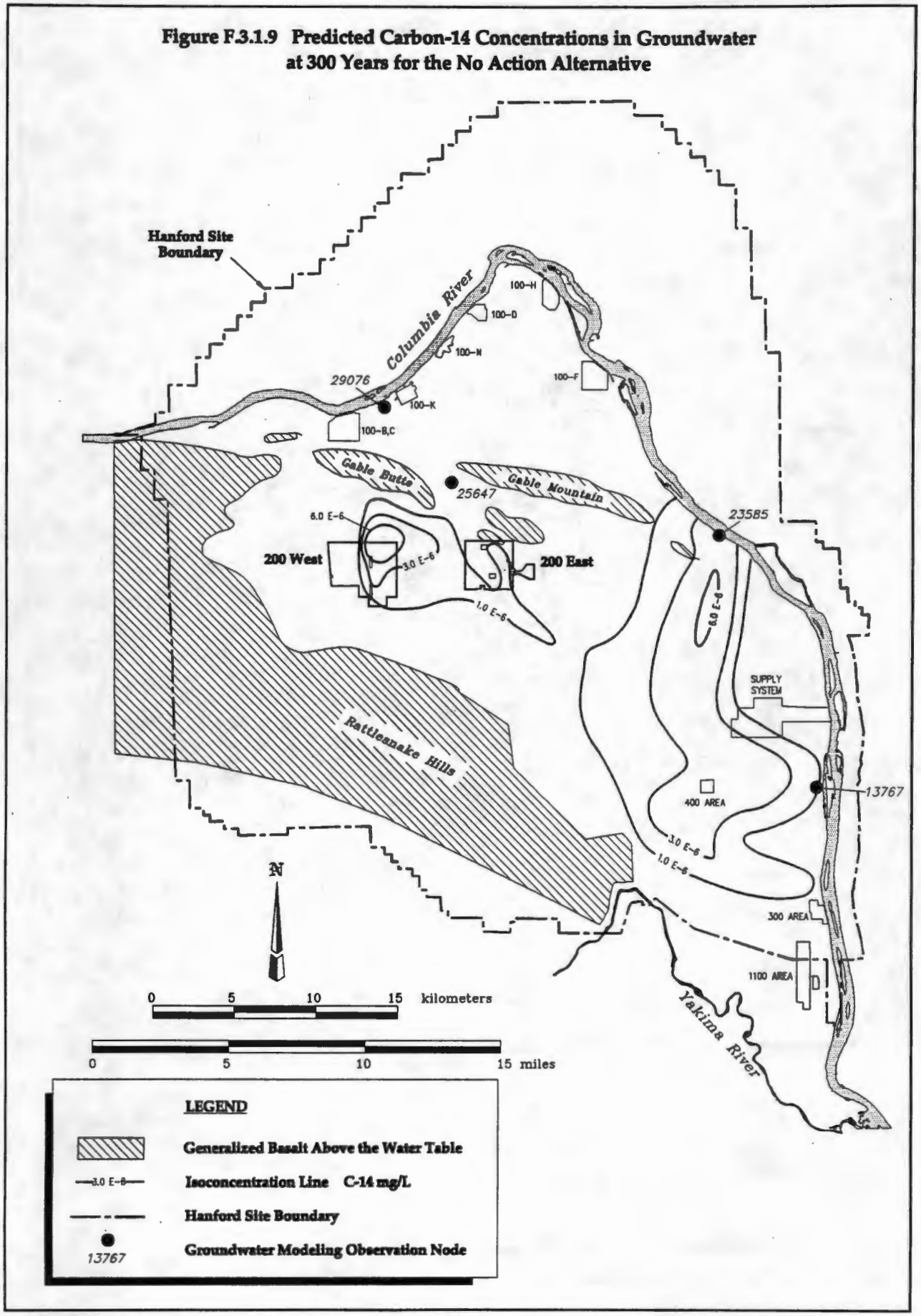

Figure F.3.1.10 Predicted Uranium-238 Concentrations in Groundwater at 300 Years for the No Action Alternative

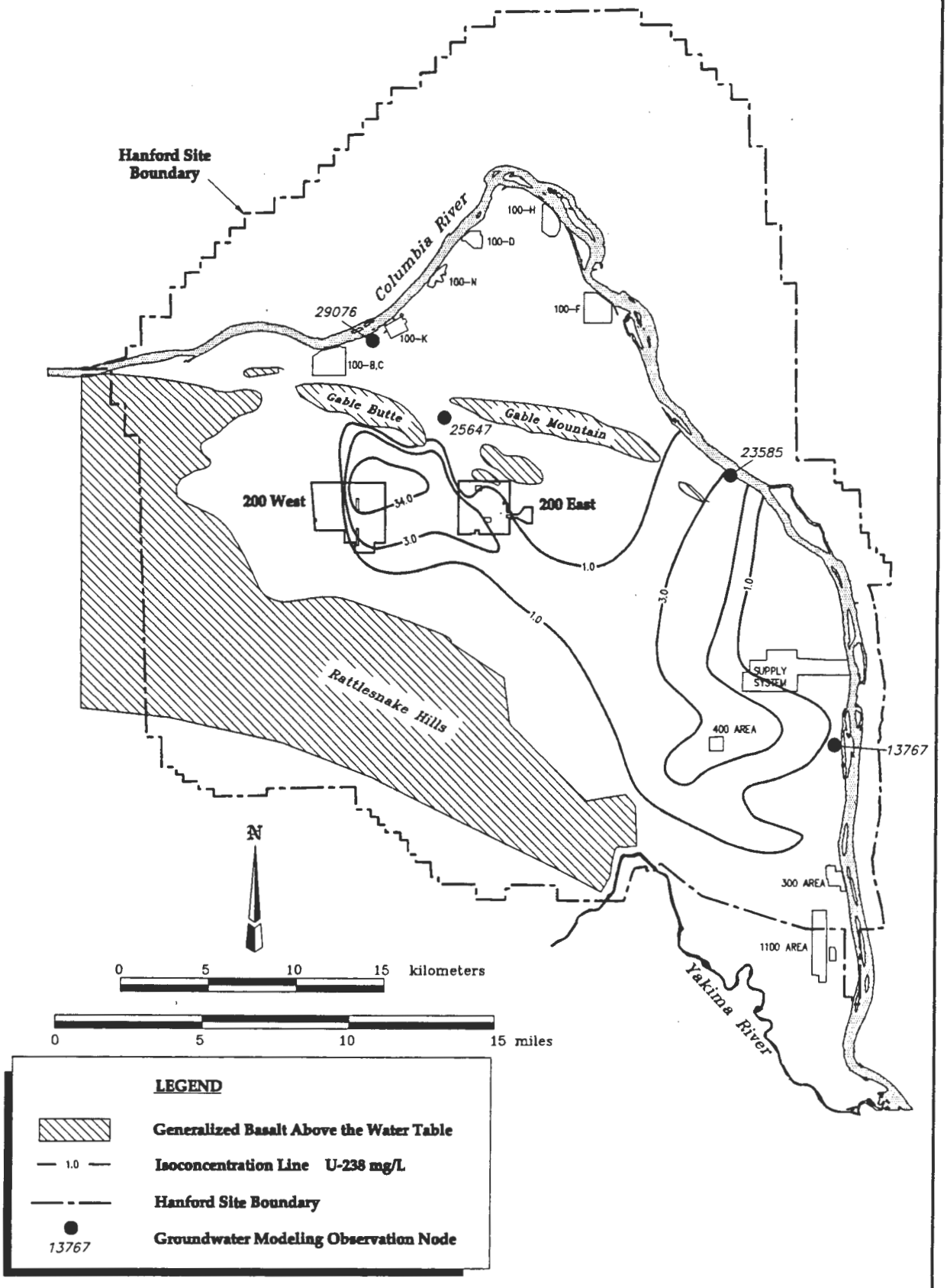

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Figure F.3.1.11 Predicted Technetium-99 Concentrations in Groundwater at 500 Years for the No Action Alternative

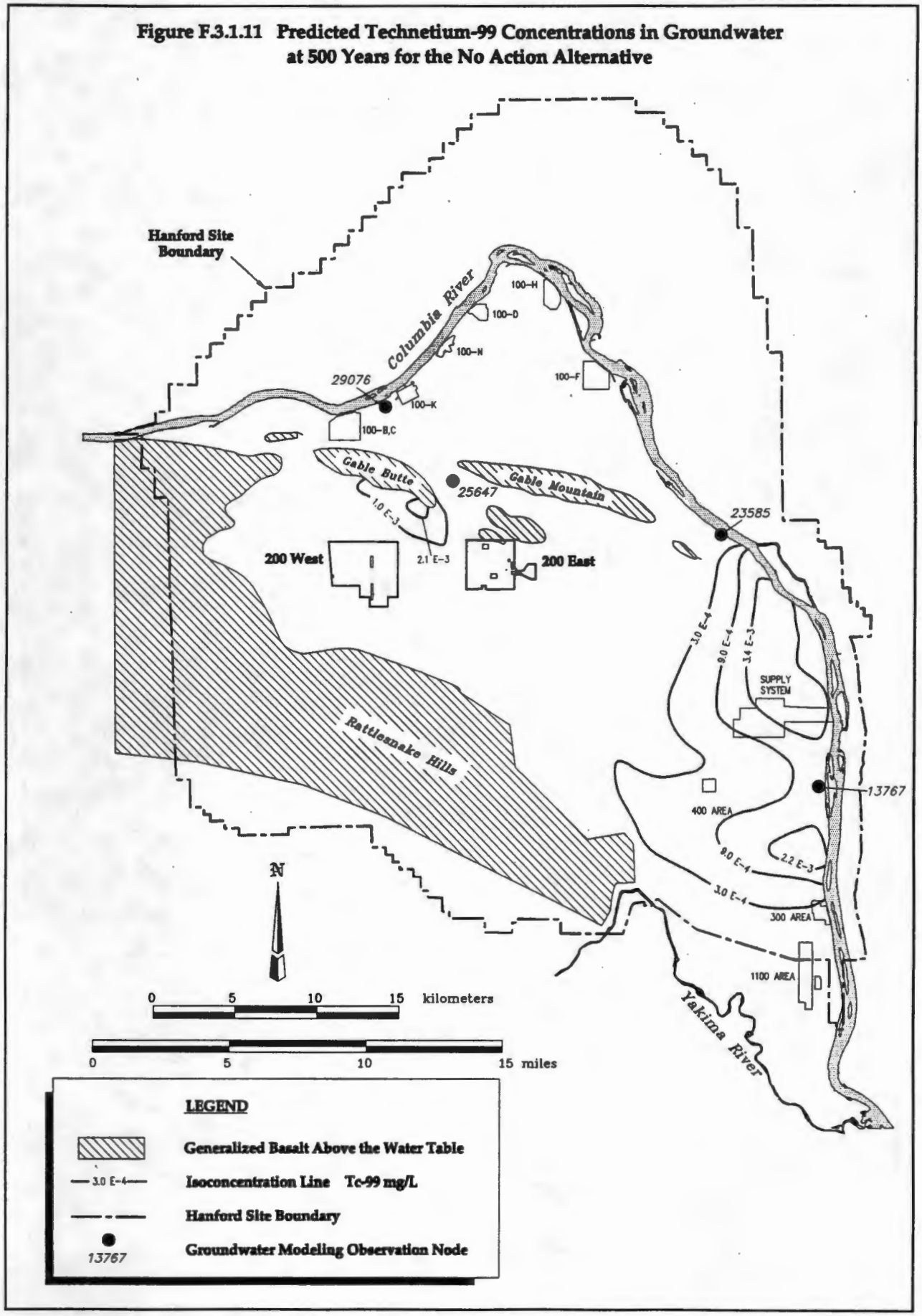

Figure F.3.1.12 Predicted Iodine-129 Concentrations in Groundwater at 500 Years for the No Action Alternative

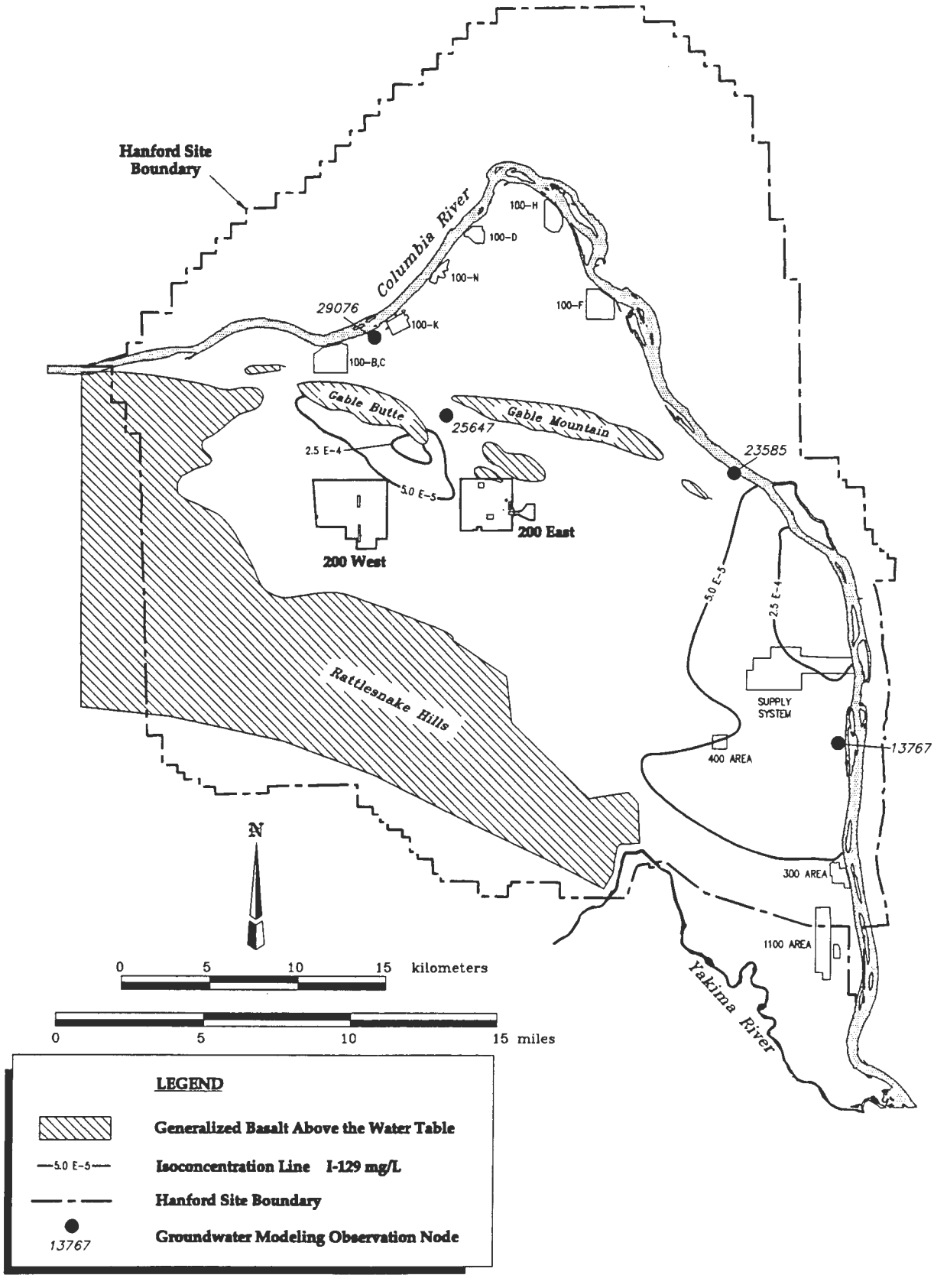

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Figure F.3.1.13 Predicted Carbon-14 Concentrations in Groundwater at 500 Years for the No Action Alternative

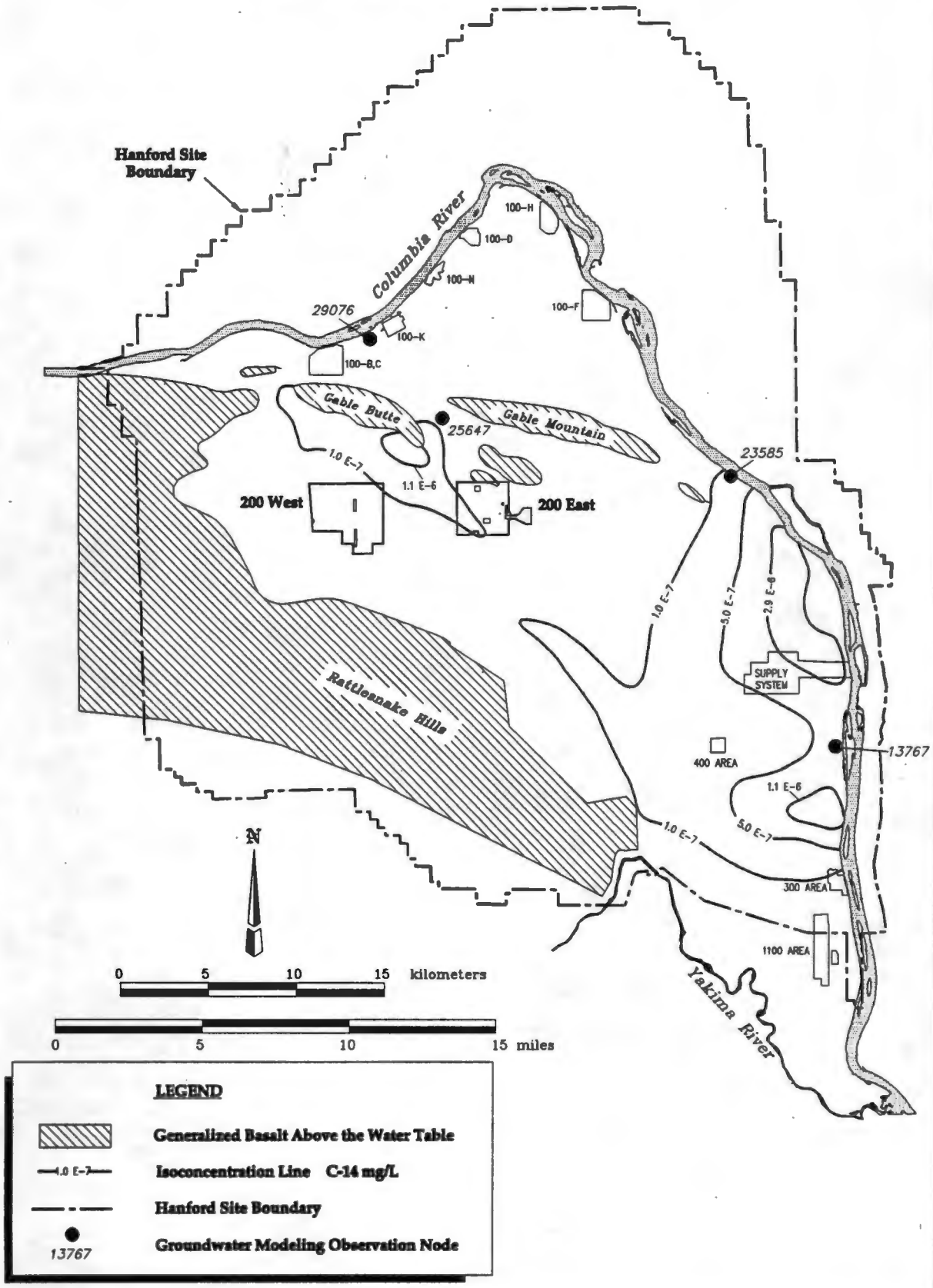

Figure F.3.1.14 Predicted Uranium-238 Concentrations in Groundwater at 500 Years for the No Action Alternative

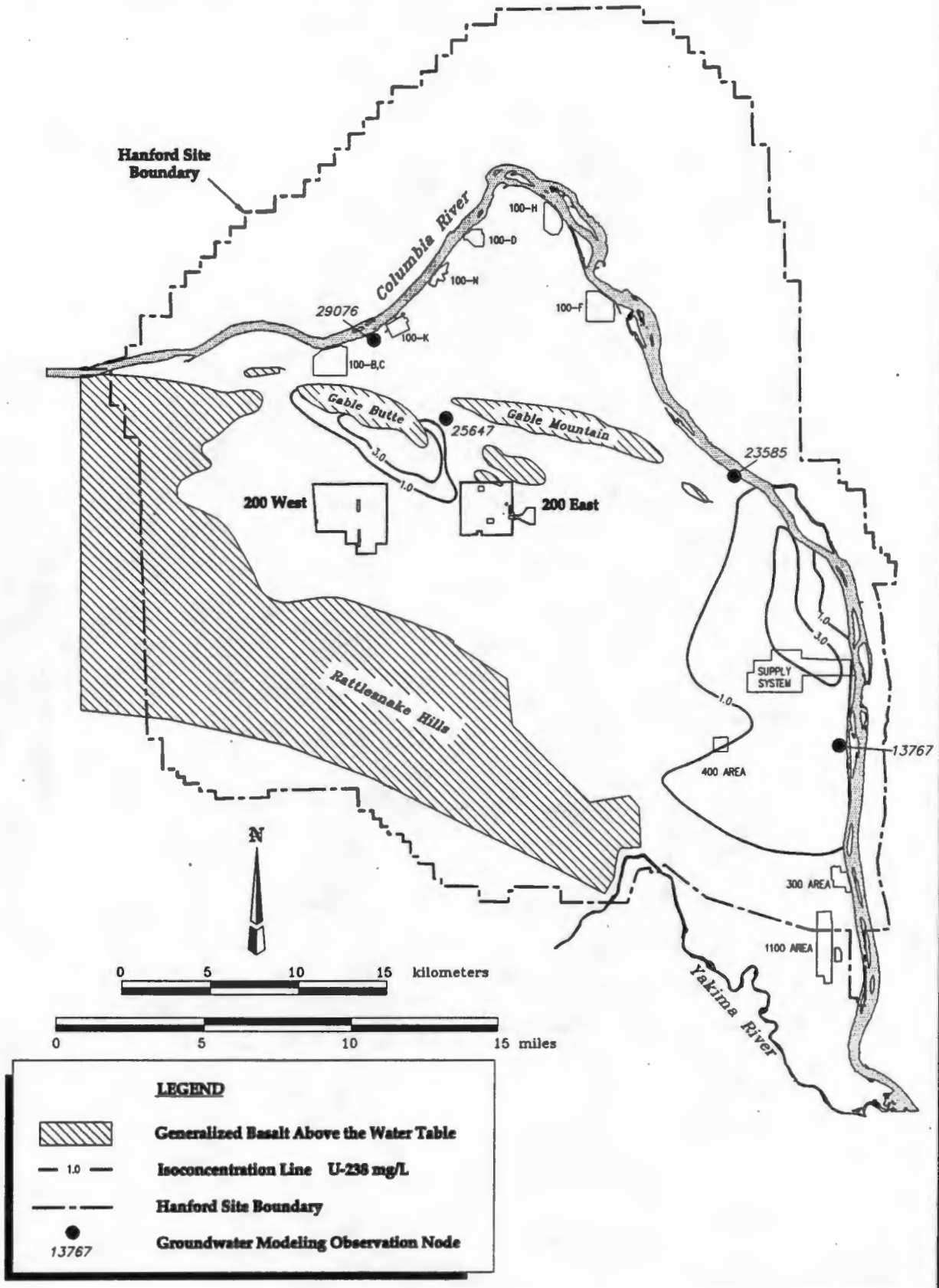

Figure F.3.1.15 Predicted Nitrate Concentrations in Groundwater at 500 Years for the No Action Alternative

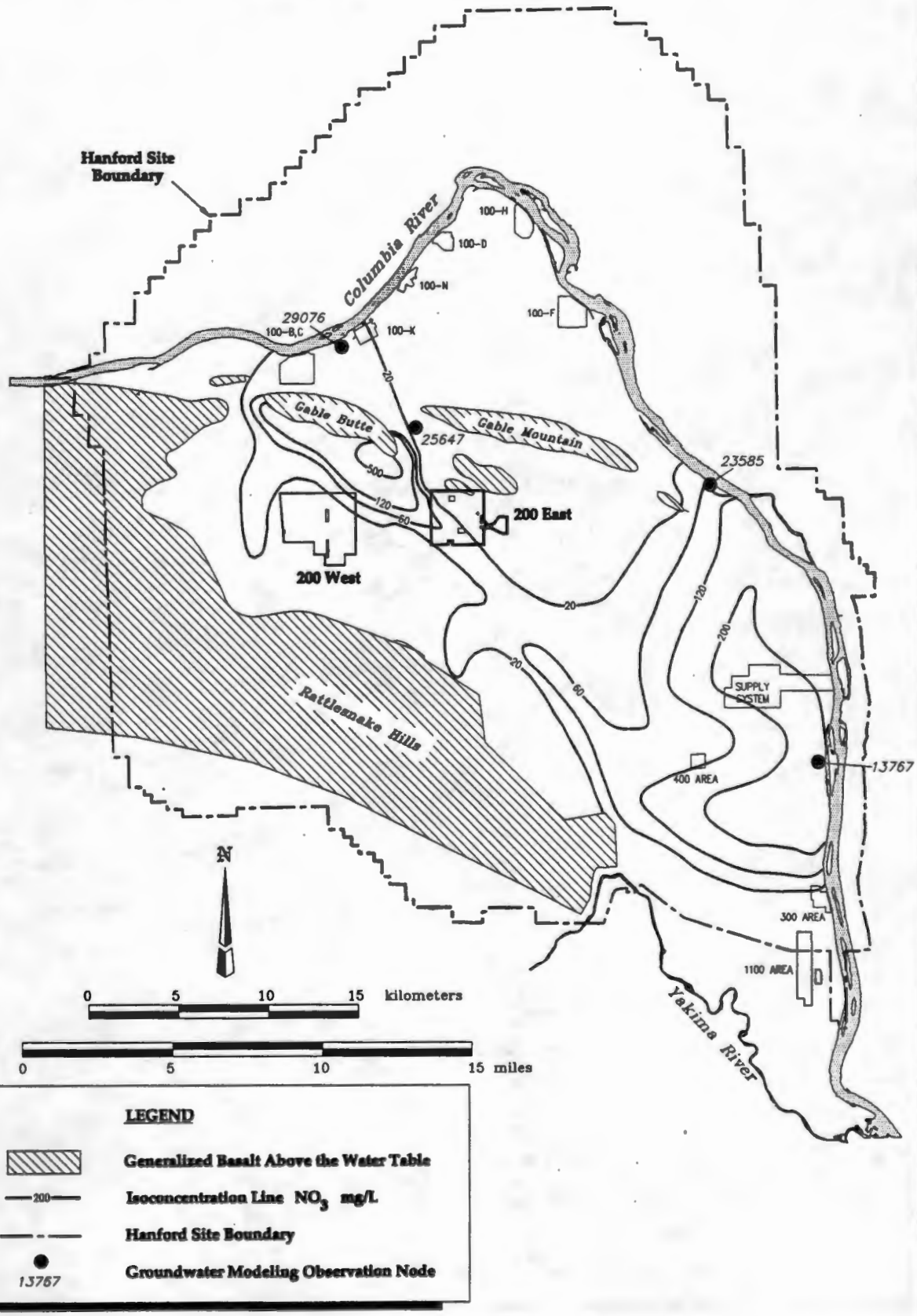

Figure F.3.1.16 Predicted Technetium-99 Concentrations in Groundwater at 2,500 Years for the No Action Alternative

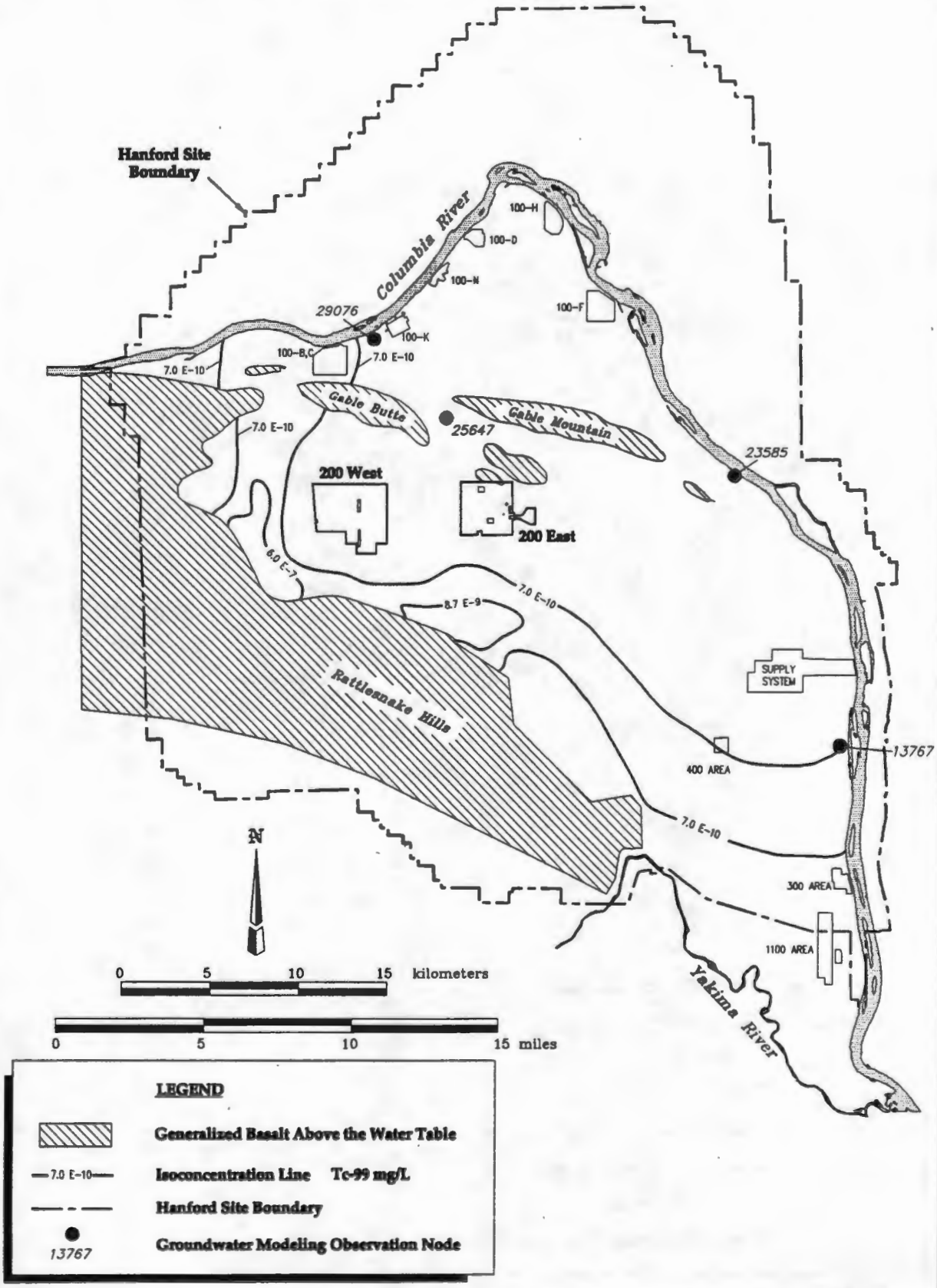

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Figure F.3.1.17 Predicted Iodine-129 Concentrations in Groundwater at 2,500 Years for the No Action Alternative

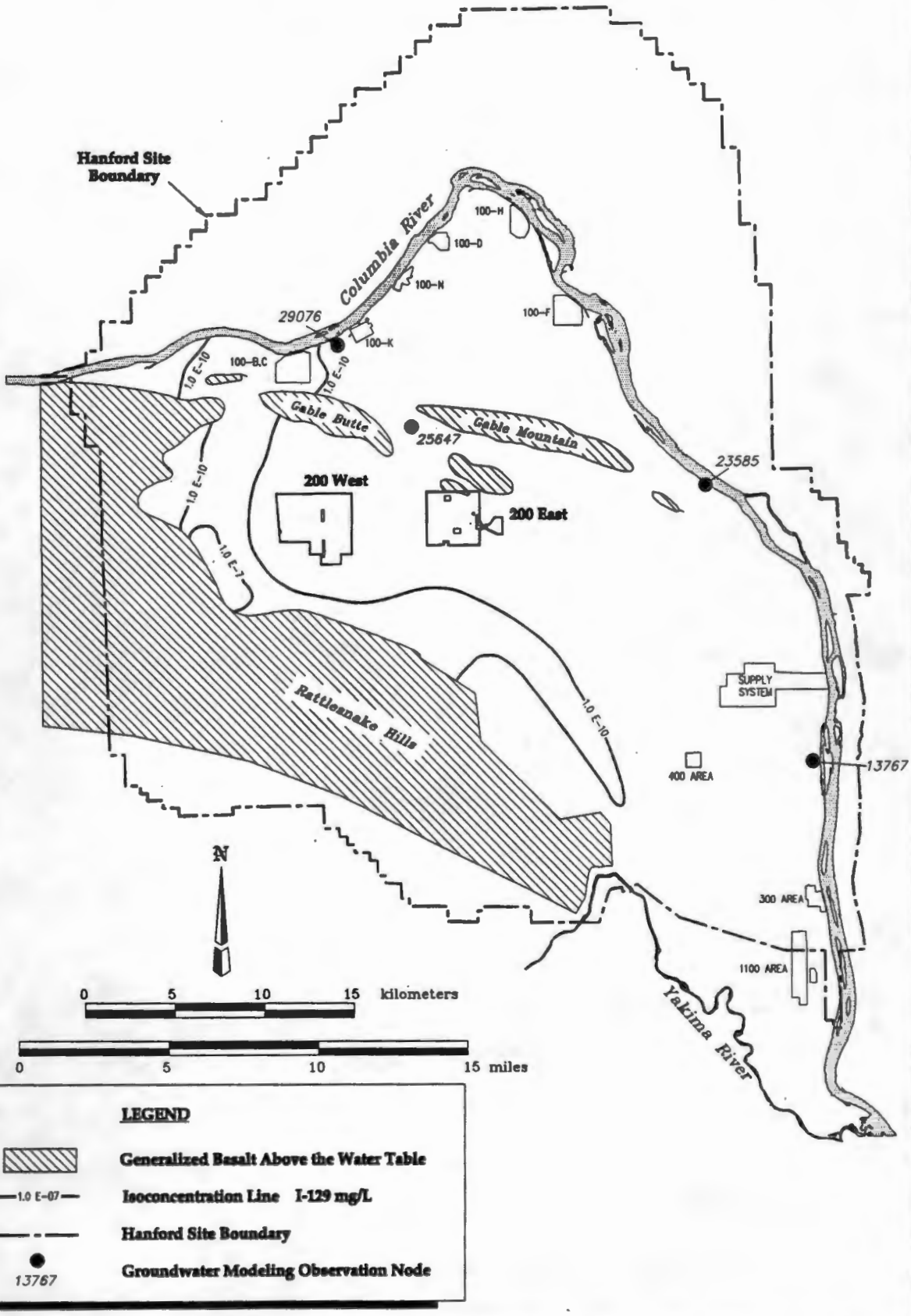

Figure F.3.1.18 Predicted Carbon-14 Concentrations in Groundwater at 2,500 Years for the No Action Alternative

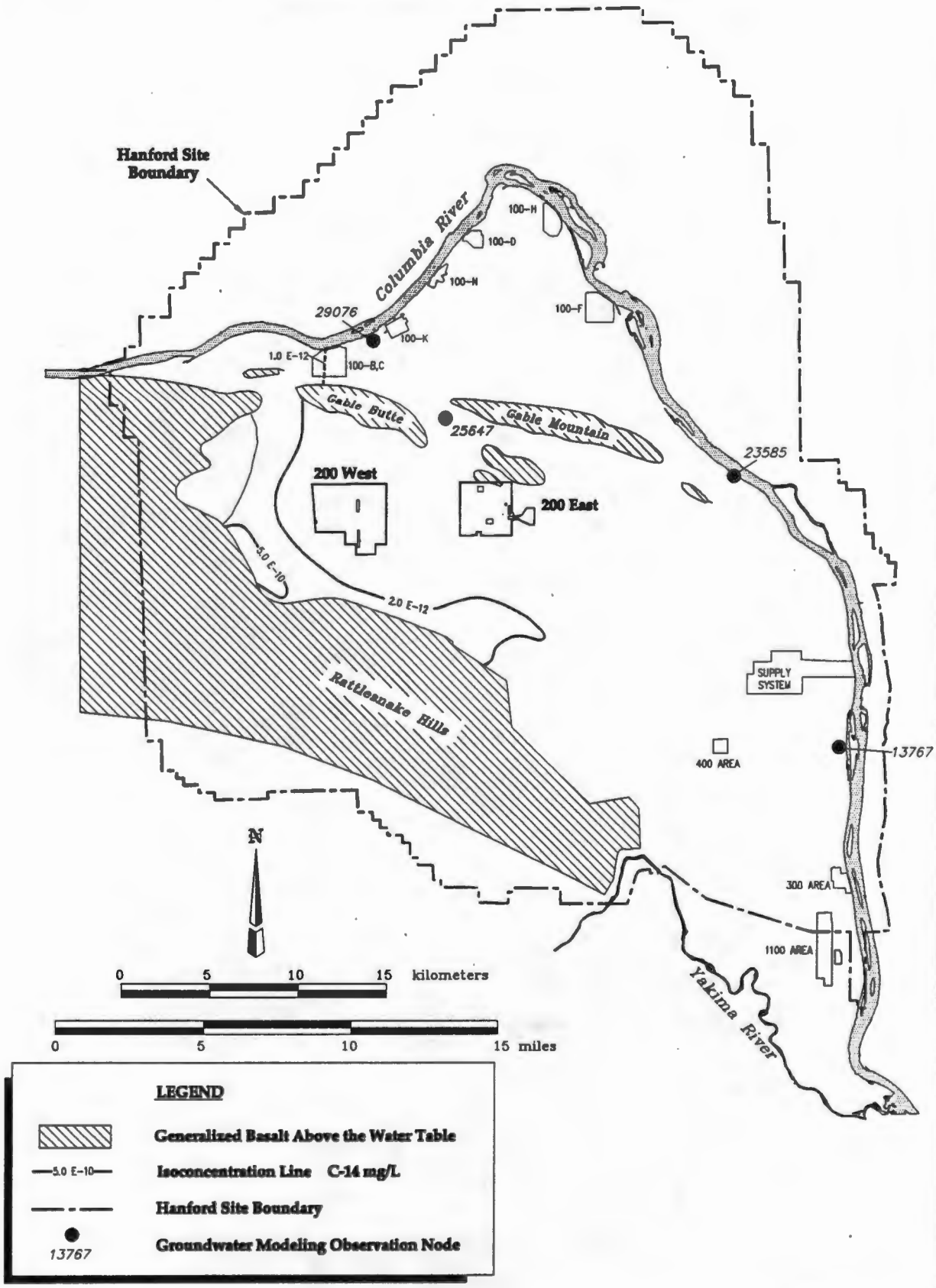

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Figure F.3.1.19 Predicted Uranium-238 Concentrations in Groundwater at 2,500 Years for the No Action Alternative

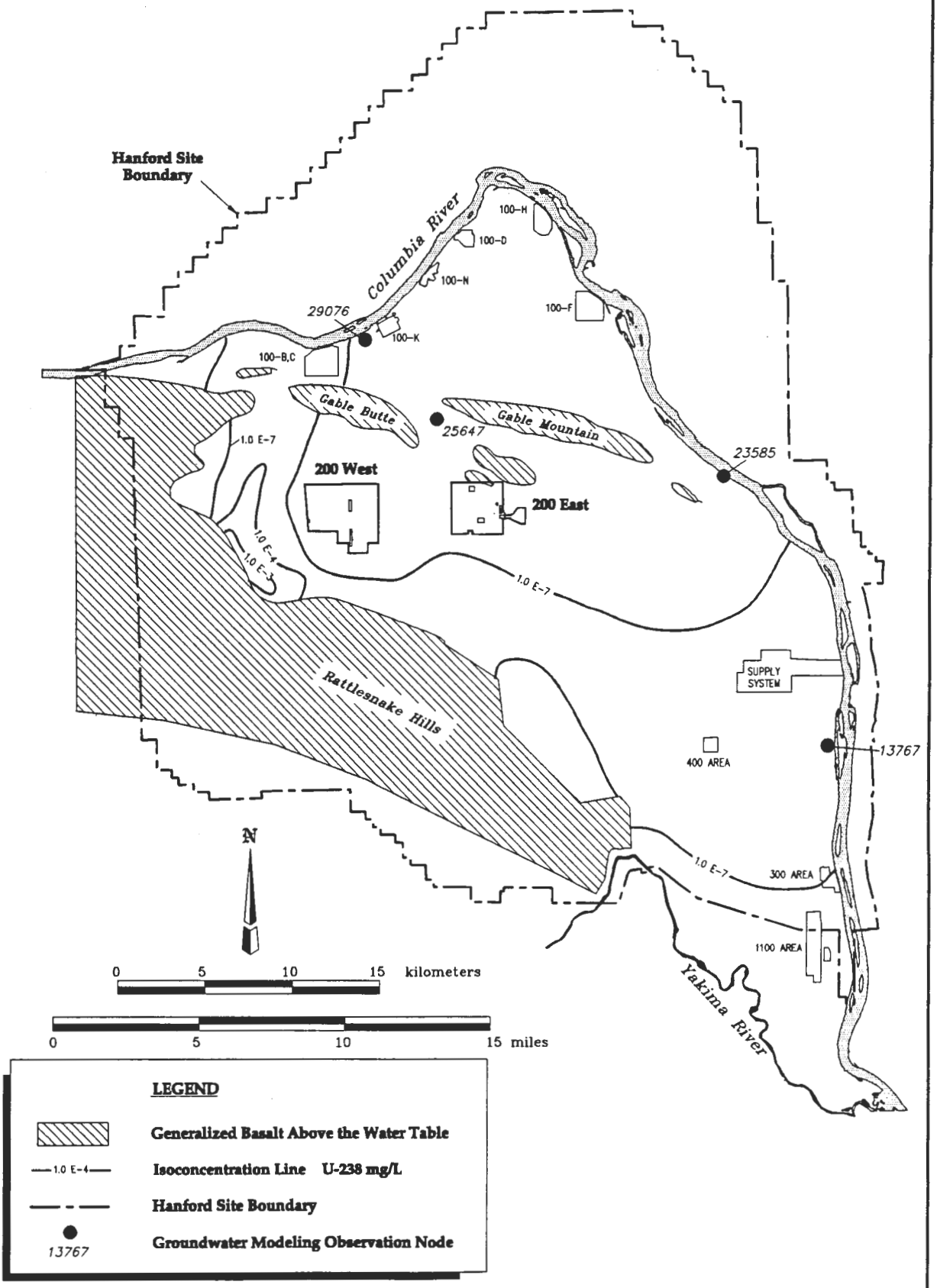


Figure F.3.1.20 Predicted Nitrate Concentrations in Groundwater at 2,500 Years for the No Action Alternative

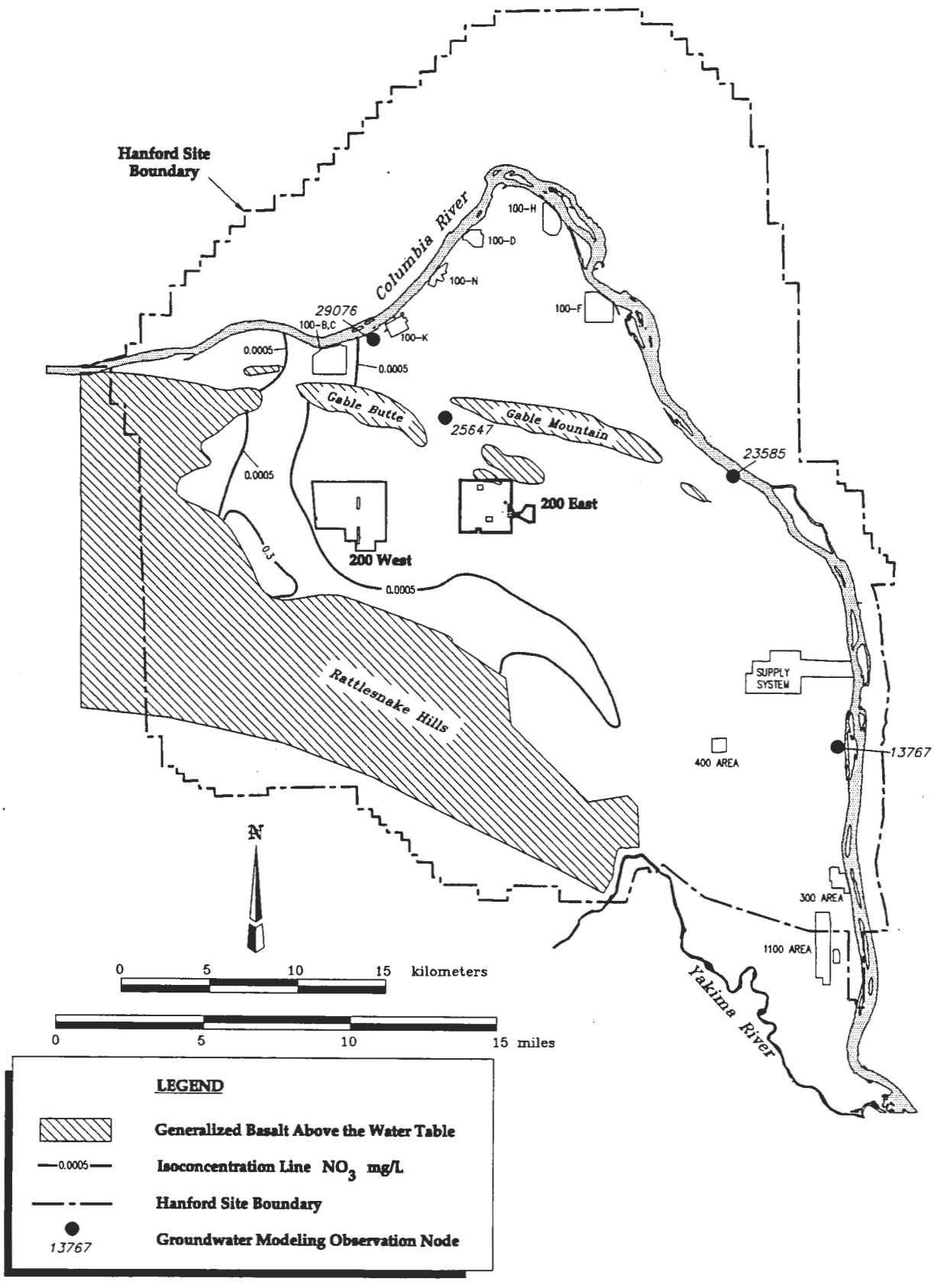
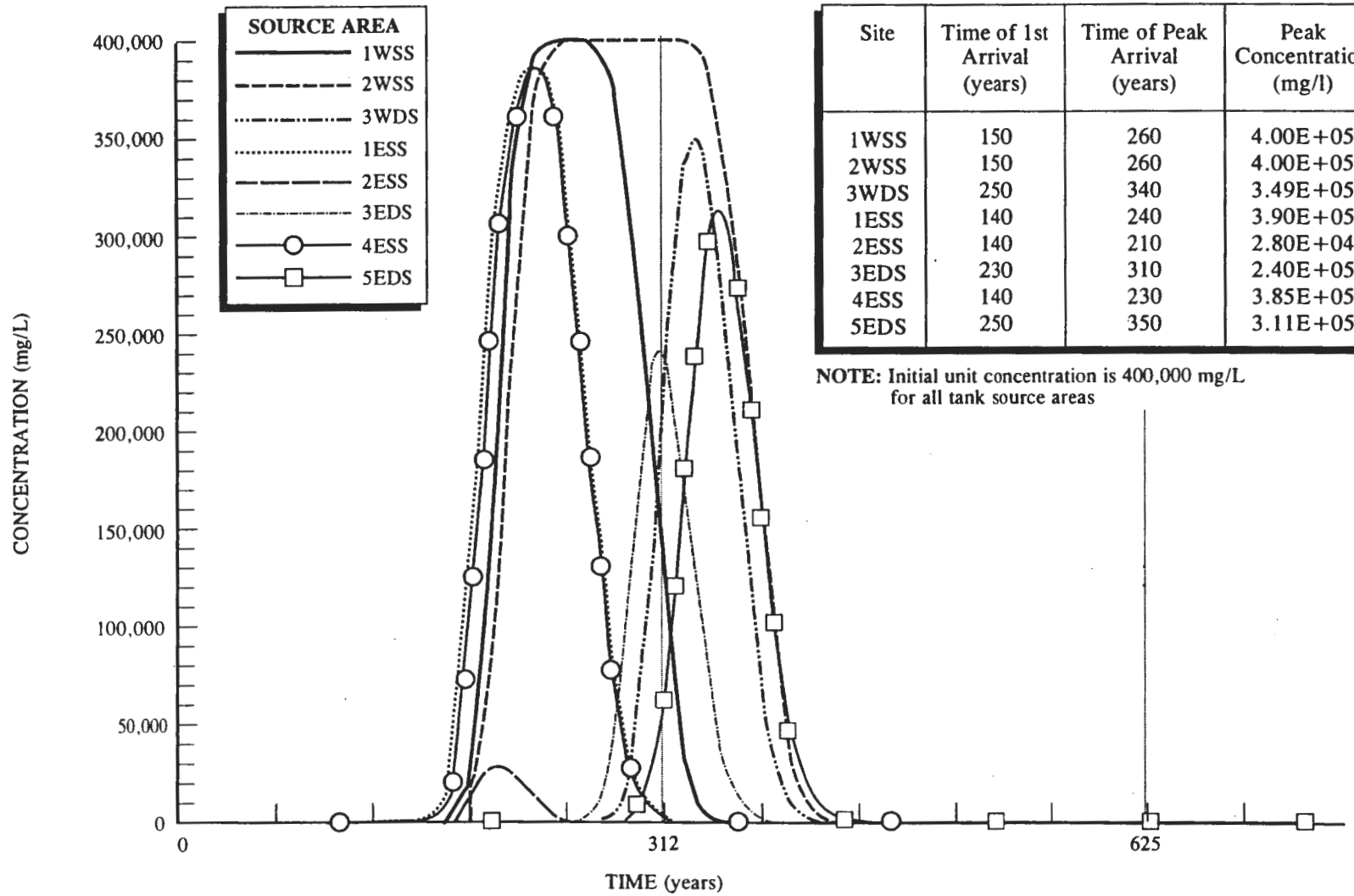


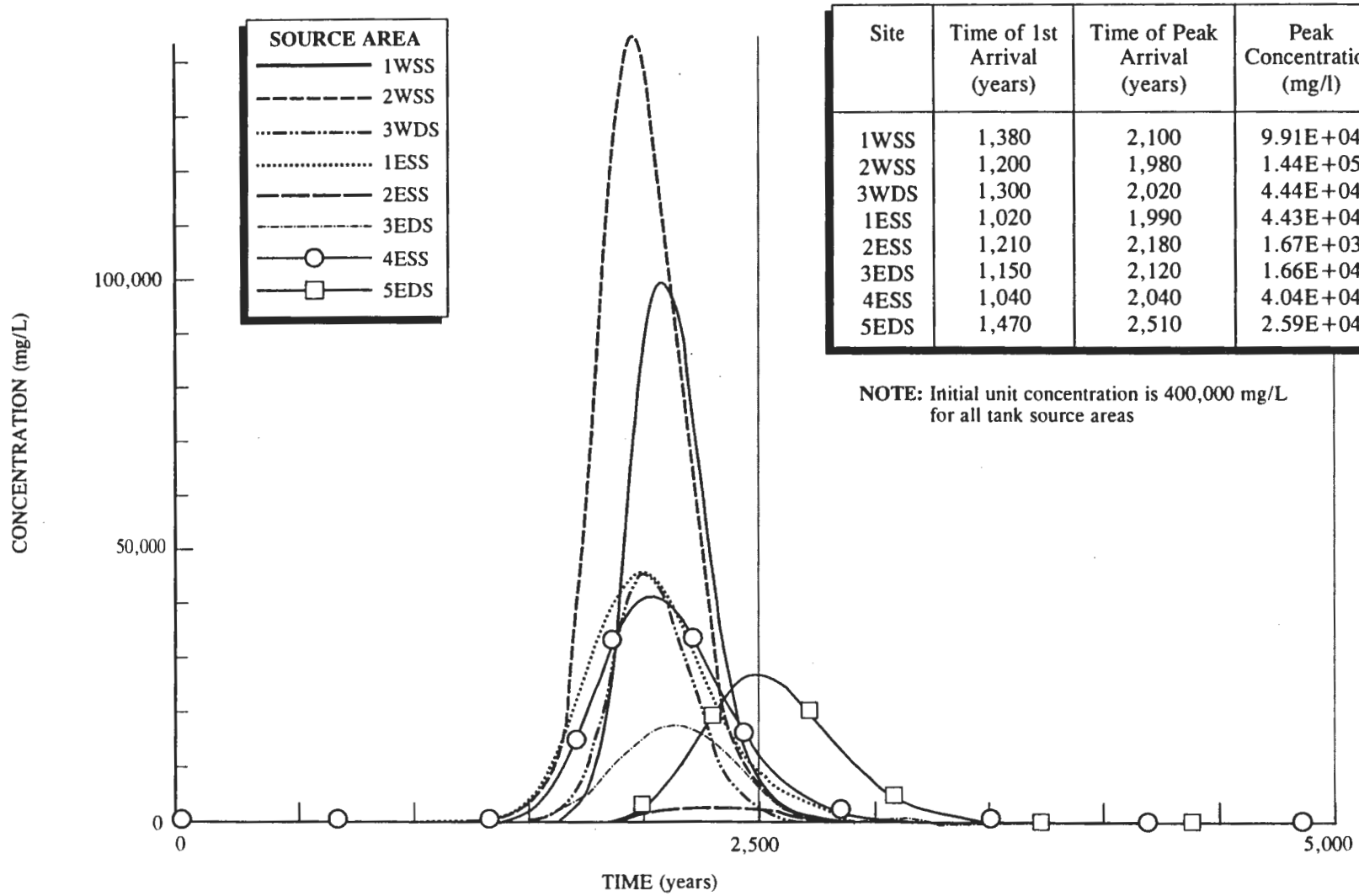
Figure F.3.2.1 Predicted Contaminant Concentration for the Long-Term Management Alternative (K_d = 0) at the Vadose Zone/Groundwater Interface



Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Concentration (mg/l)
1WSS	150	260	4.00E+05
2WSS	150	260	4.00E+05
3WDS	250	340	3.49E+05
1ESS	140	240	3.90E+05
2ESS	140	210	2.80E+04
3EDS	230	310	2.40E+05
4ESS	140	230	3.85E+05
5EDS	250	350	3.11E+05

NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas

Figure F.3.2.2 Predicted Contaminant Concentration for the Long-Term Management Alternative (K_d = 1) at the Vadose Zone/Groundwater Interface



Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Concentration (mg/l)
1WSS	1,380	2,100	9.91E+04
2WSS	1,200	1,980	1.44E+05
3WDS	1,300	2,020	4.44E+04
1ESS	1,020	1,990	4.43E+04
2ESS	1,210	2,180	1.67E+03
3EDS	1,150	2,120	1.66E+04
4ESS	1,040	2,040	4.04E+04
5EDS	1,470	2,510	2.59E+04

NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas

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Figure F.3.2.3 Predicted Nitrate Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative

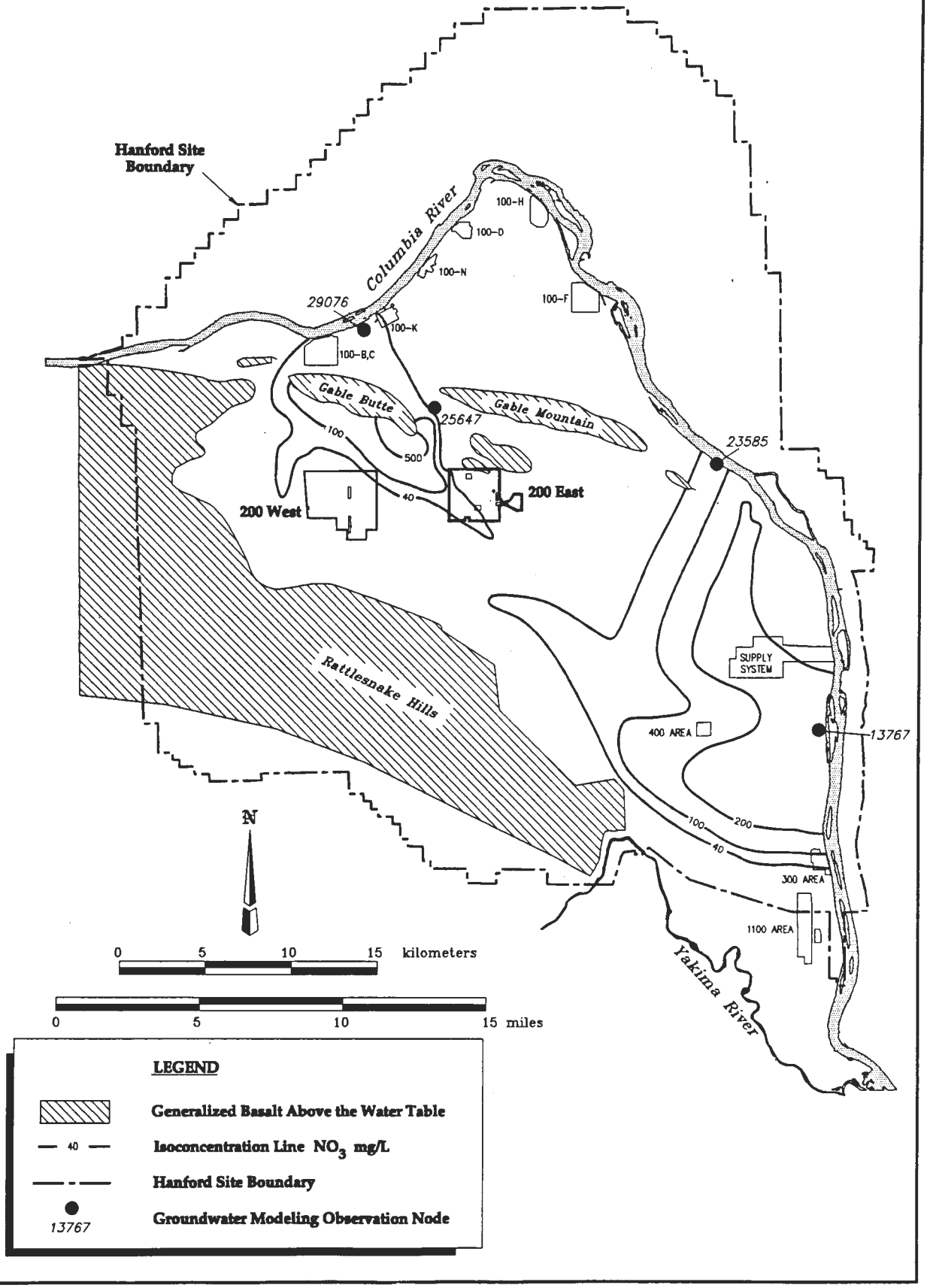
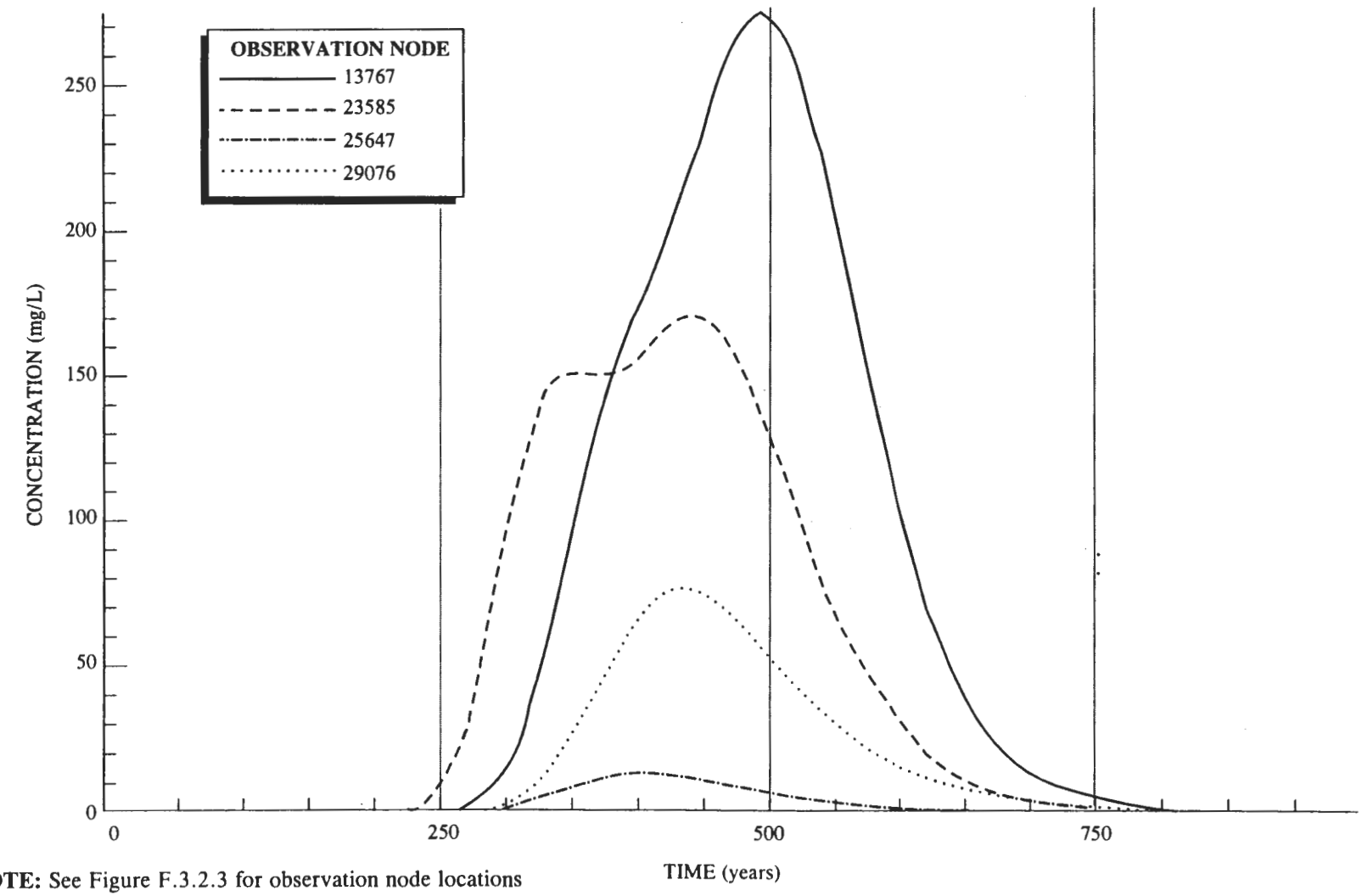


Figure F.3.2.4 Predicted Concentration of Nitrate in Groundwater at Selected Locations for the Long-Term Management Alternative (K_d = 0)



NOTE: See Figure F.3.2.3 for observation node locations

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Figure F.3.2.5 Predicted Bismuth Concentrations in Groundwater at 5,000 Years for the Long-Term Management Alternative

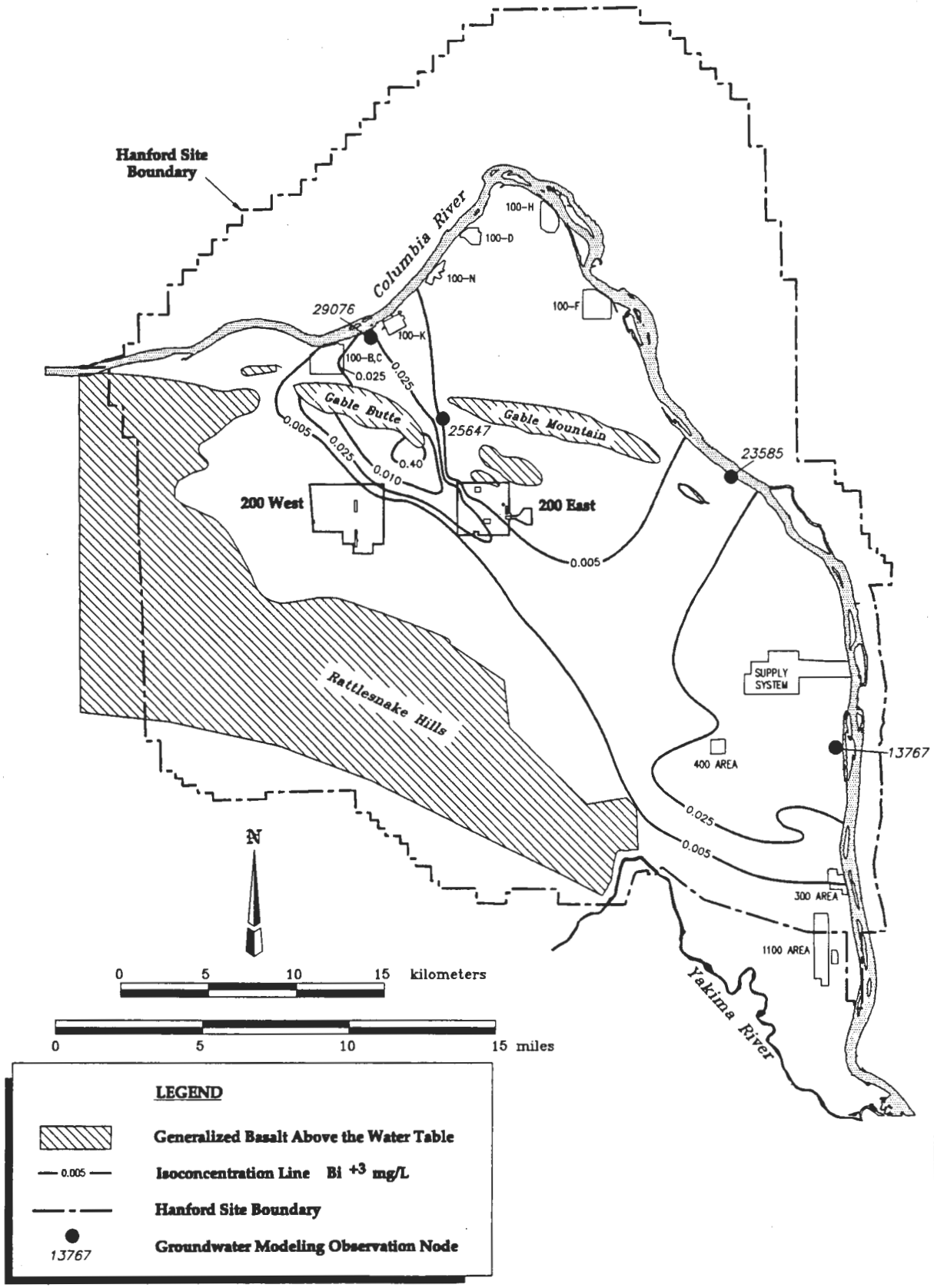
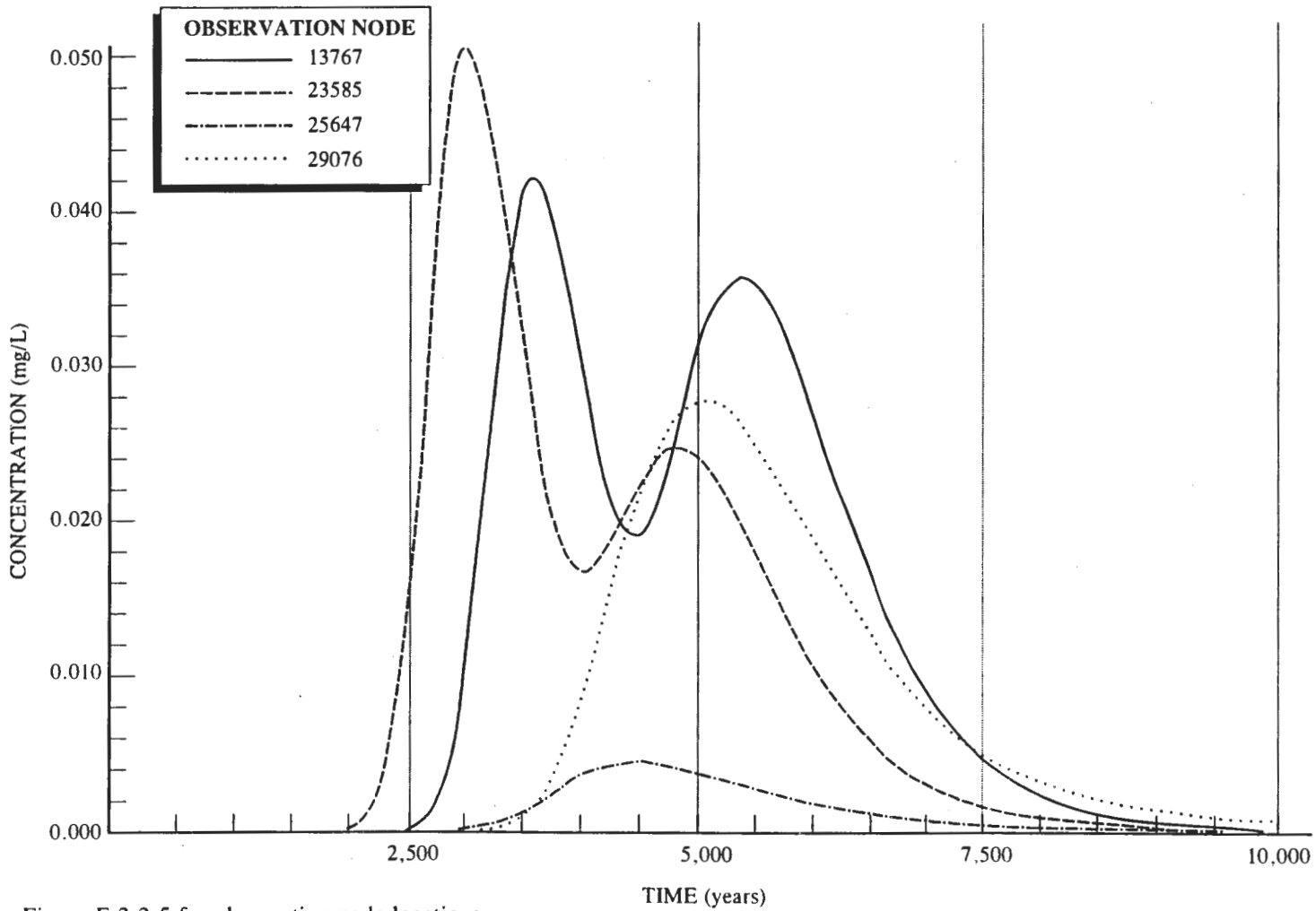


Figure F.3.2.6 Predicted Concentration of Bismuth in Groundwater at Selected Locations for the Long-Term Management Alternative (K_d = 1)



NOTE: See Figure F.3.2.5 for observation node locations

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Figure F.3.2.7 Predicted Technetium-99 Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative

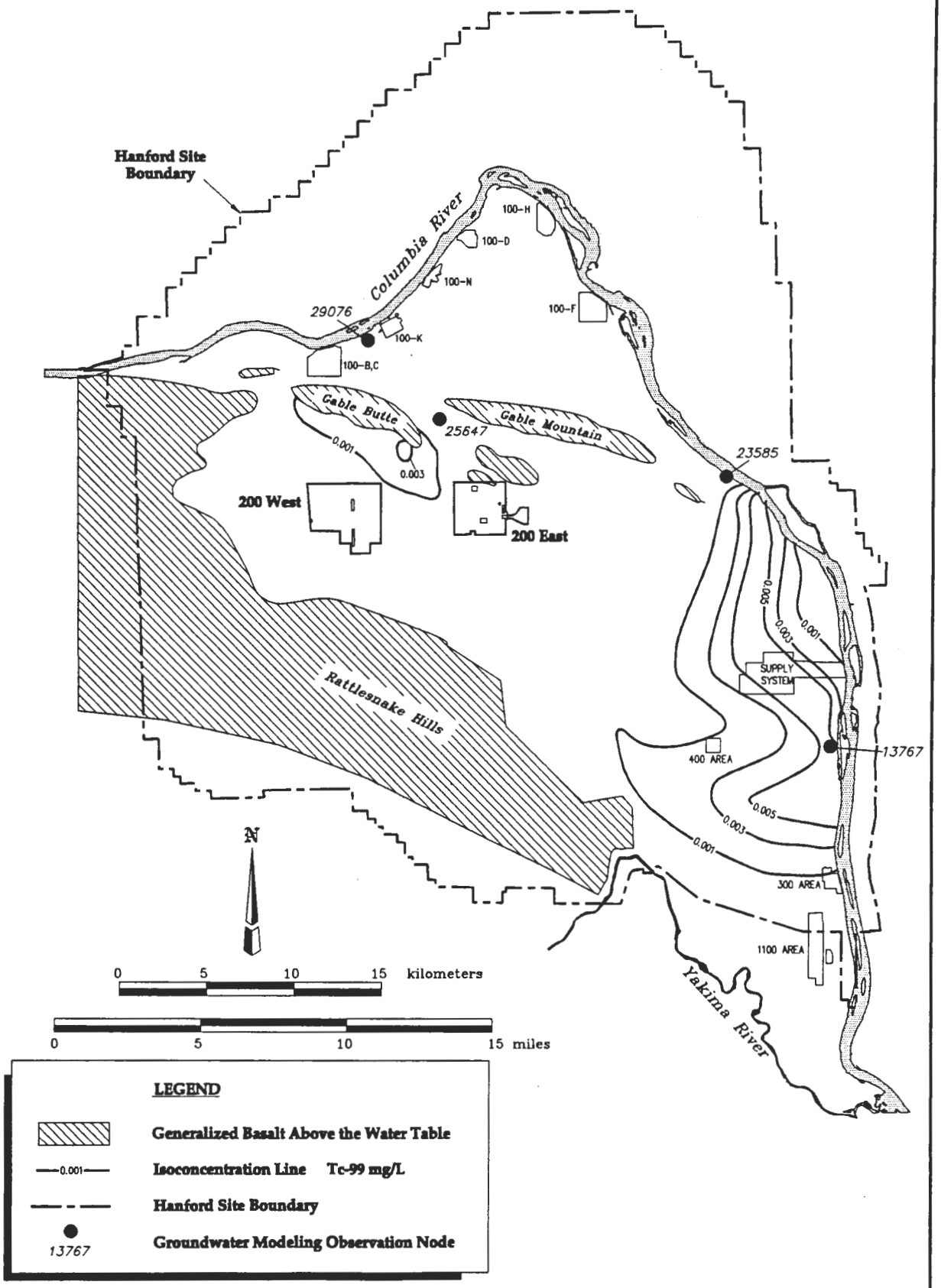

Figure F.3.2.8 Predicted Iodine-129 Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative

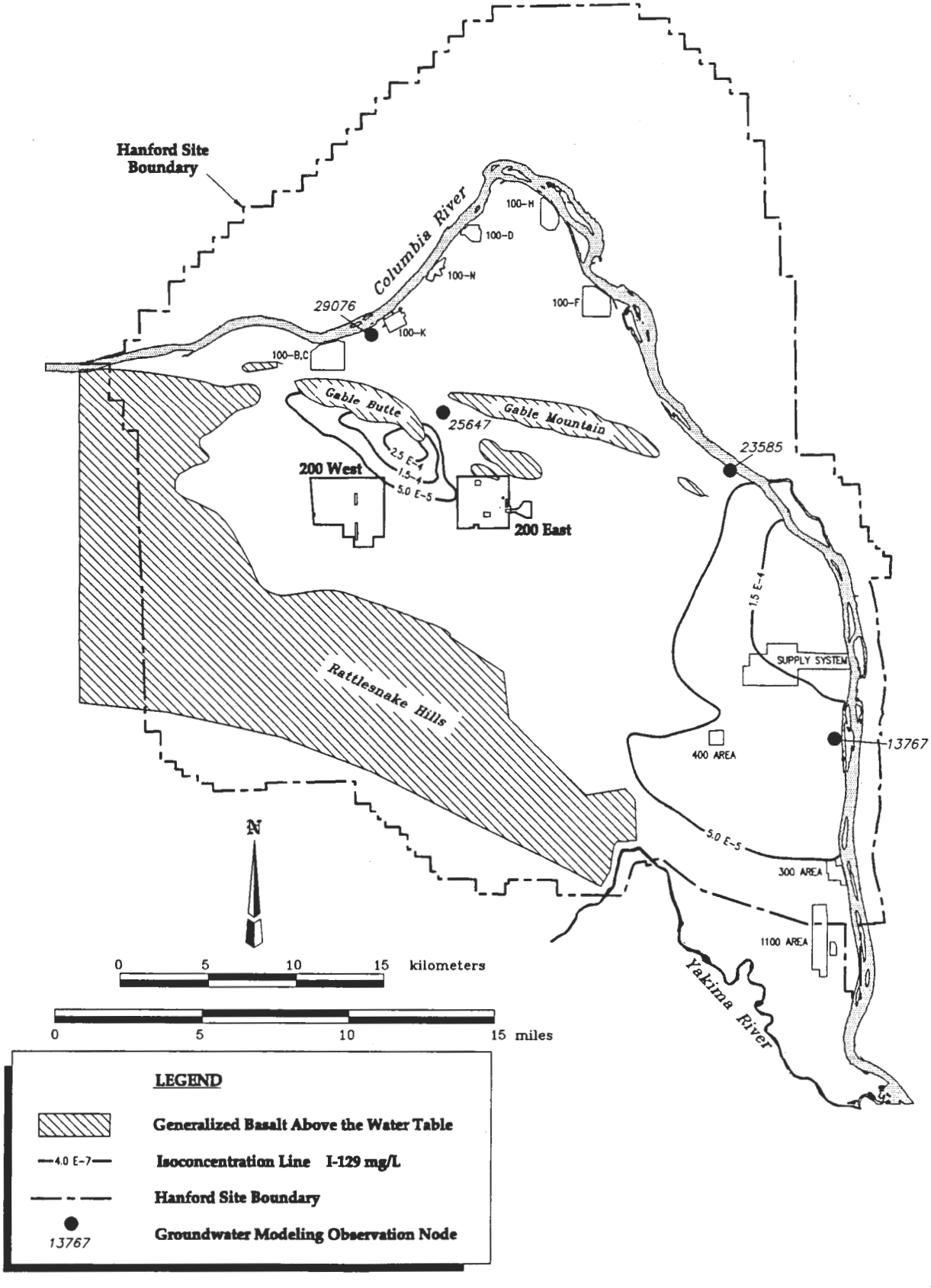

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Figure F.3.2.9 Predicted Carbon-14 Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative

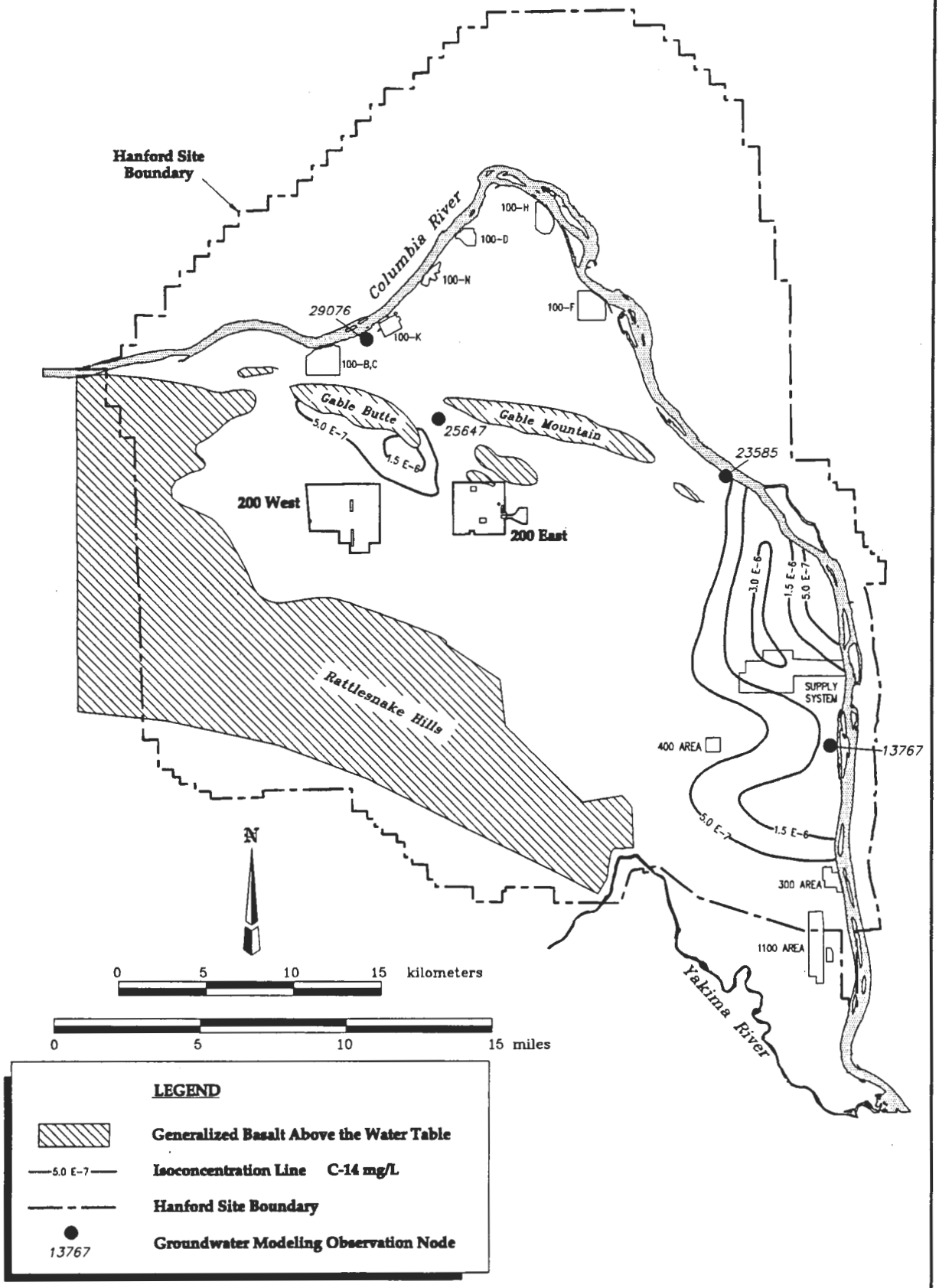

Figure F.3.2.10 Predicted Uranium-238 Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative

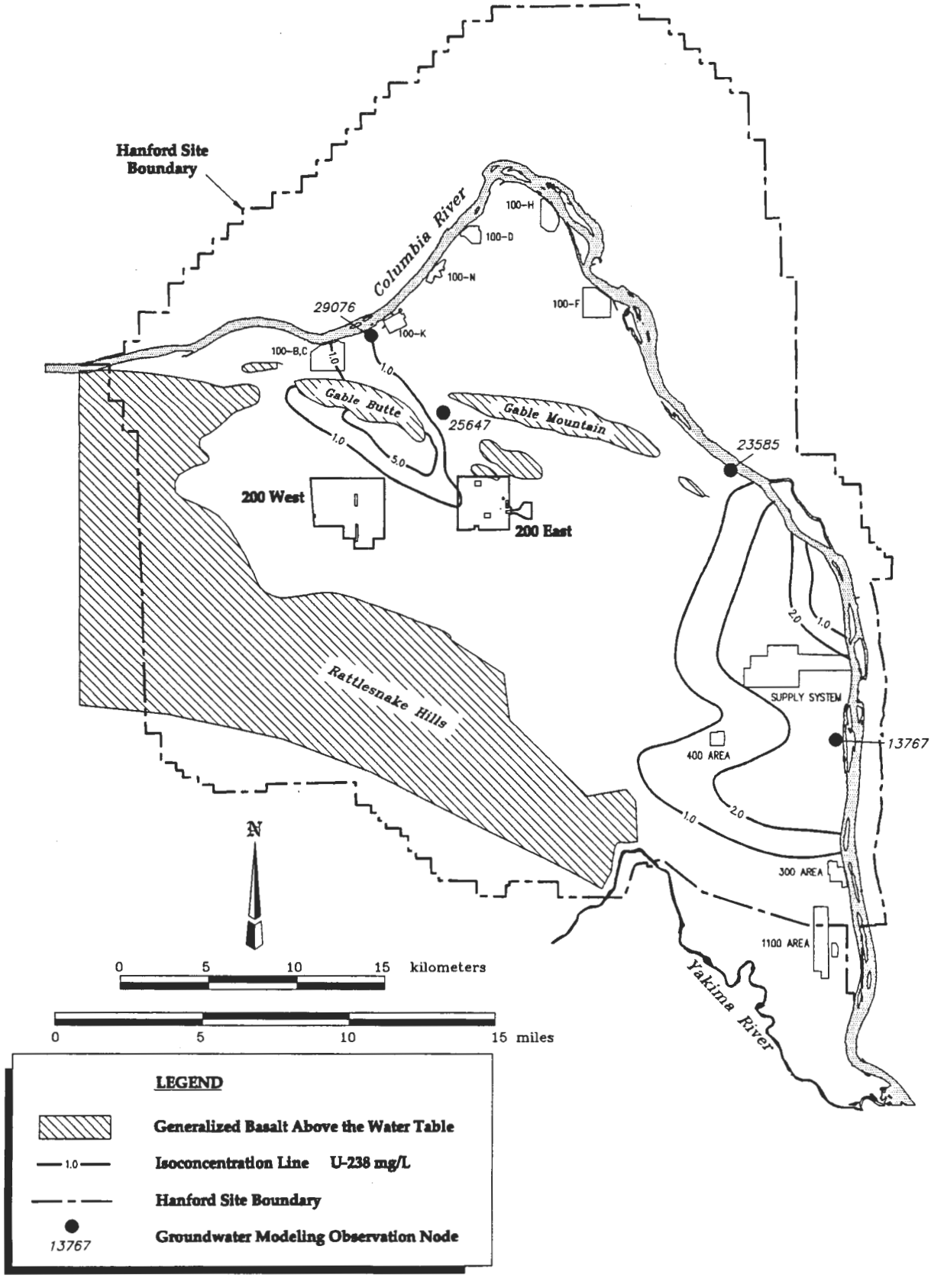

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Figure F.3.2.11 Predicted Technetium-99 Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative

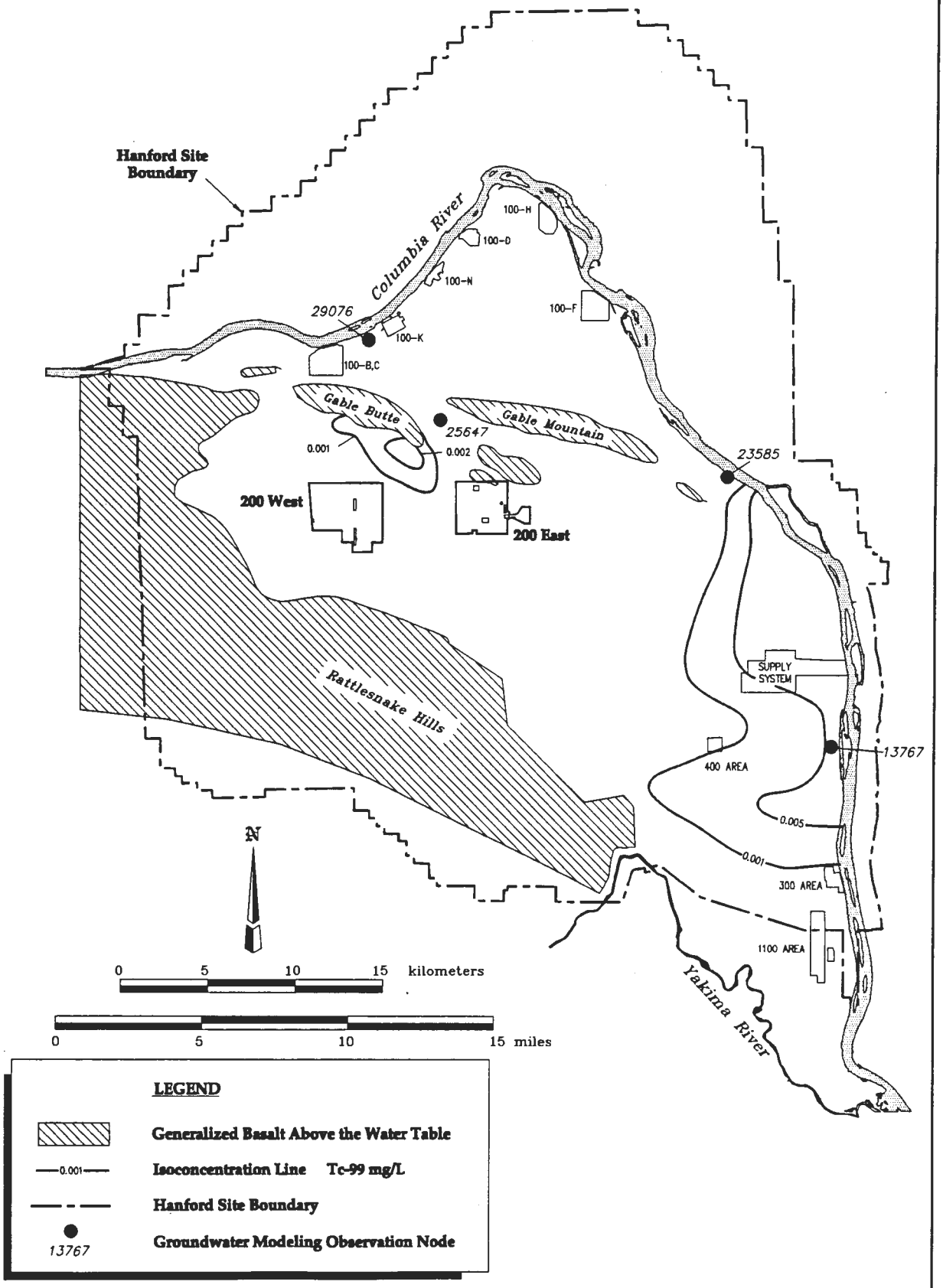
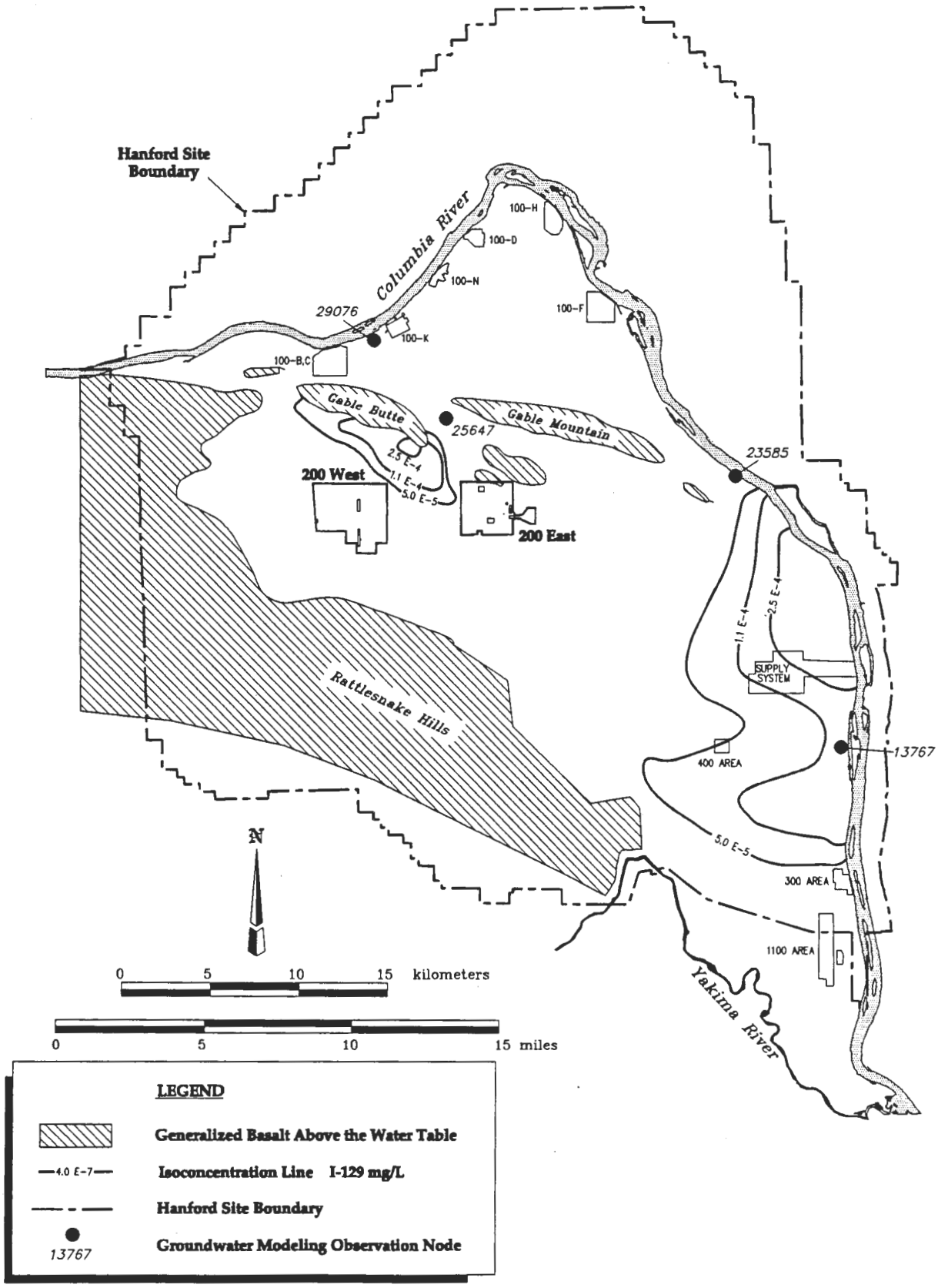
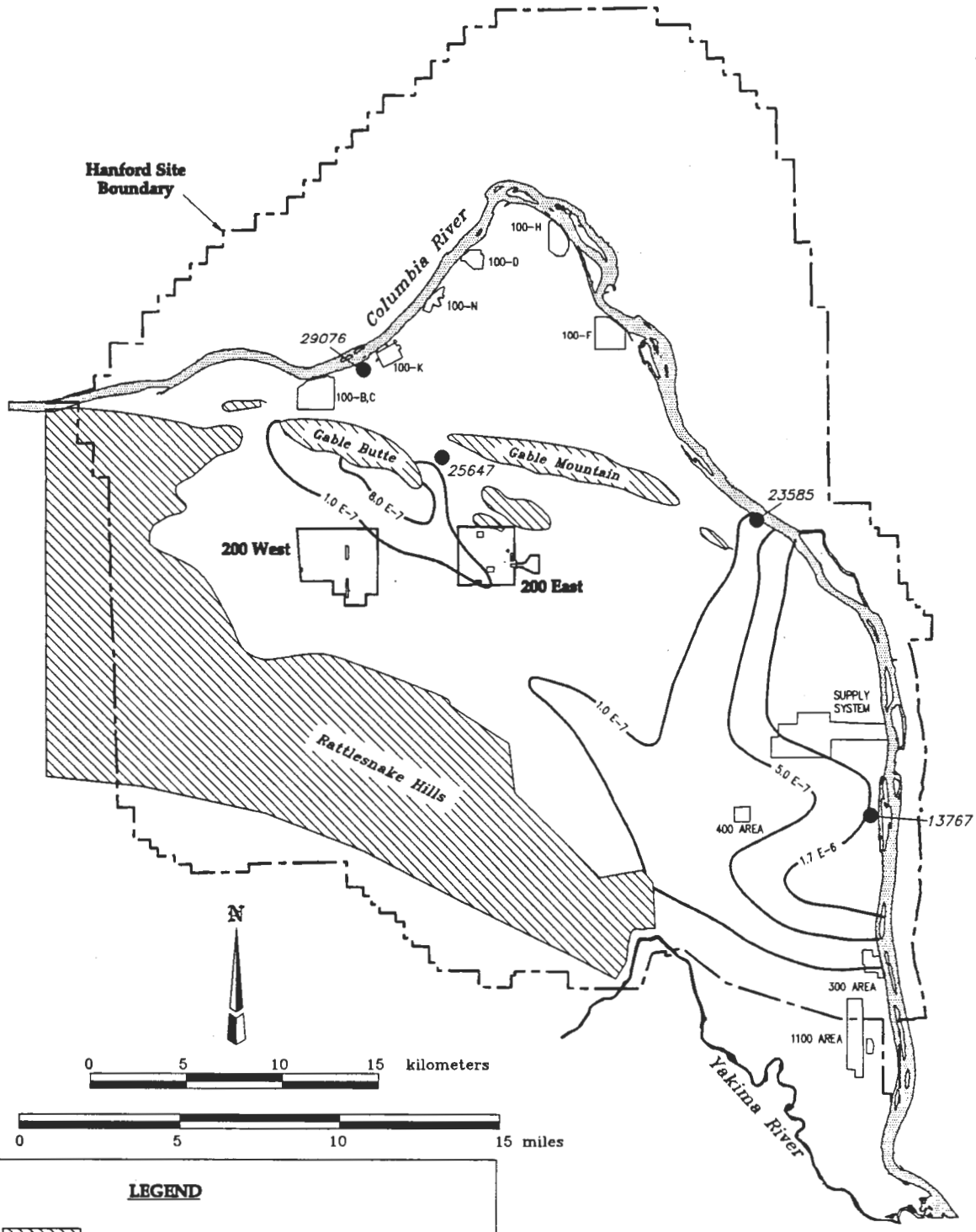


Figure F.3.2.12 Predicted Iodine-129 Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative



9613459.1007

Figure F.3.2.13 Predicted Carbon-14 Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative



LEGEND

- Generalized Basalt Above the Water Table
- 1.0 E-7 — Isoconcentration Line C-14 mg/L
- Hanford Site Boundary
- 13767 — Groundwater Modeling Observation Node

Figure F.3.2.14 Predicted Uranium-238 Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative

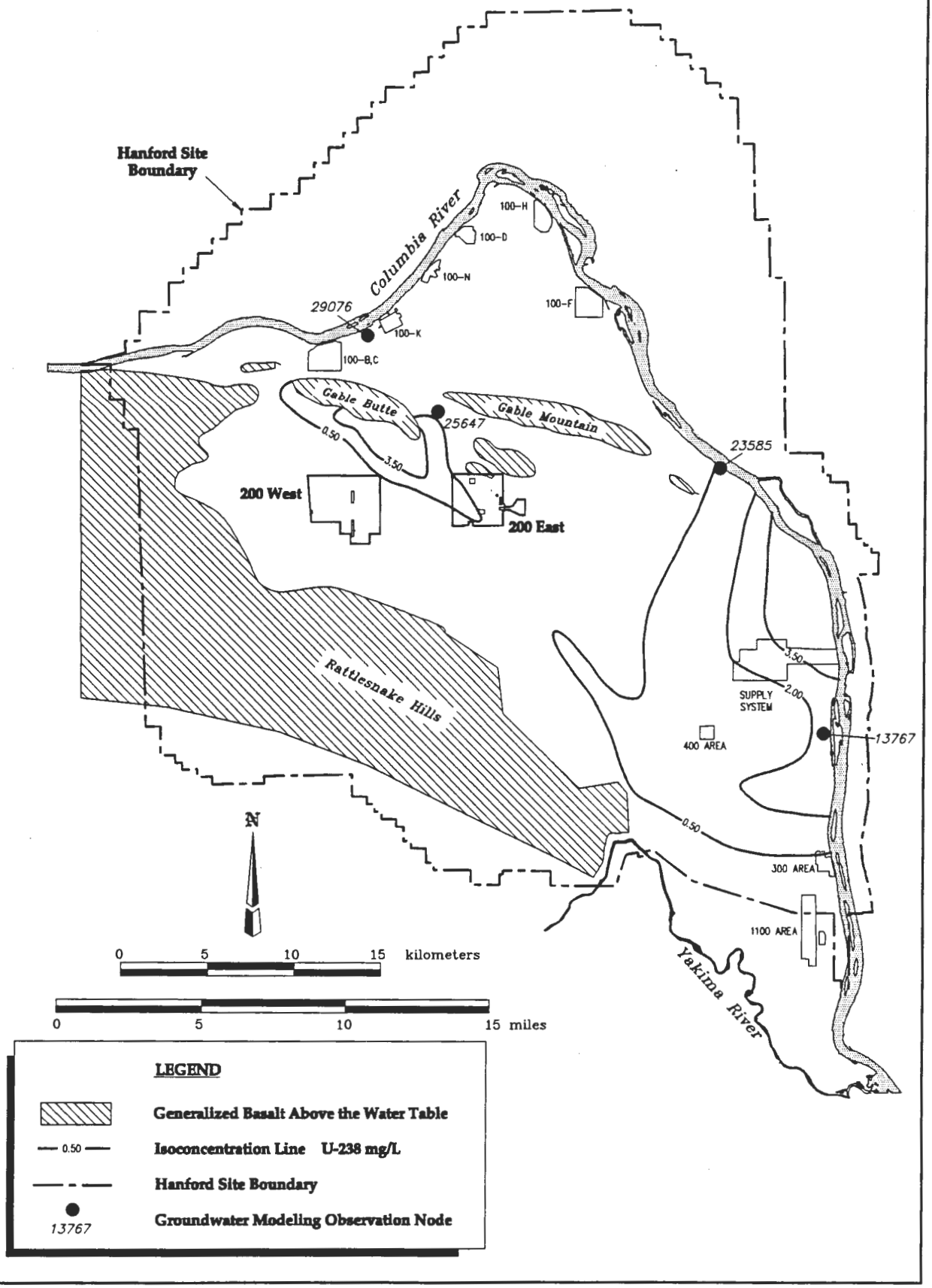


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Figure F.3.2.15 Predicted Nitrate Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative

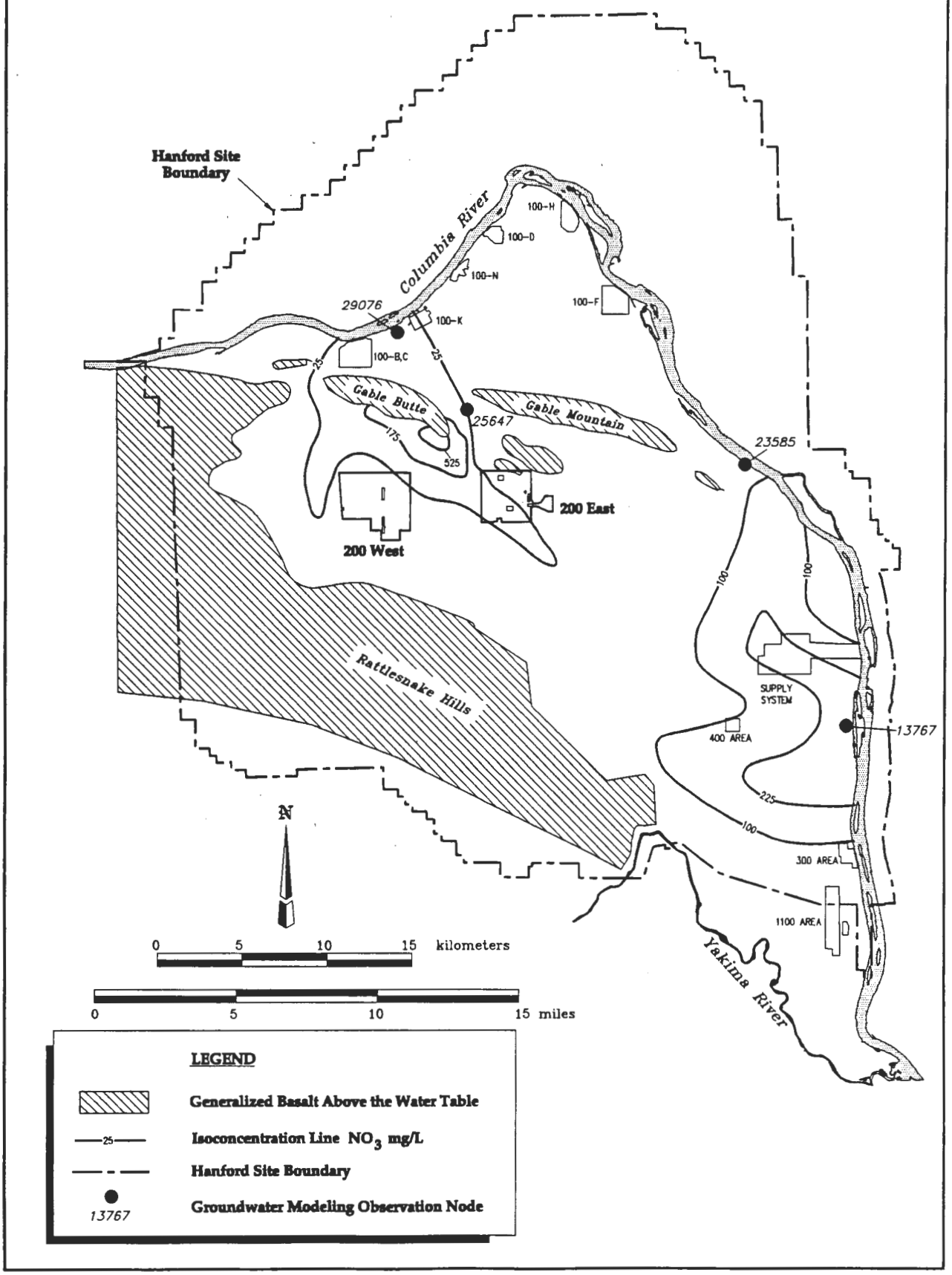

Figure F.3.2.16 Predicted Technetium-99 Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative

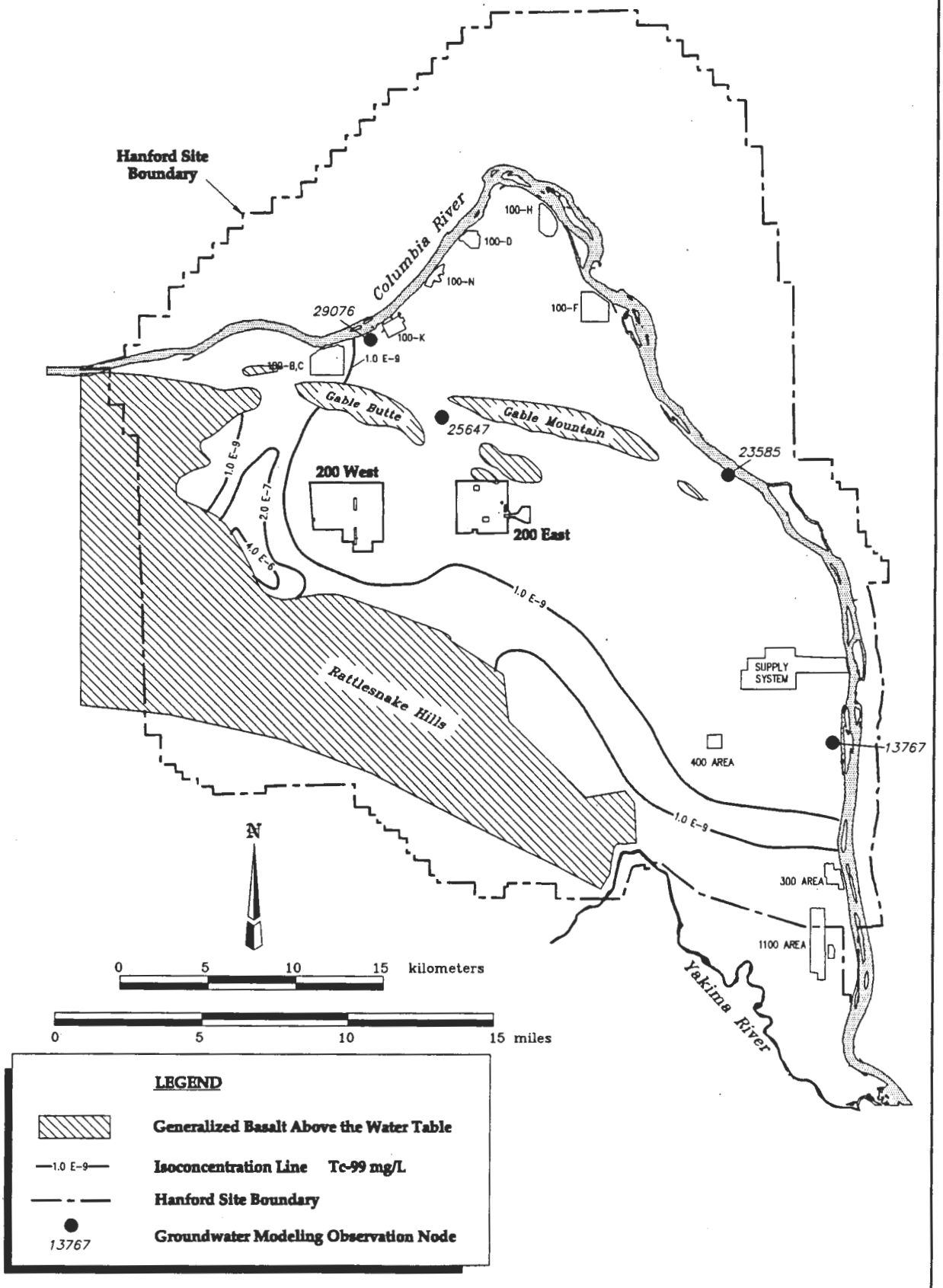

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Figure F.3.2.17 Predicted Iodine-129 Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative

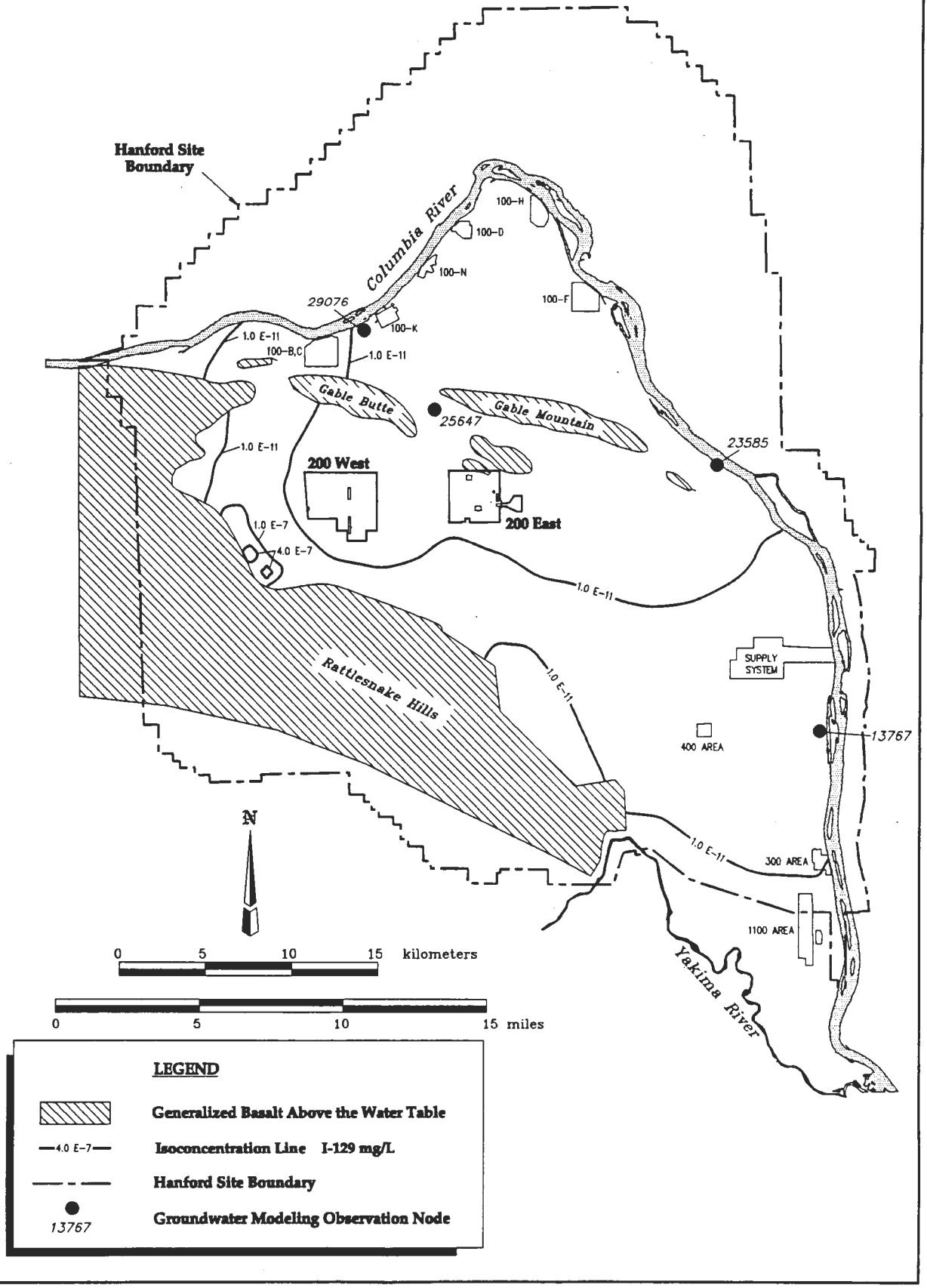

Figure F.3.2.18 Predicted Carbon-14 Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative

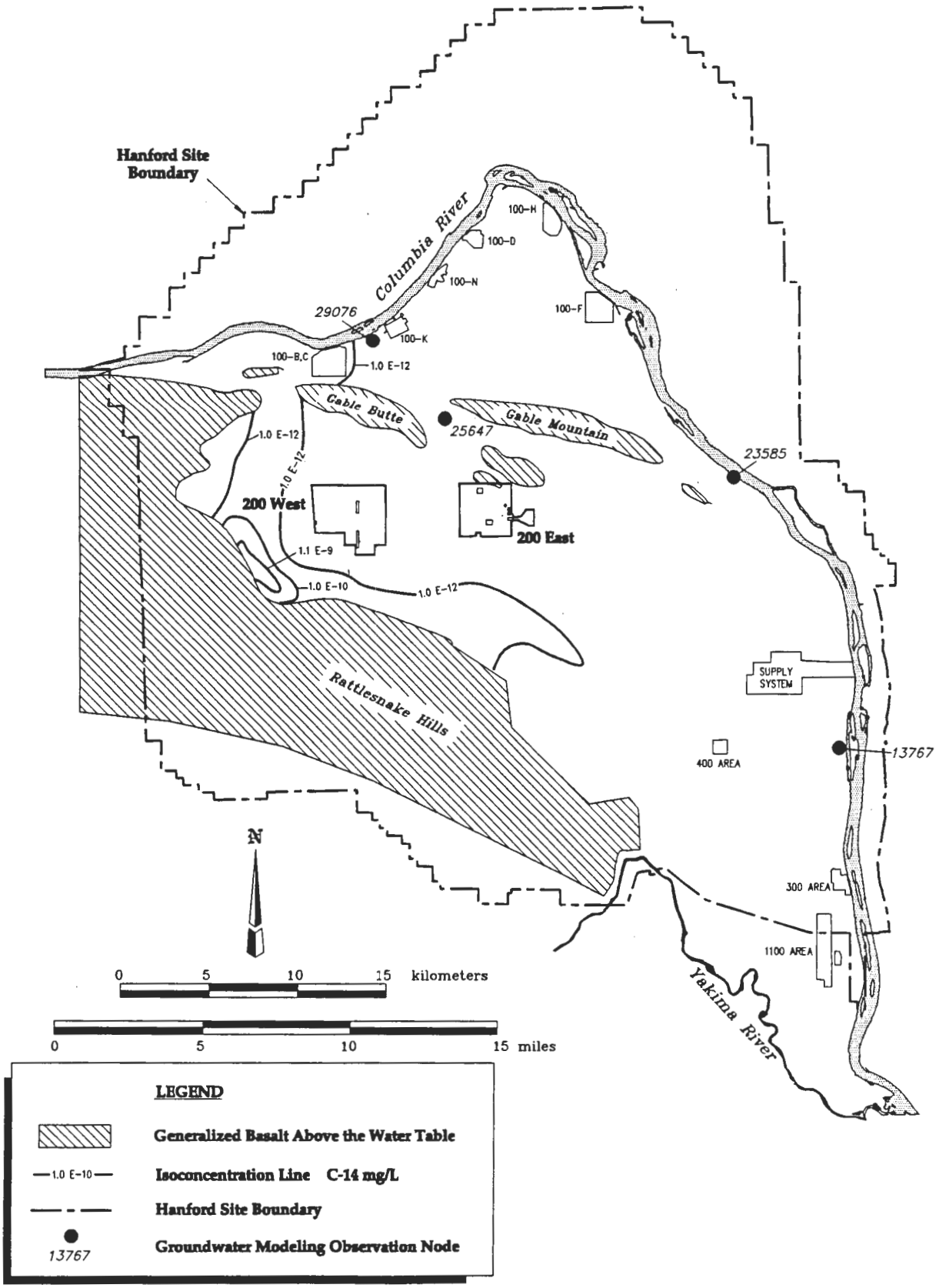

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Figure F.3.2.19 Predicted Uranium-238 Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative

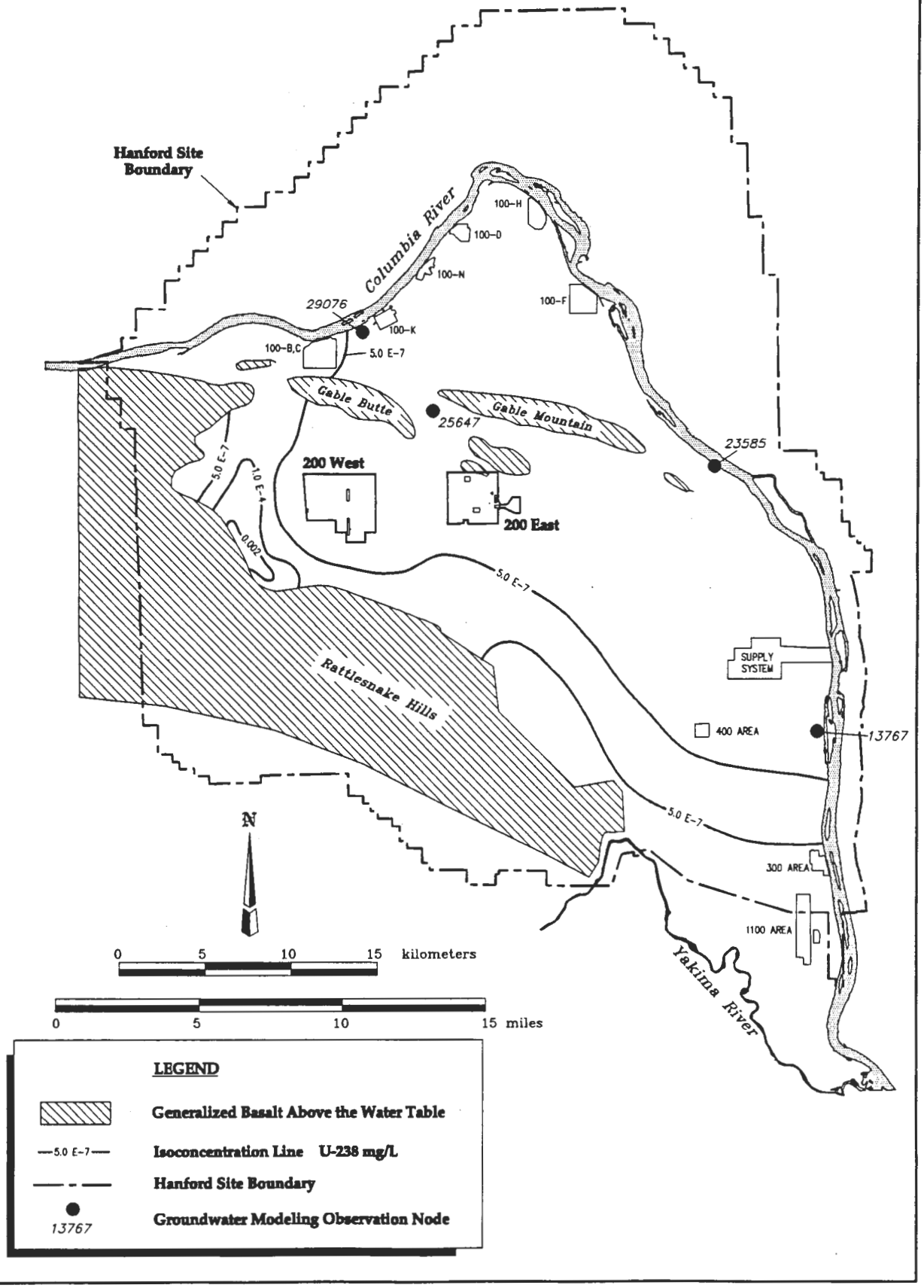


Figure F.3.2.20 Predicted Nitrate Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative

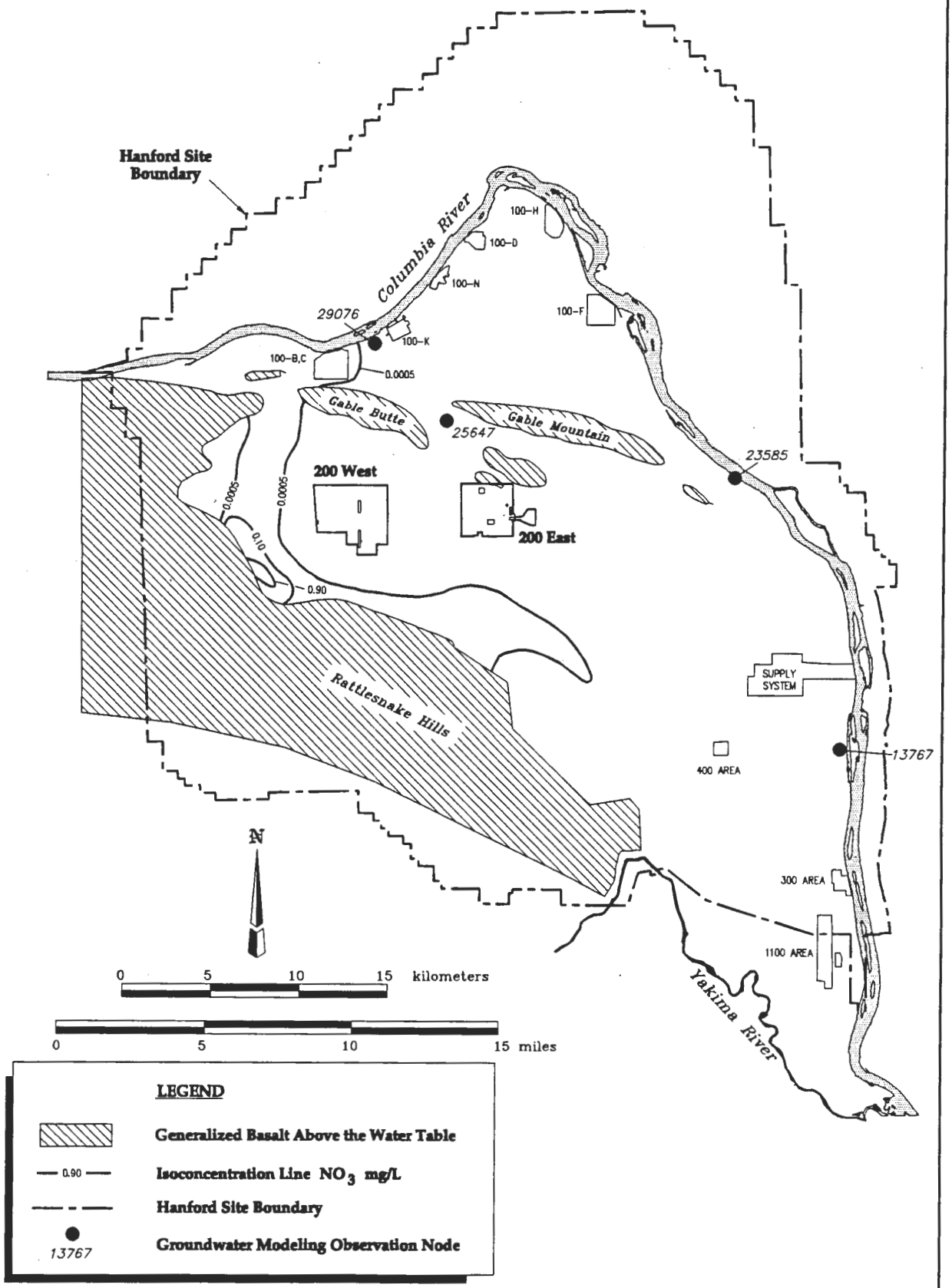
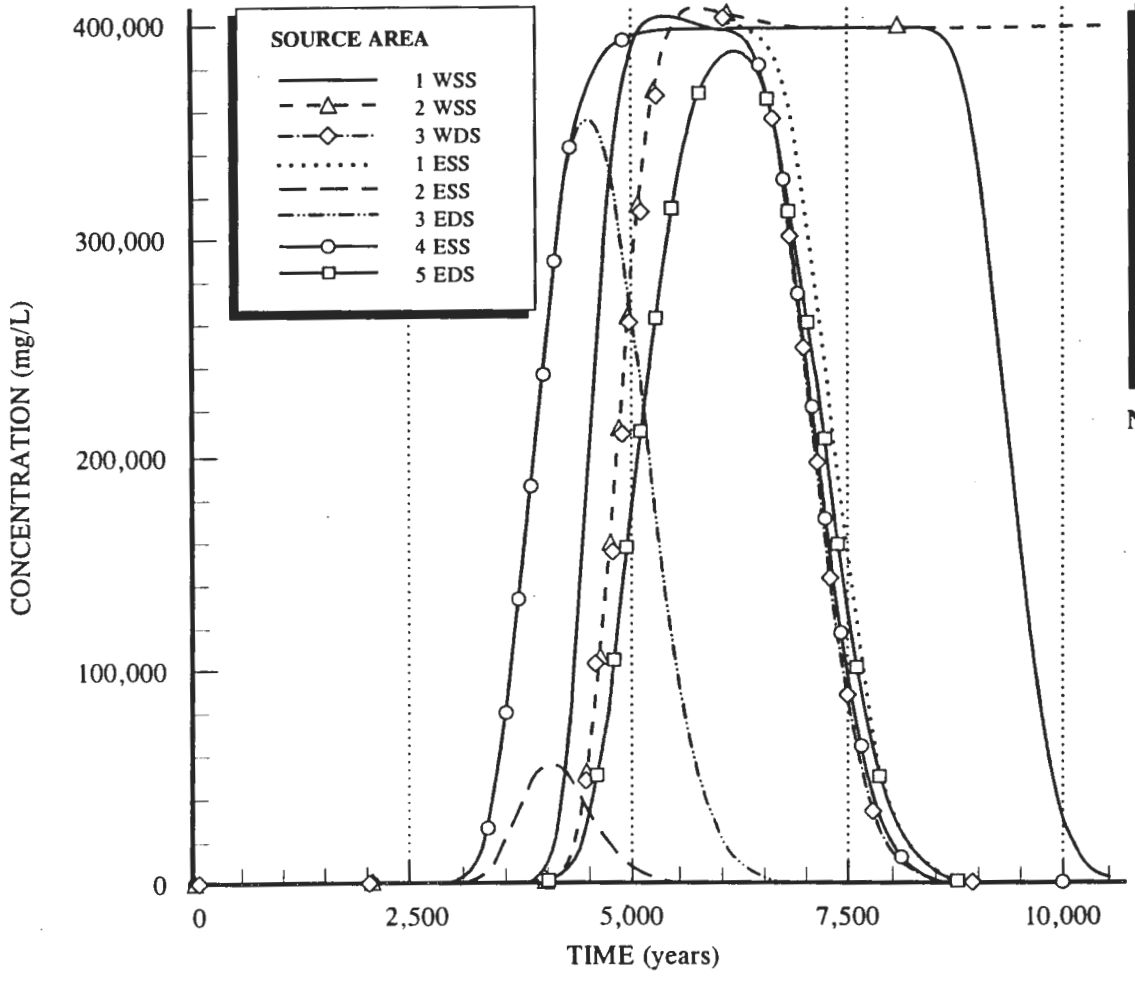


Figure F.3.3.1 Predicted Concentration for the In Situ Fill and Cap Alternative (K_d = 0) at the Vadose Zone/Groundwater Interface



Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Conc. (mg/l)
1WSS	3,250	4,830	4.00E+05
2WSS	3,380	5,370	4.00E+05
3WDS	3,380	5,480	4.00E+05
1ESS	2,340	5,300	4.00E+05
2ESS	2,450	4,080	5.51E+04
3EDS	2,330	4,600	3.57E+05
4ESS	2,330	5,940	4.00E+05
5EDS	3,230	6,300	3.99E+05

NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas

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Figure F.3.3.2 Predicted Nitrate Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative

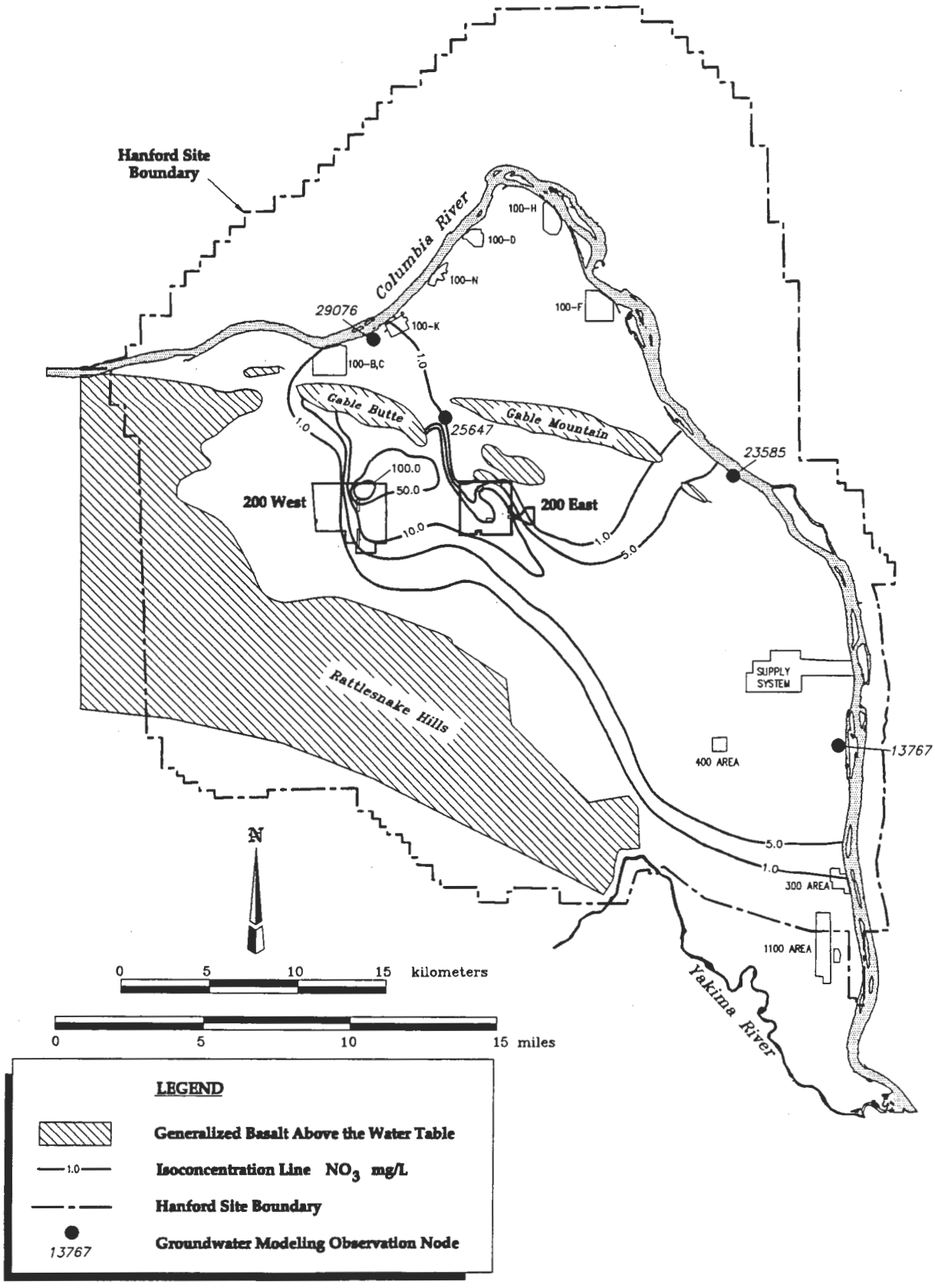
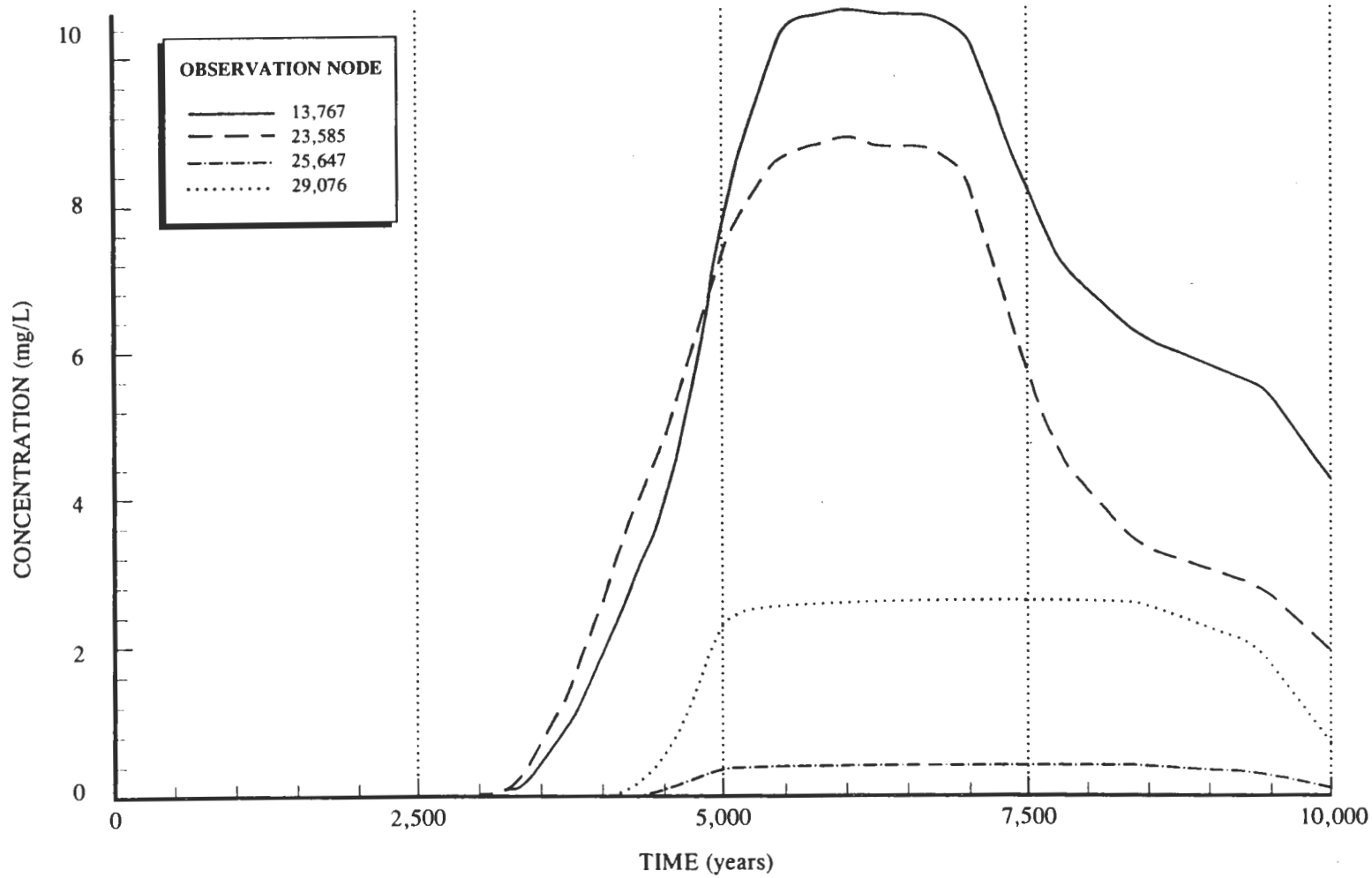


Figure F.3.3.3 Predicted Concentration of Nitrate in Groundwater at Selected Locations for the In Situ Fill and Cap Alternative (K_d = 0)



NOTE: See Figure F.3.3.2 for observation node location

Figure F.3.3.4 Predicted Technetium-99 Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative

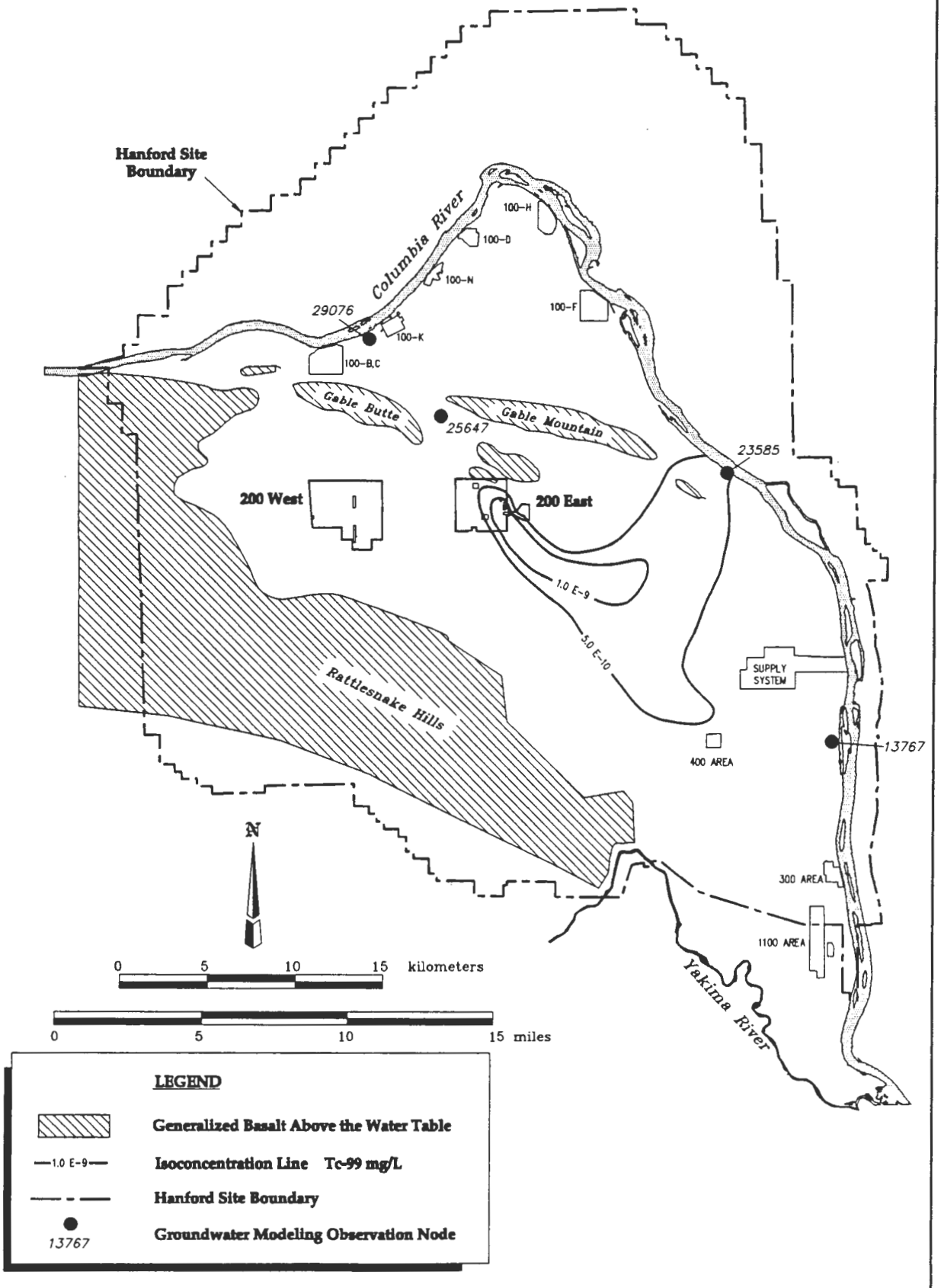


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Figure F.3.3.5 Predicted Iodine-129 Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative

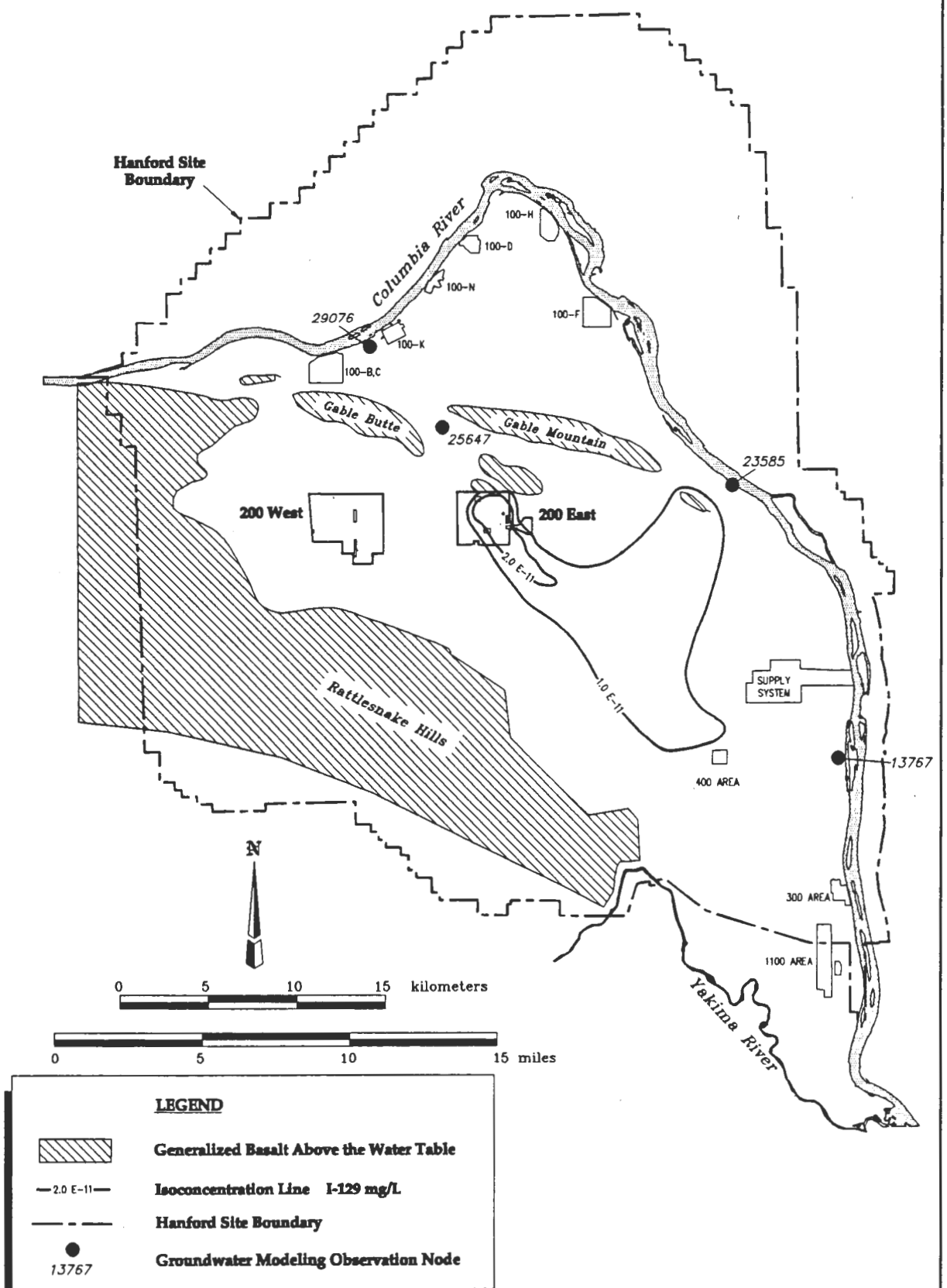

Figure F.3.3.6 Predicted Carbon-14 Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative

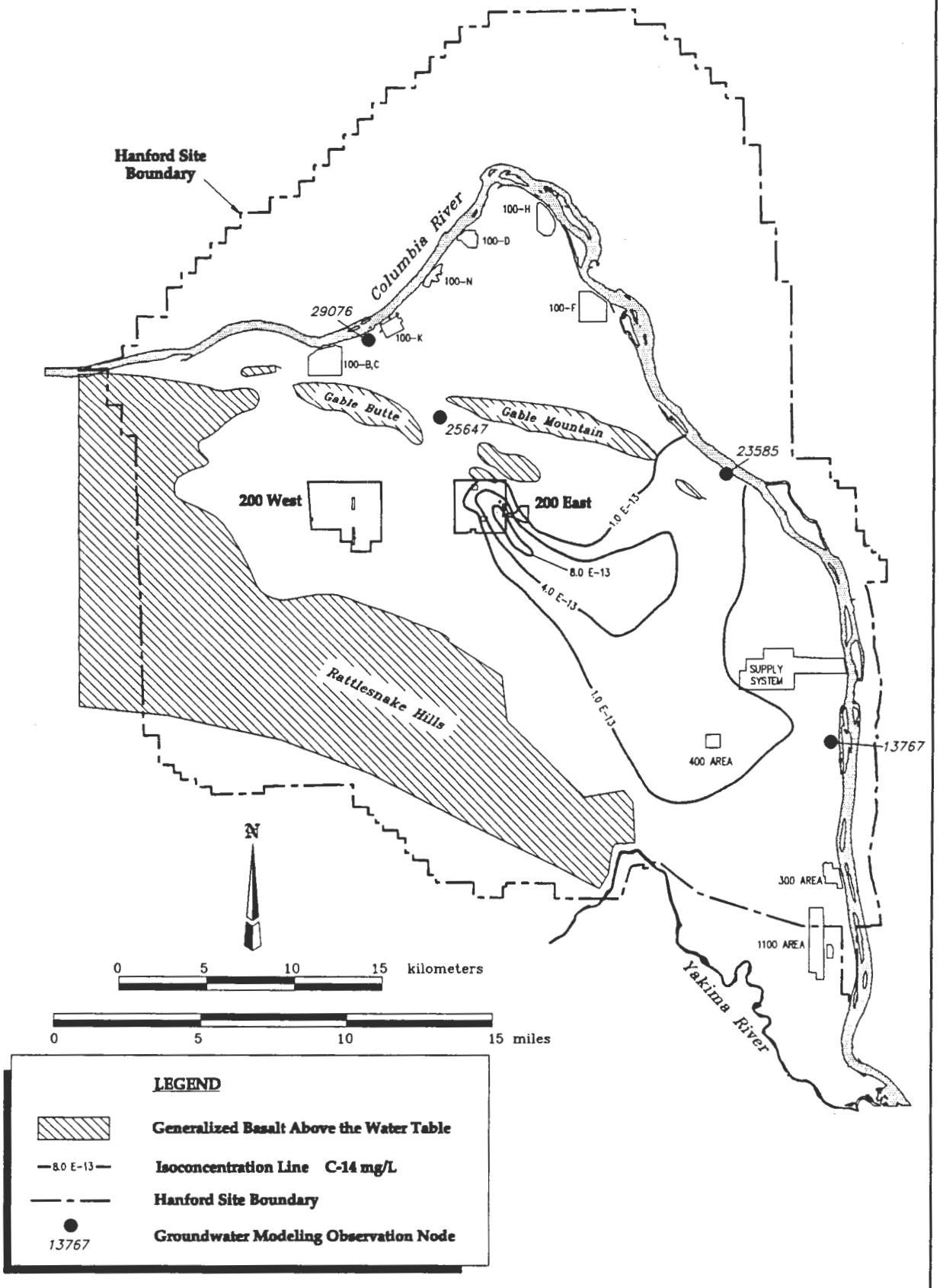

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Figure F.3.3.7 Predicted Uranium-238 Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative

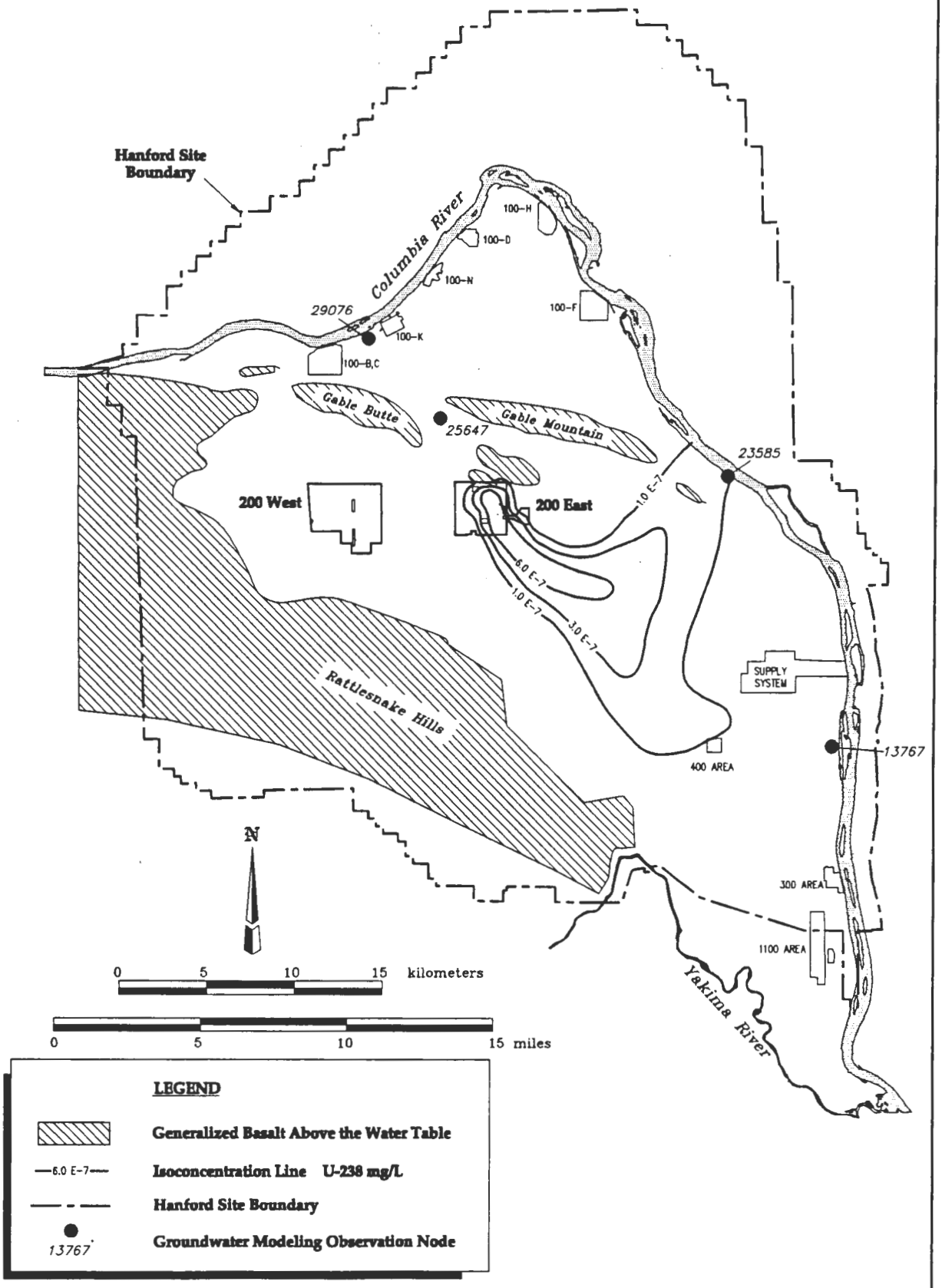

Figure F.3.3.8 Predicted Nitrate Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative

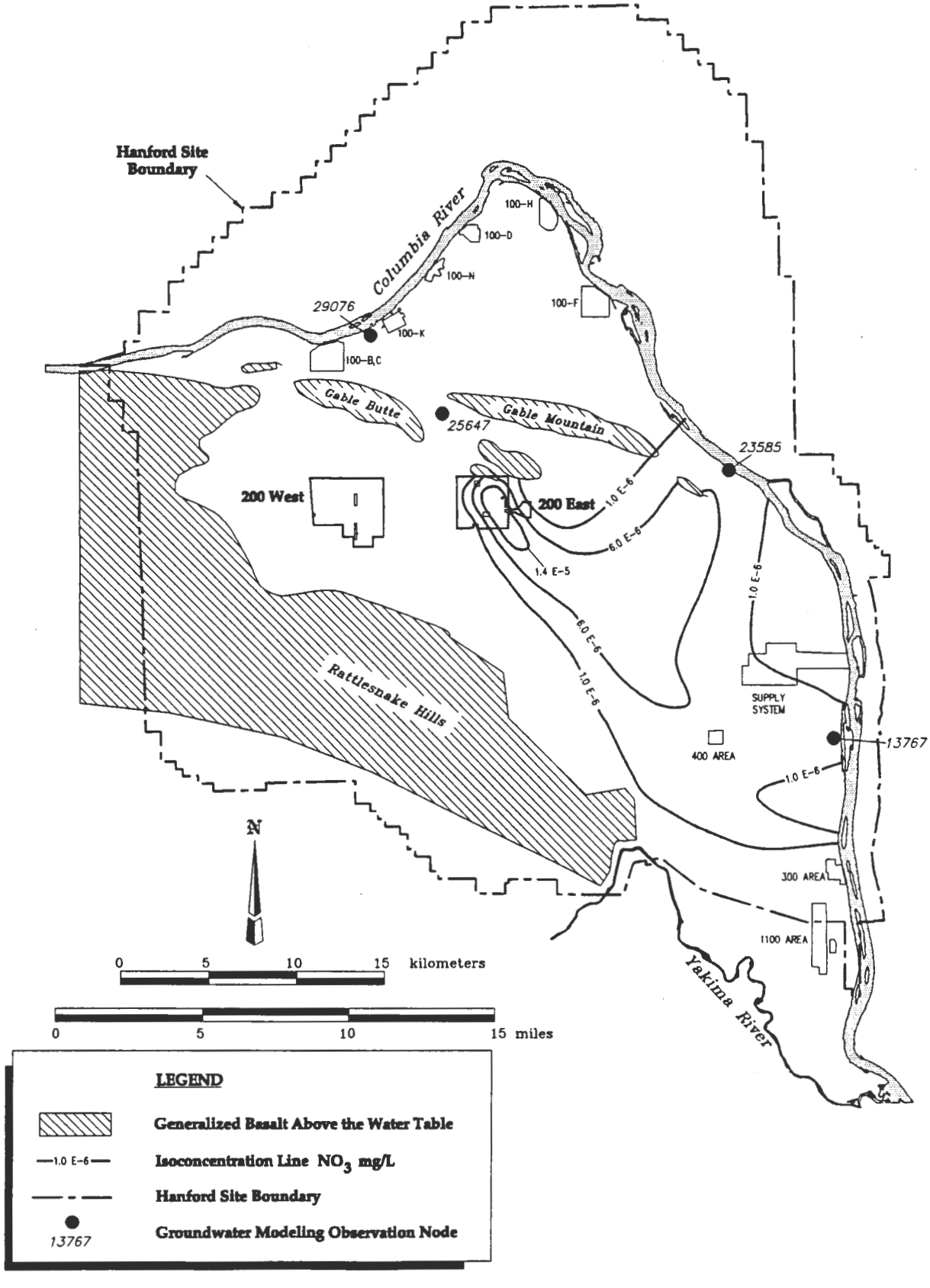

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Figure F.3.3.9 Predicted Technetium-99 Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative

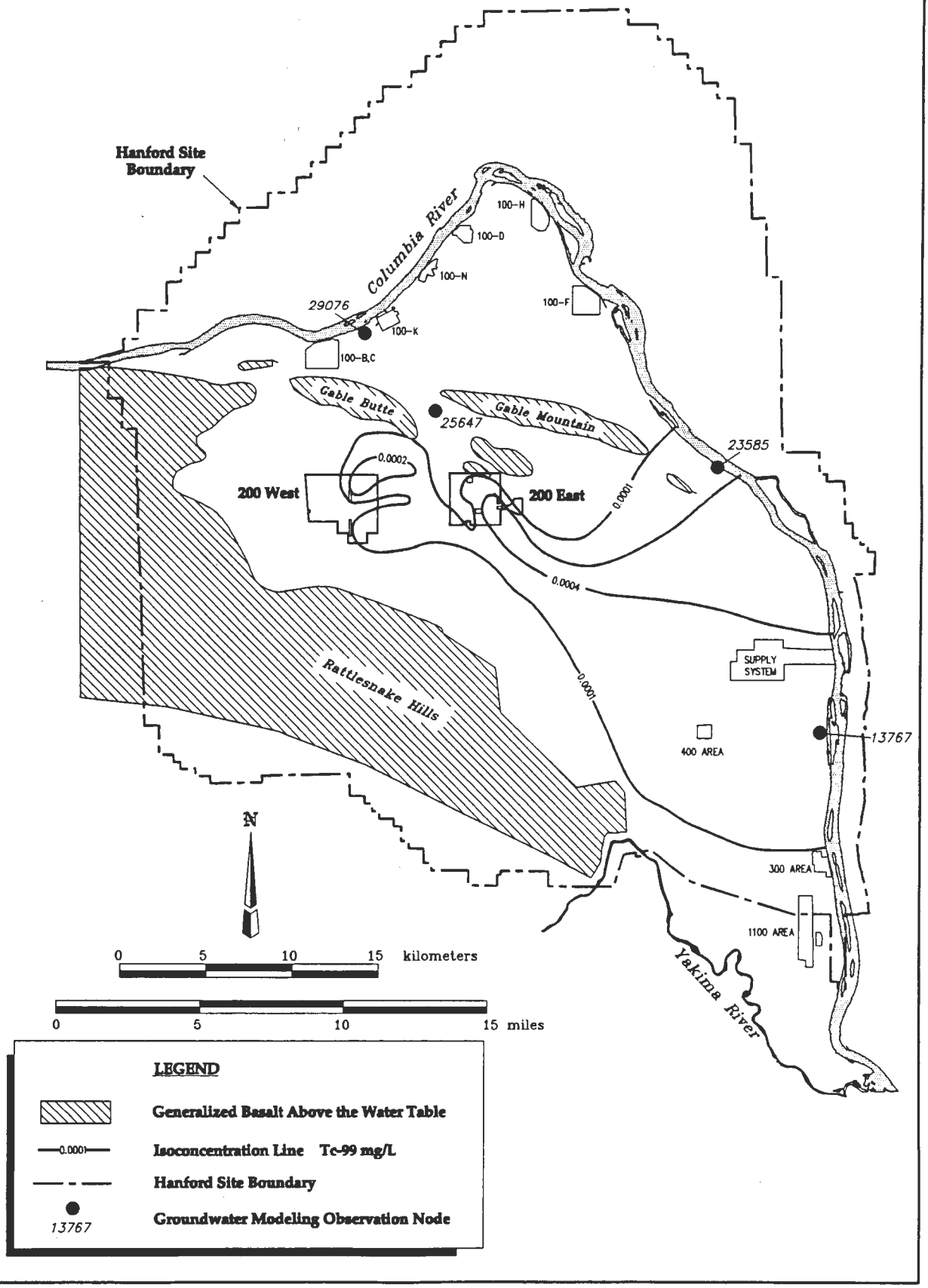

Figure F.3.3.10 Predicted Iodine-129 Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative

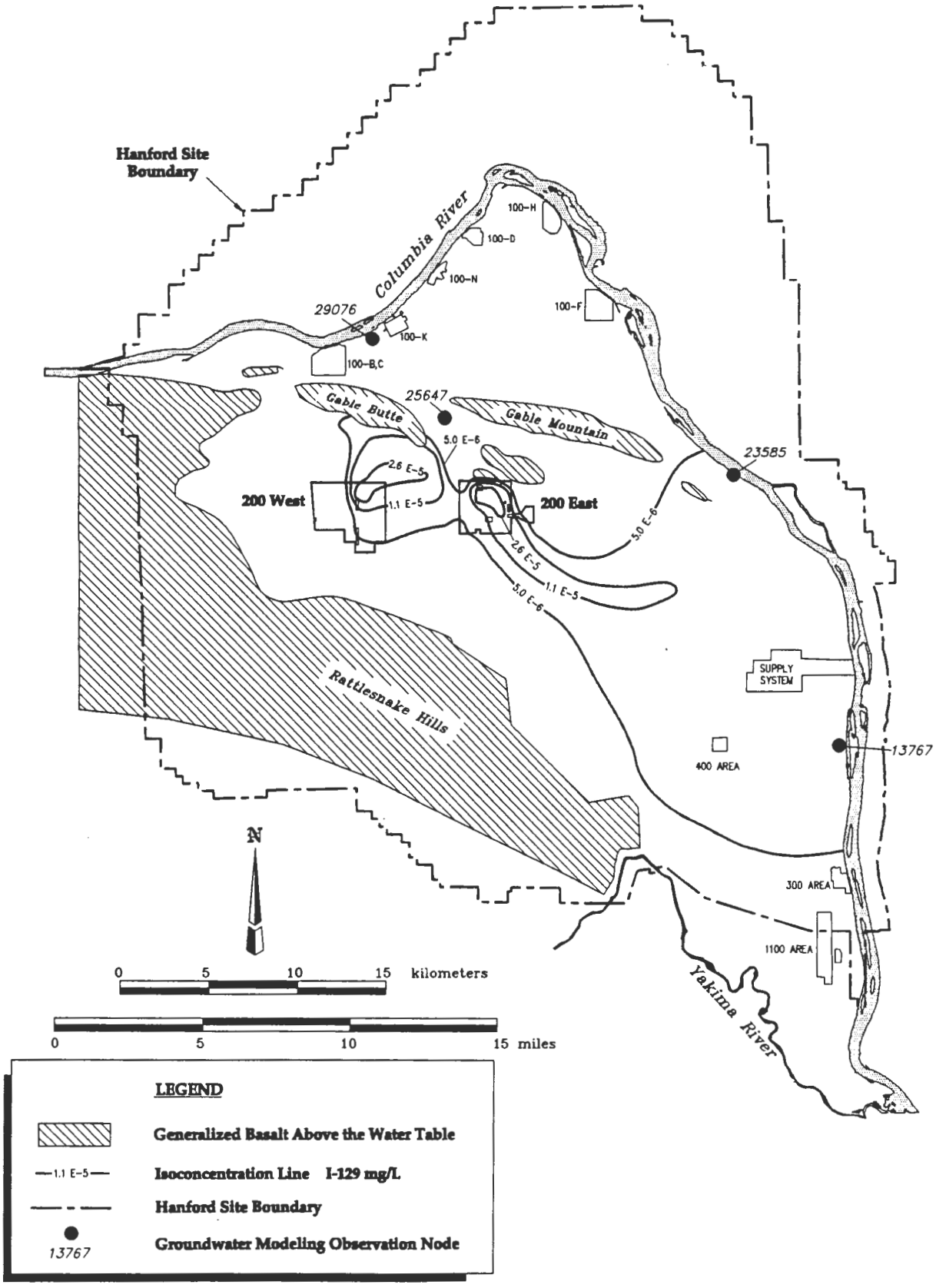

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Figure F.3.3.11 Predicted Carbon-14 Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative

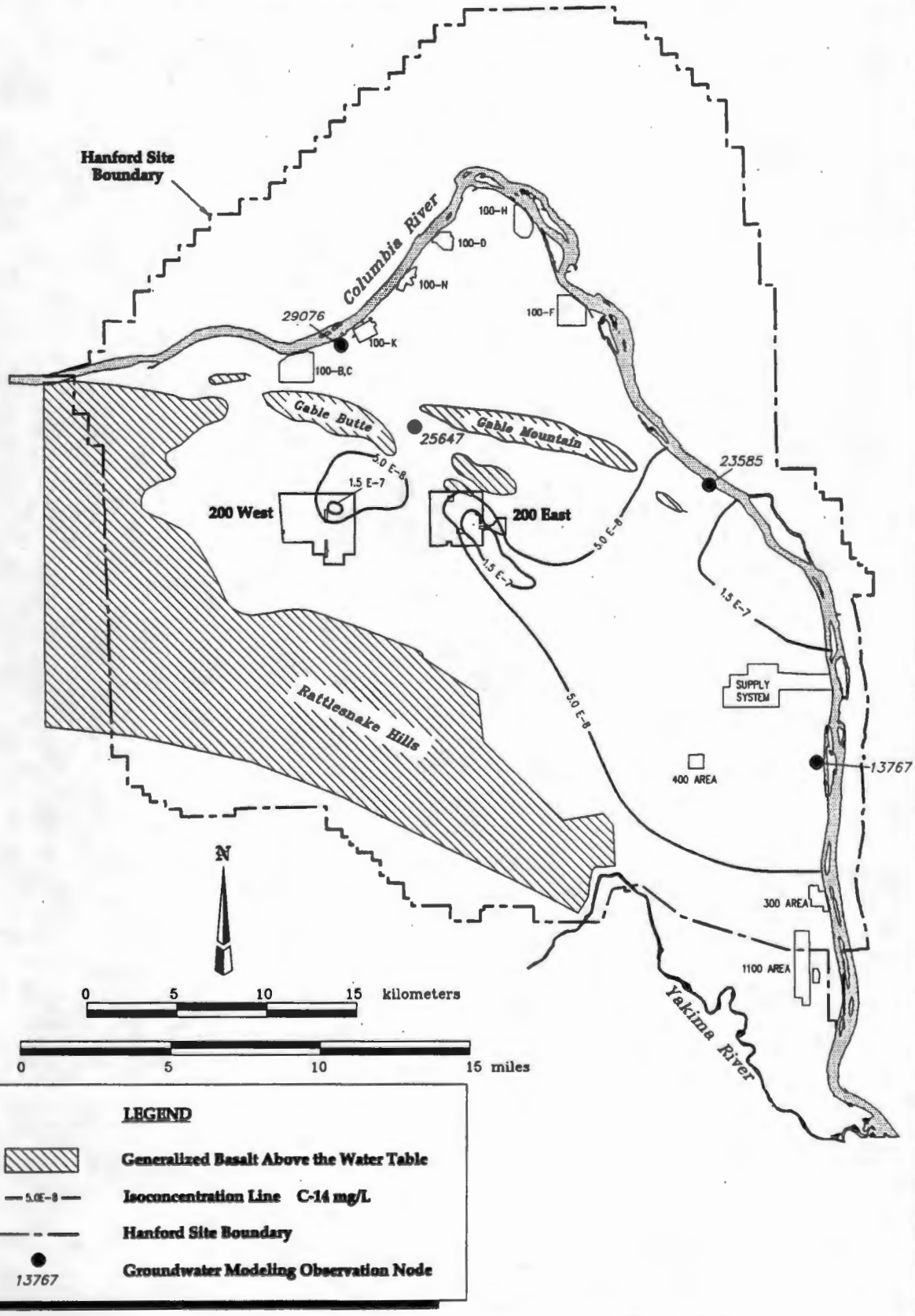

Figure F.3.3.12 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative

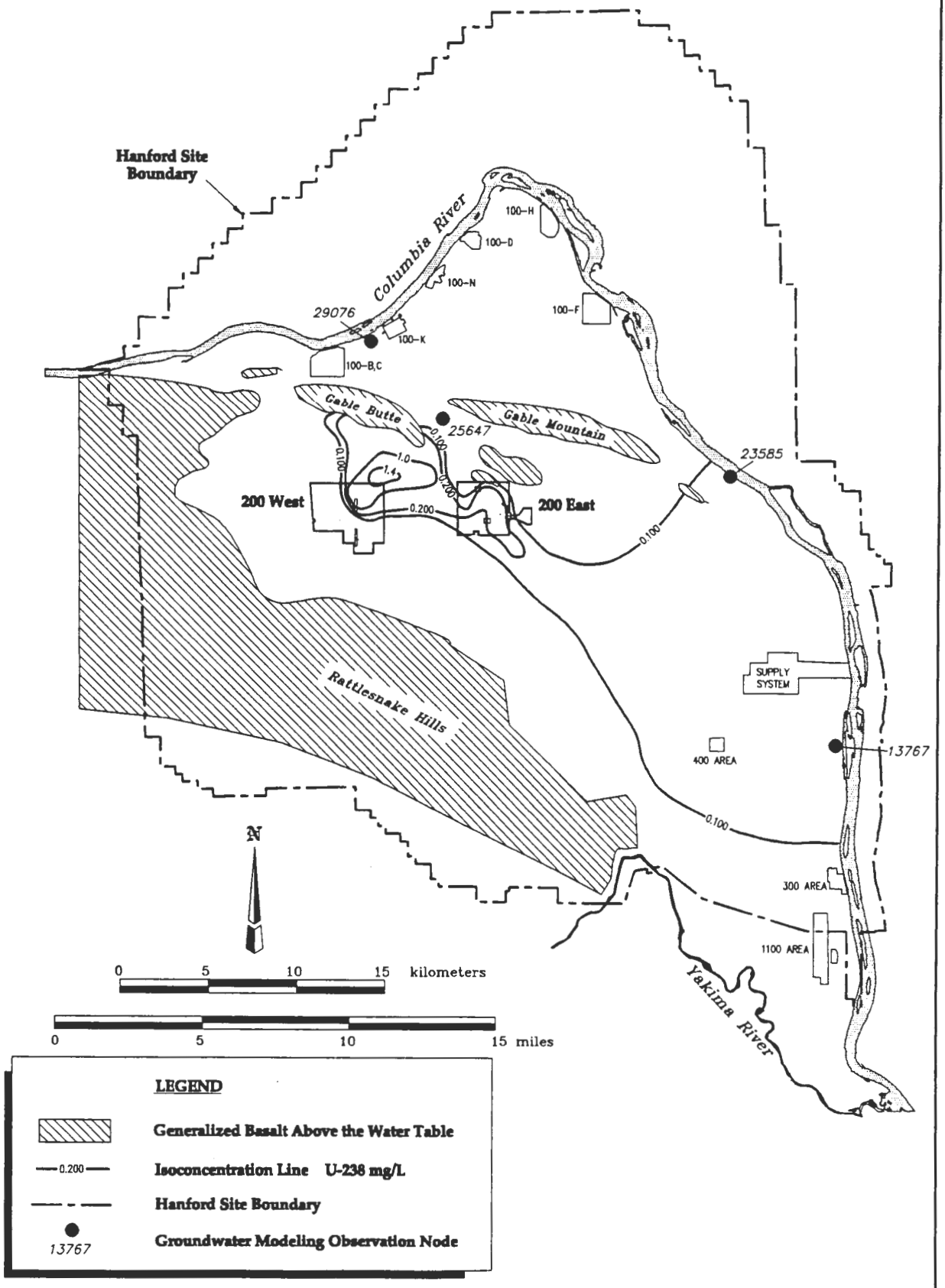

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Figure F.3.3.13 Predicted Technetium-99 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative

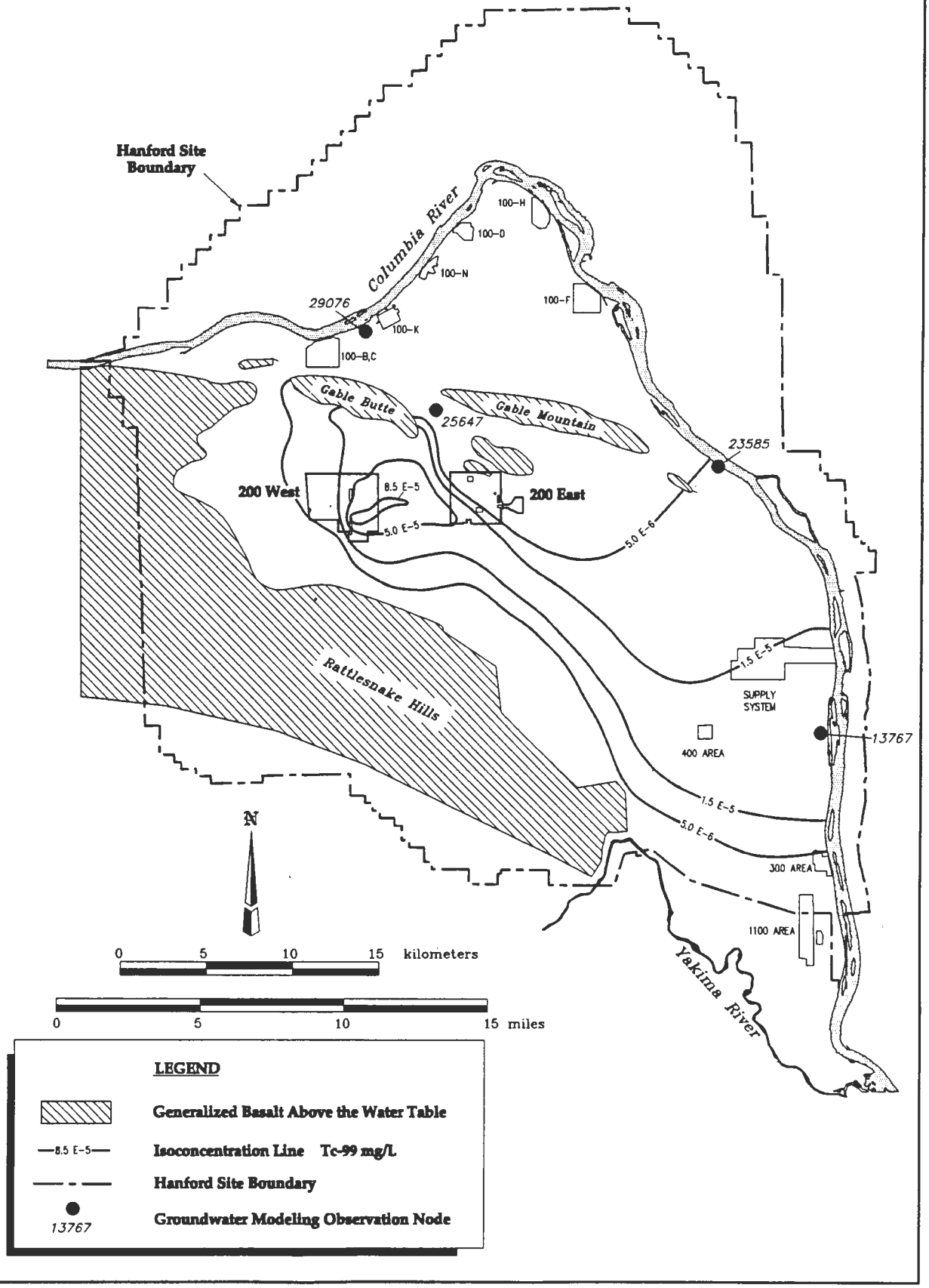

Figure F.3.3.14 Predicted Iodine-129 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative

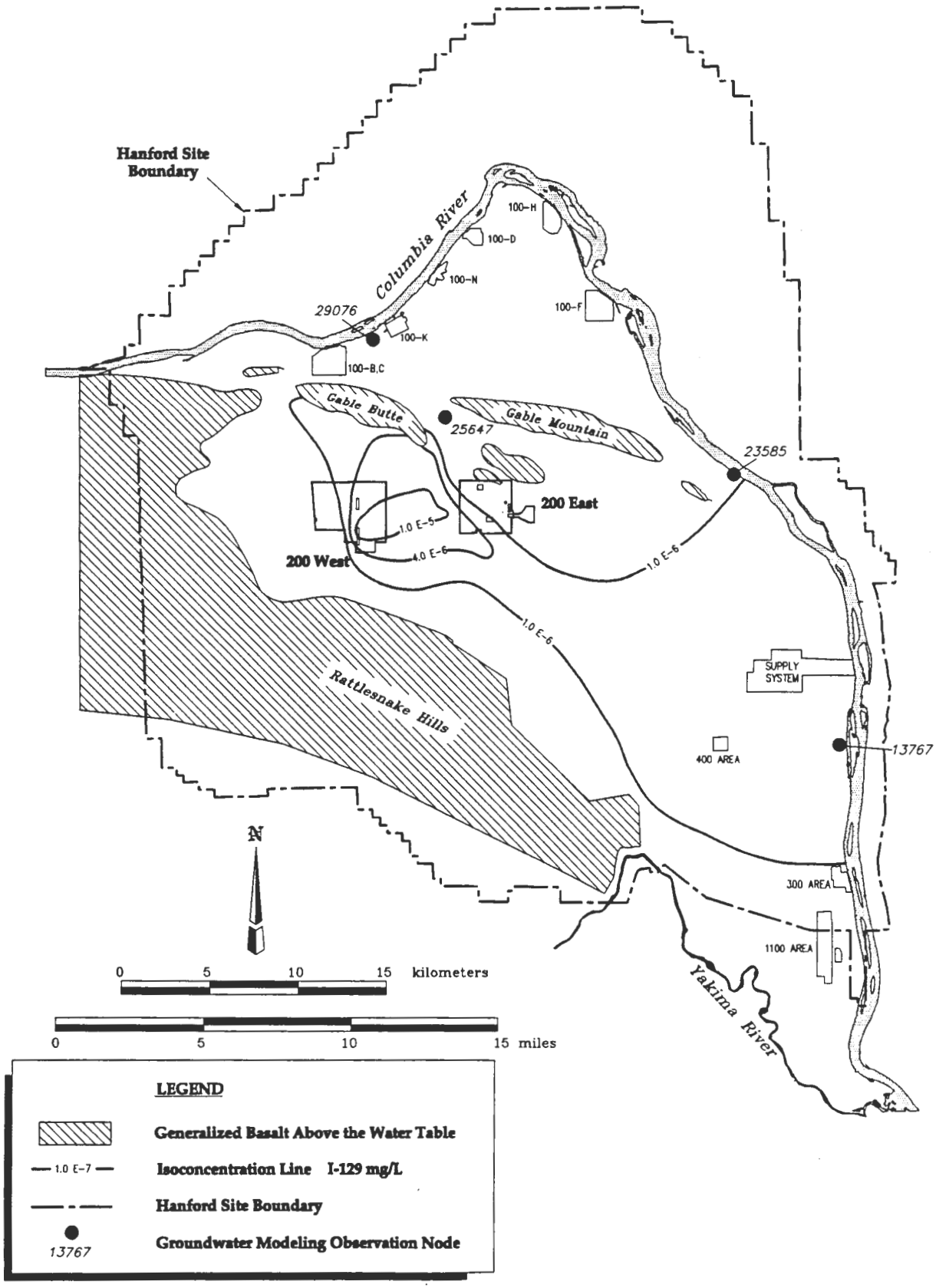

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Figure F.3.3.15 Predicted Carbon-14 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative

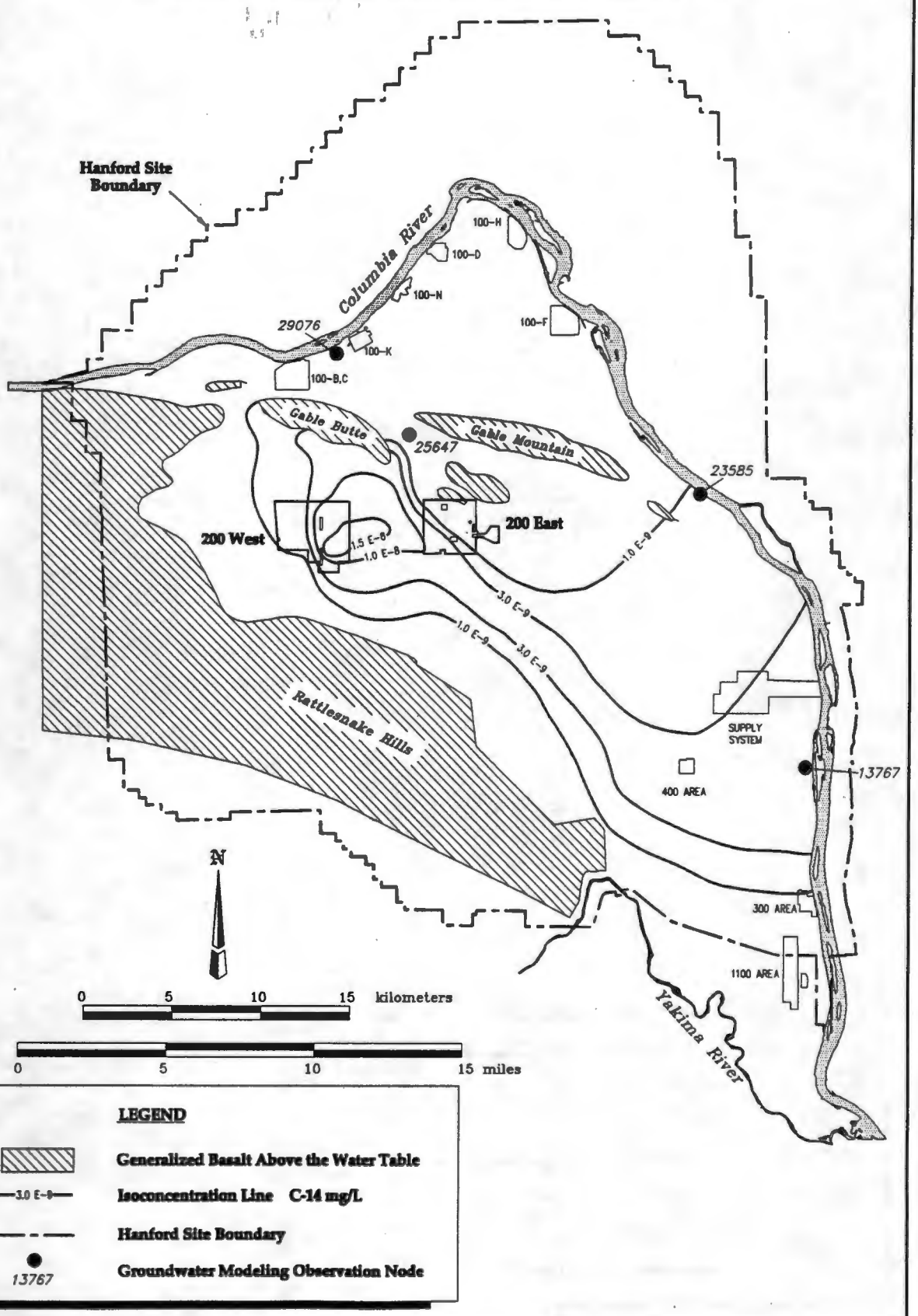

Figure F.3.3.16 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative

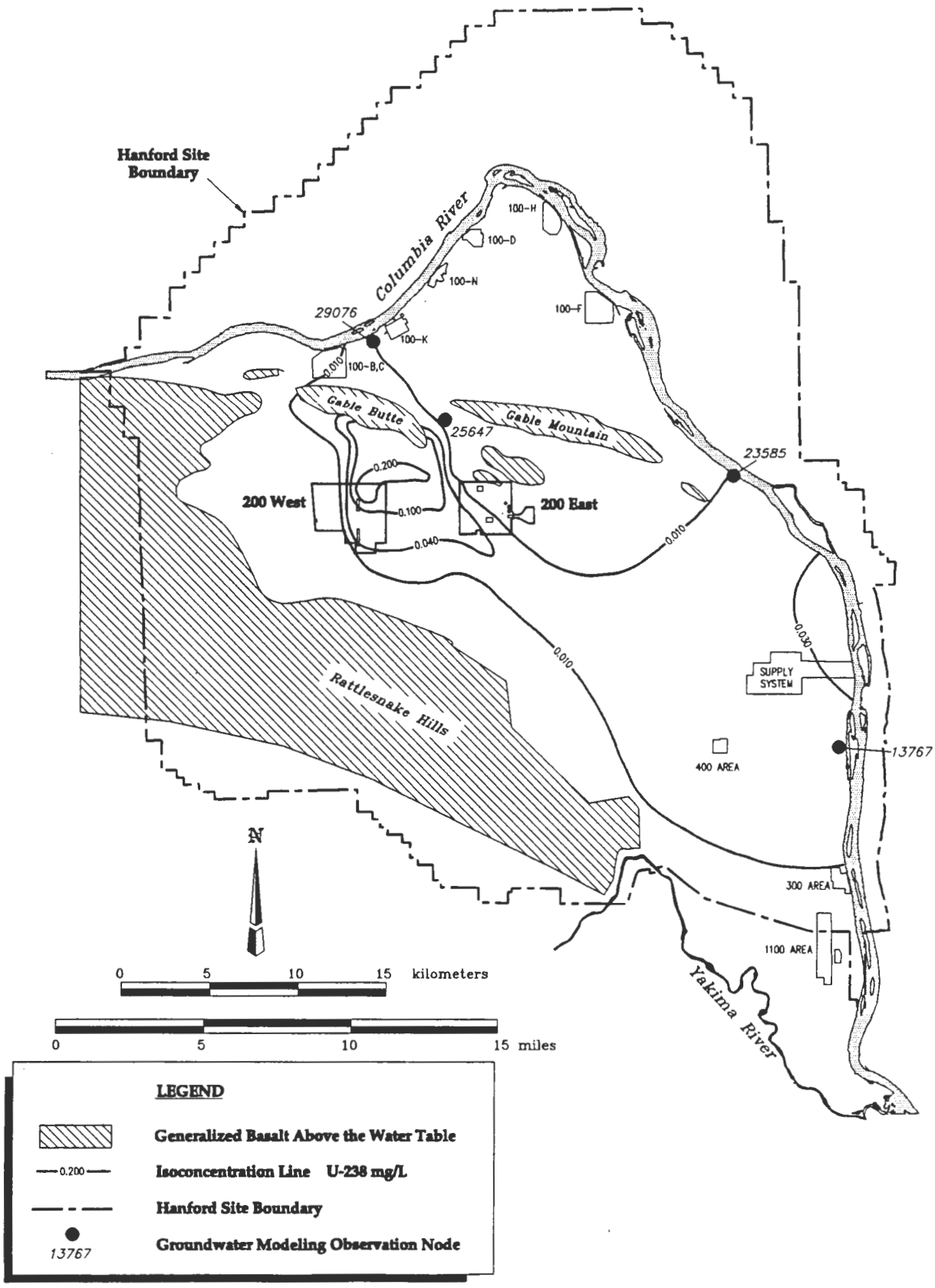

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Figure F.3.3.17 Predicted Nitrate Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative

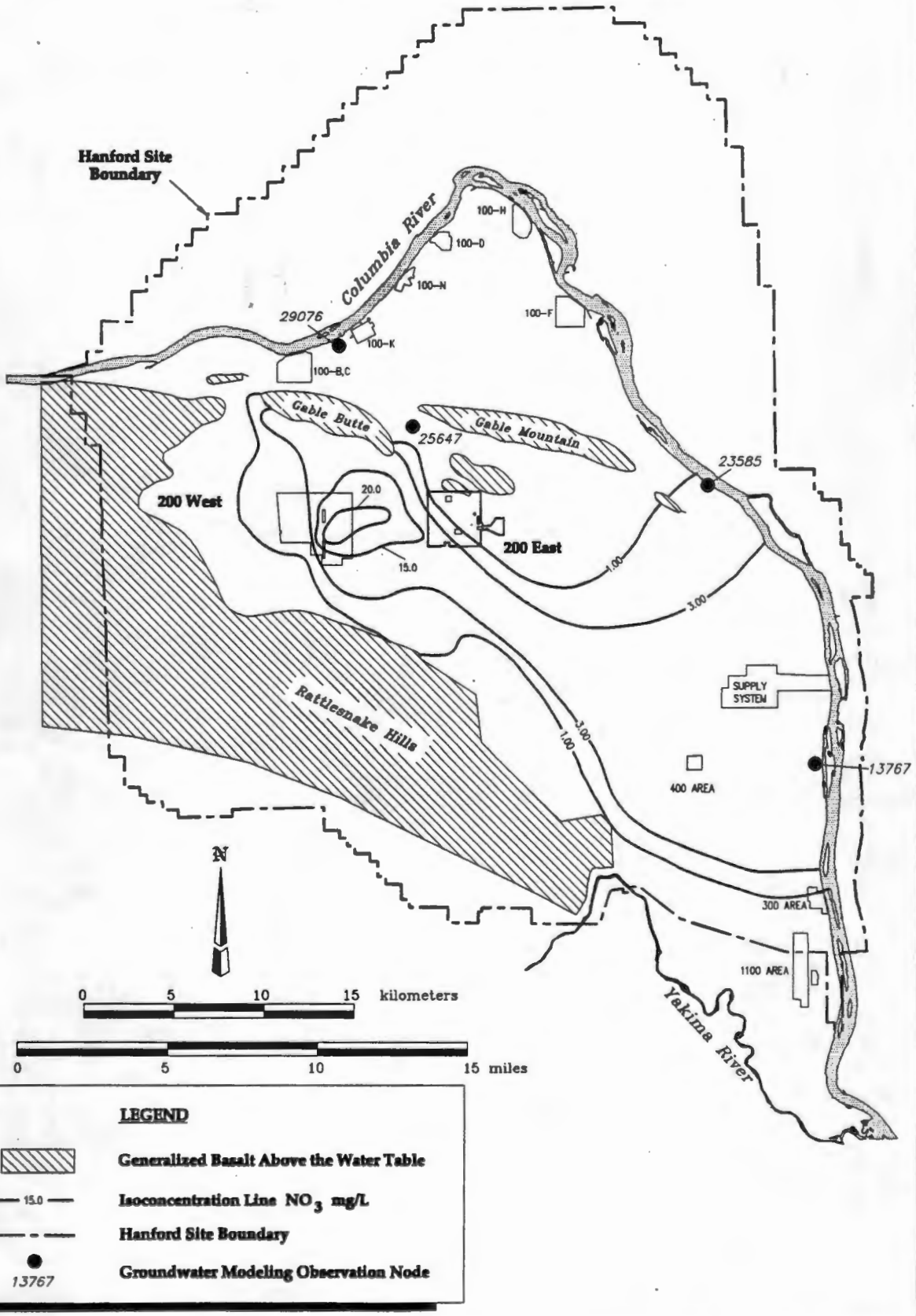
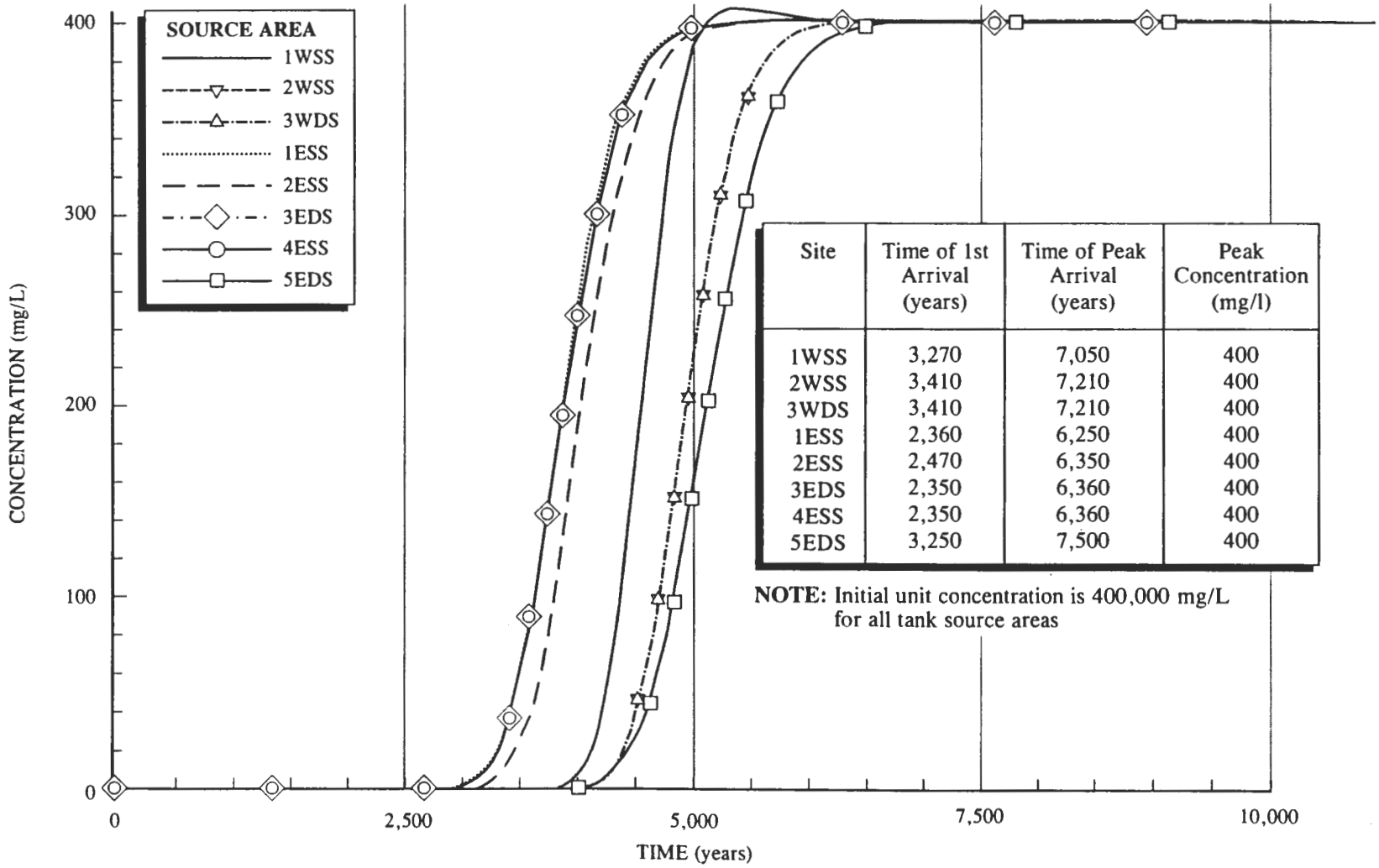


Figure F.3.4.1 Predicted Contaminant Concentration for the In Situ Vitrification Alternative at the Vadose Zone/Groundwater Interface



Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Concentration (mg/l)
1WSS	3,270	7,050	400
2WSS	3,410	7,210	400
3WDS	3,410	7,210	400
1ESS	2,360	6,250	400
2ESS	2,470	6,350	400
3EDS	2,350	6,360	400
4ESS	2,350	6,360	400
5EDS	3,250	7,500	400

NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas

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Figure F.3.4.2 Predicted Technetium-99 Concentrations in Groundwater at 5,000 Years for the In Situ Vitrification Alternative

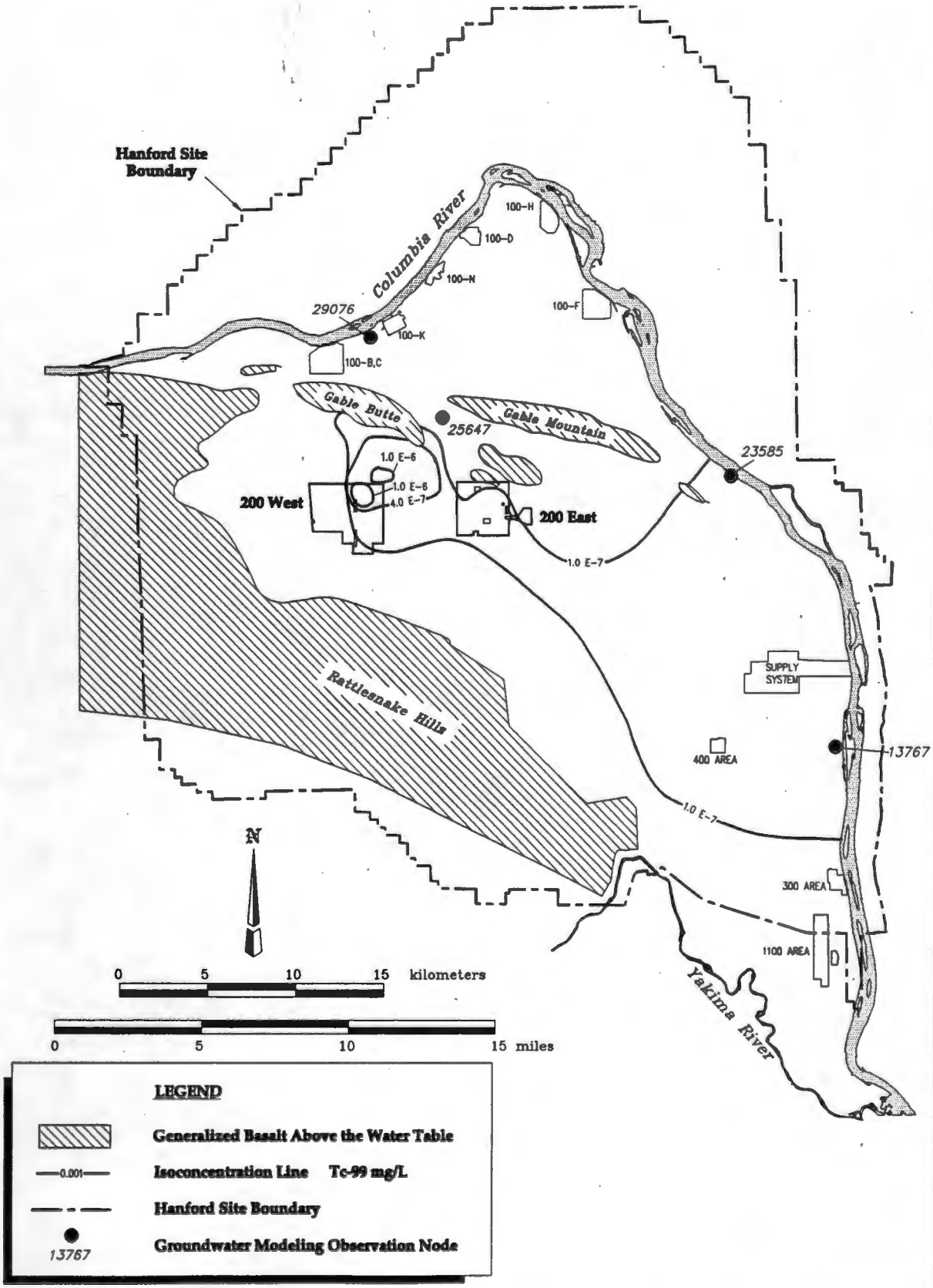


Figure F.3.4.3 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the In Situ Vitrification Alternative

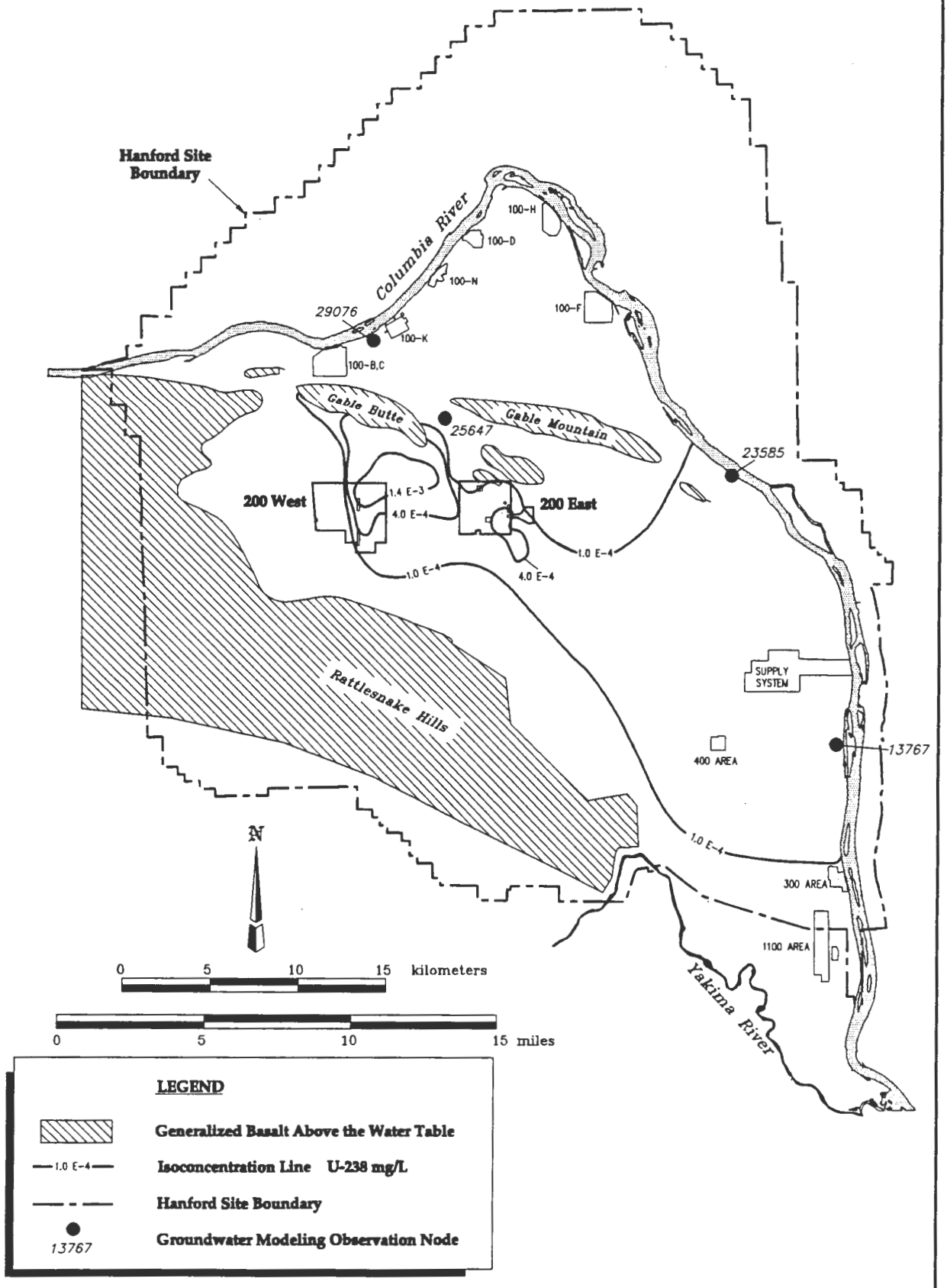
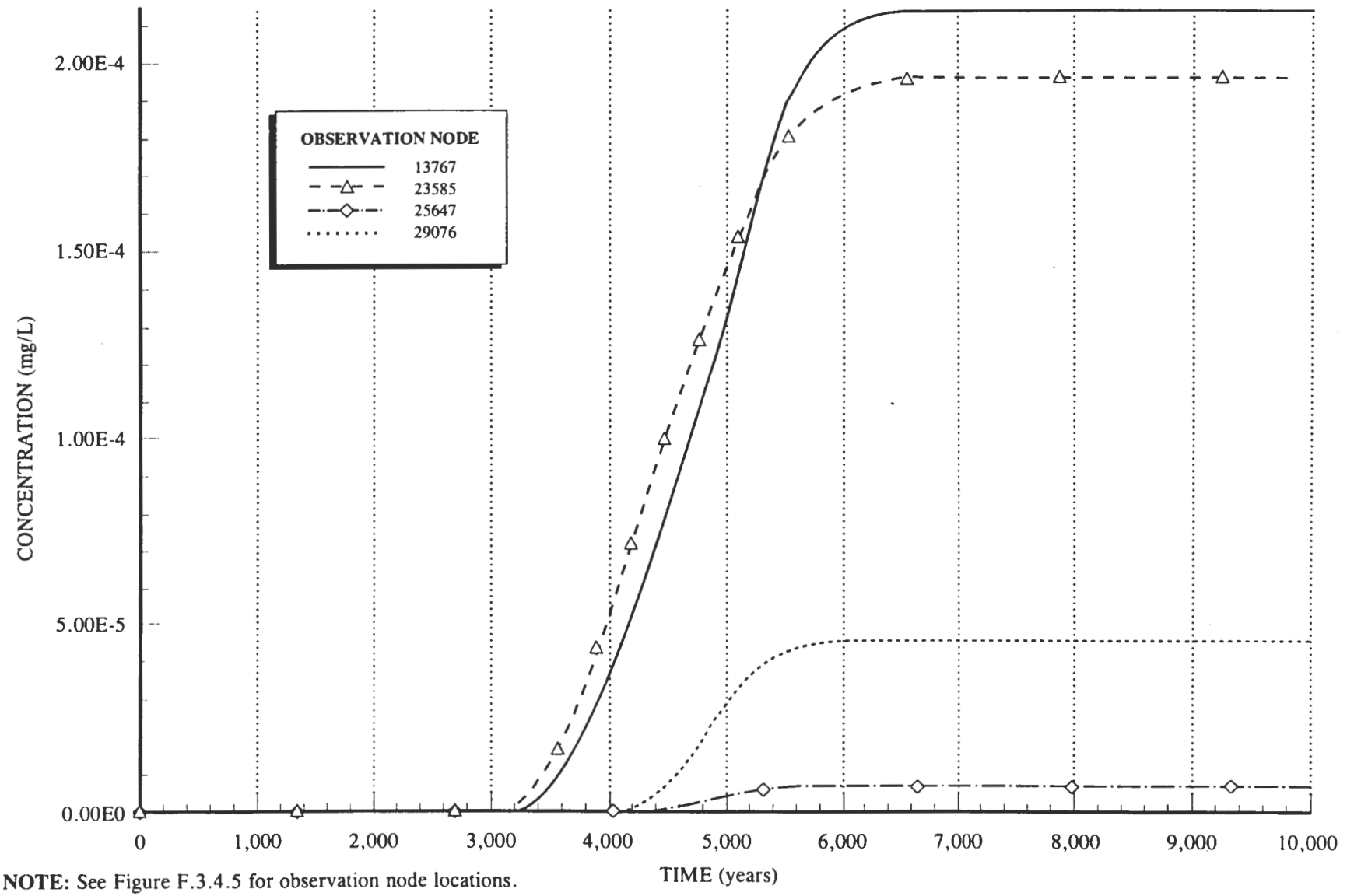


Figure F.3.4.4 Predicted Concentration of Uranimum-238 in Groundwater at Selected Locations for the In Situ Vitrification Alternative (K_d=0)



NOTE: See Figure F.3.4.5 for observation node locations.

Figure F.3.4.5 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the In Situ Vitrification Alternative

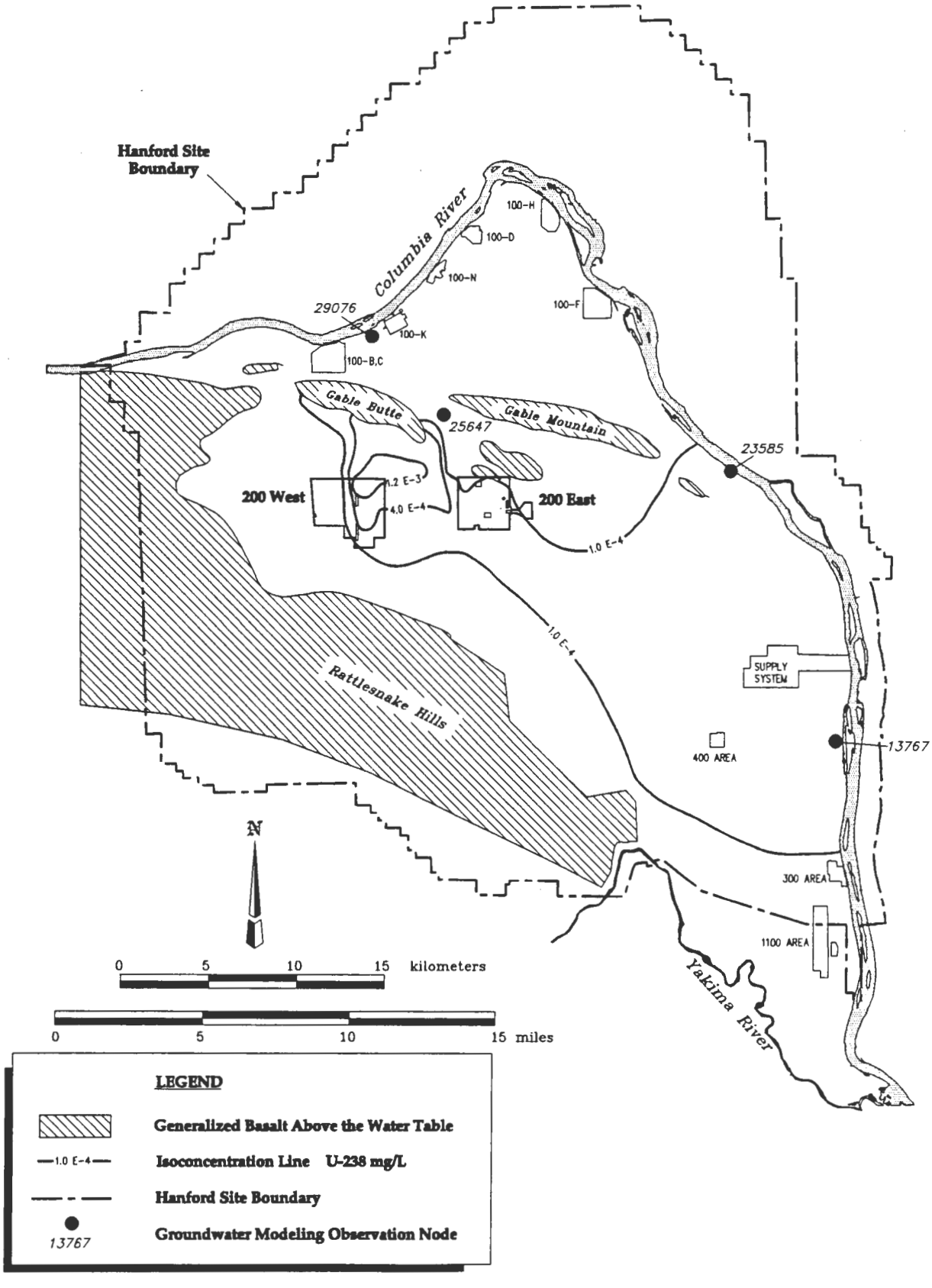
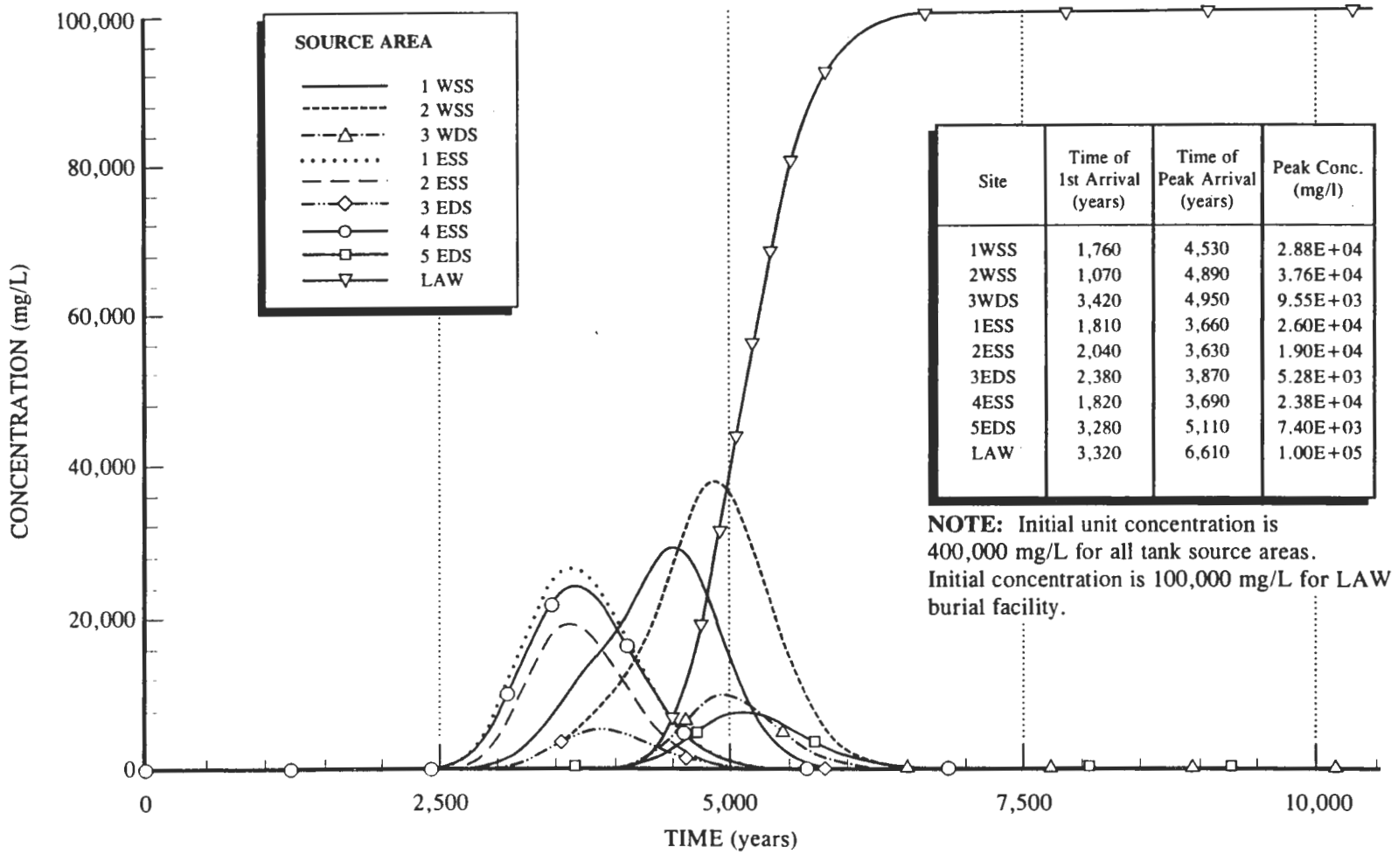


Figure F.3.5.1 Predicted Contaminant Concentration for the Ex Situ Intermediate Separations Alternative at the Vadose Zone/Groundwater Interface ($K_d = 0$)



Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Conc. (mg/l)
1WSS	1,760	4,530	2.88E+04
2WSS	1,070	4,890	3.76E+04
3WDS	3,420	4,950	9.55E+03
1ESS	1,810	3,660	2.60E+04
2ESS	2,040	3,630	1.90E+04
3EDS	2,380	3,870	5.28E+03
4ESS	1,820	3,690	2.38E+04
5EDS	3,280	5,110	7.40E+03
LAW	3,320	6,610	1.00E+05

NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas. Initial concentration is 100,000 mg/L for LAW burial facility.

Figure F.3.5.2 Predicted Nitrate Concentrations in Groundwater at 5,000 Years for the Ex Situ Intermediate Separations Alternative (Tank Sources Only)

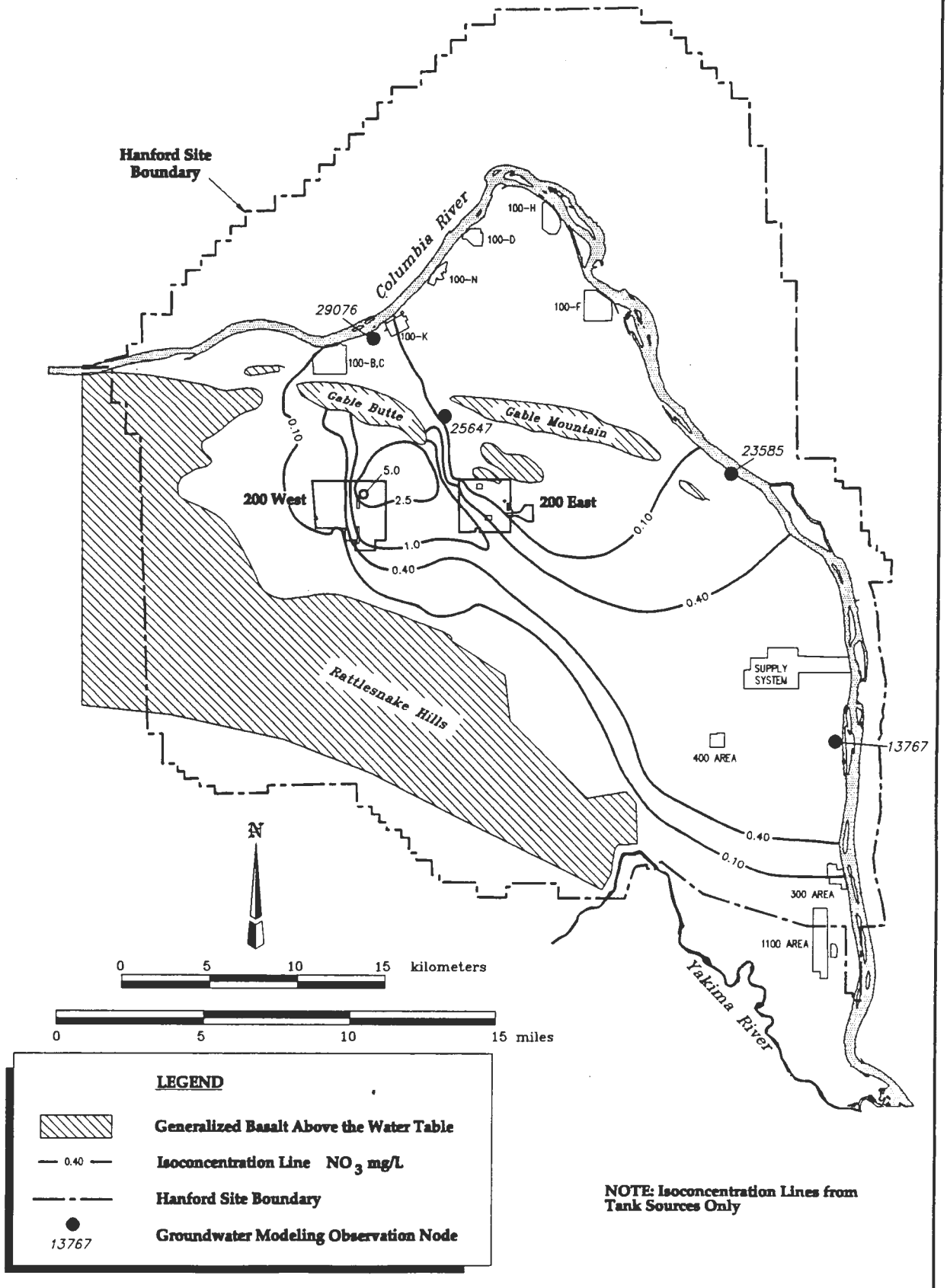
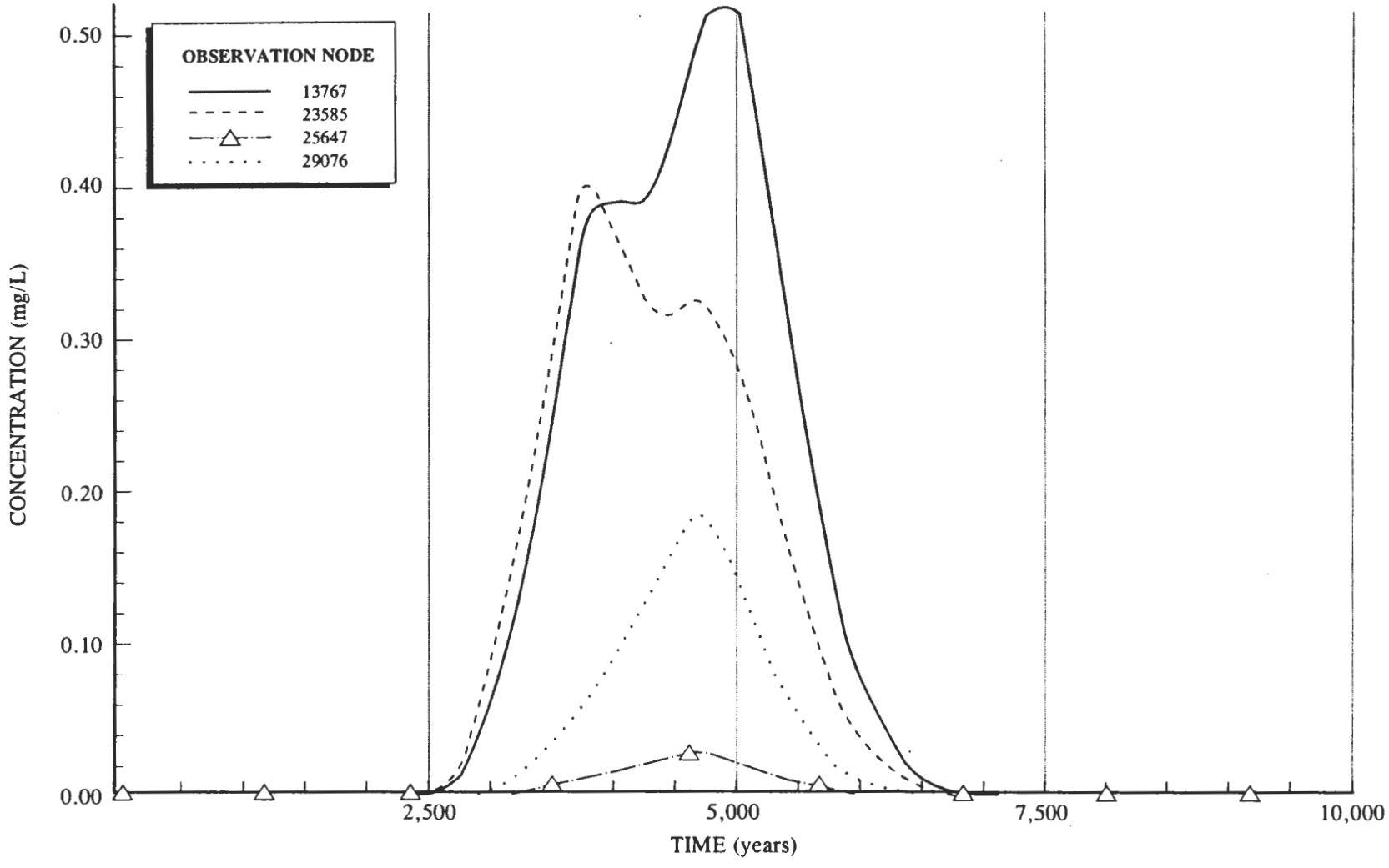


Figure F.3.5.3 Predicted Concentration of Nitrate in Groundwater at Selected Locations for the Ex Situ Intermediate Separations Alternative (Tank Sources Only)



NOTE: See Figure F.3.5.2 for Observation Node locations

Figure F.3.5.4 Predicted Concentration of Uranium-238 at Selected Locations for the Ex Situ Intermediate Separations Alternative (Tank Sources Only)

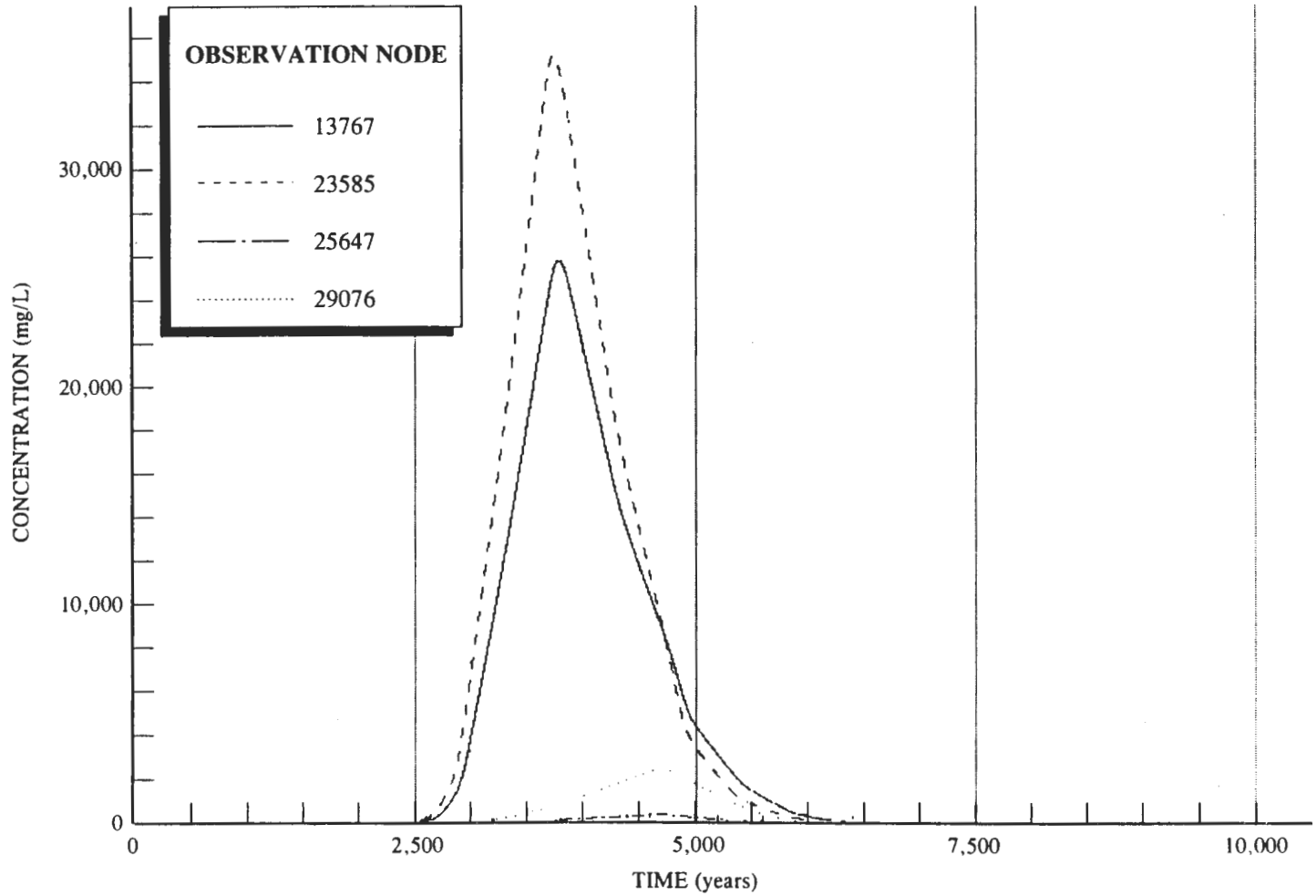
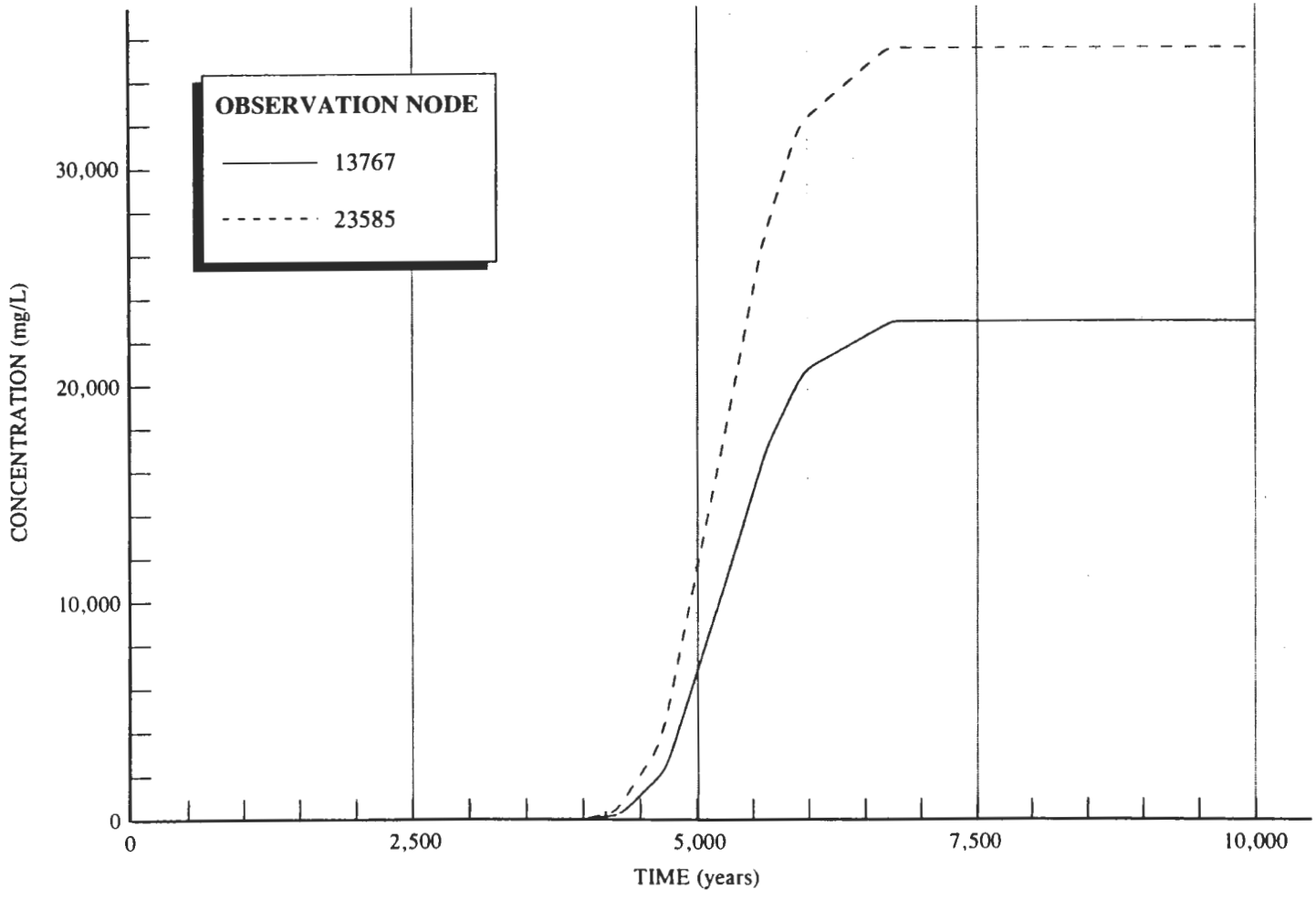


Figure F.3.5.5 Predicted Concentration of Uranium-238 at Selected Locations for the Ex Situ Intermediate Separations Alternative (LAW Vault Sources Only))



NOTE: See Figure F.3.5.2 for observation node locations

Figure F.3.5.6 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ Intermediate Separations Alternative (Tank and LAW Vault Sources Combined)

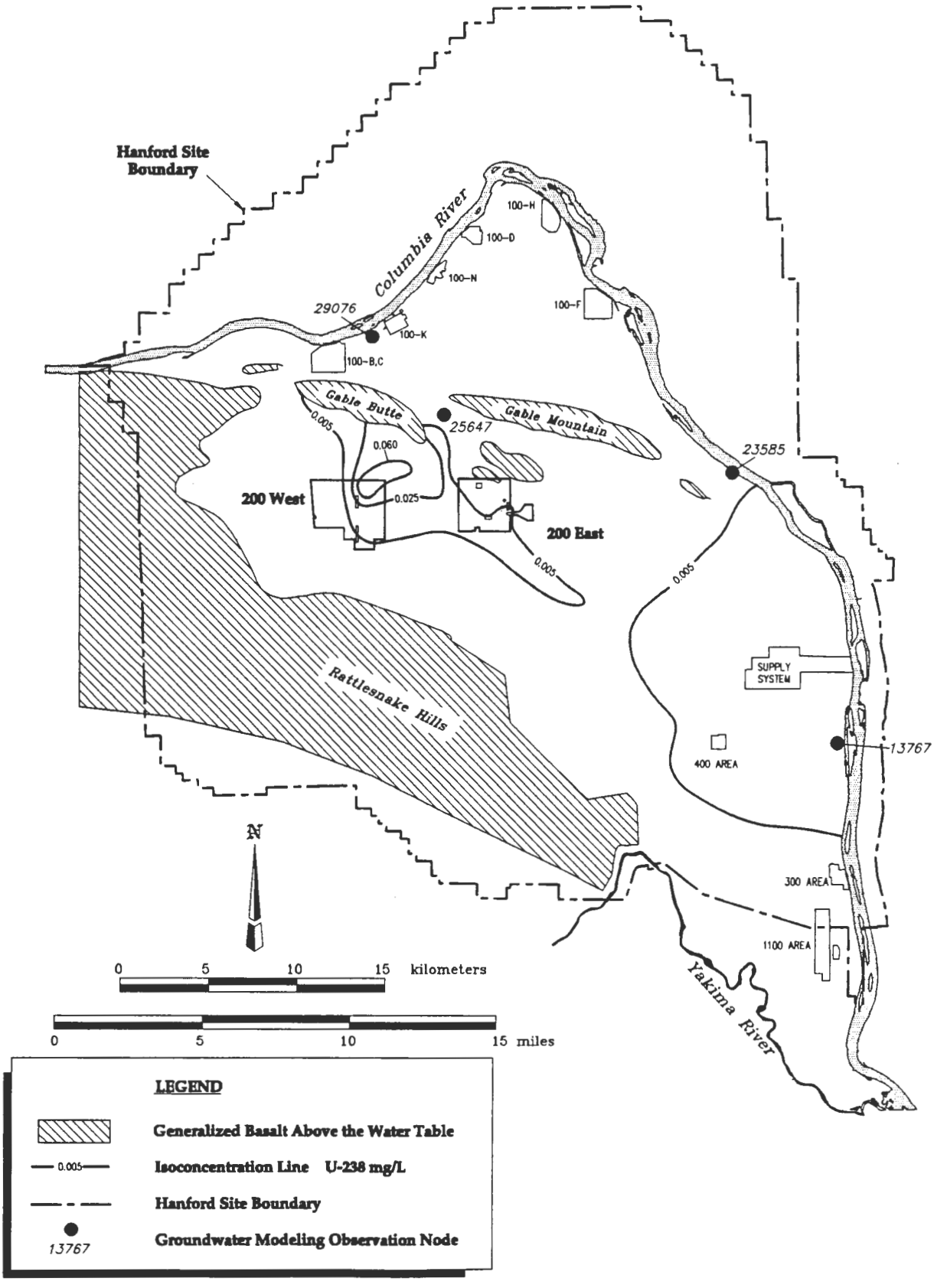


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Figure F.3.6.1 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ No Separations Alternative (Tank Sources Only)

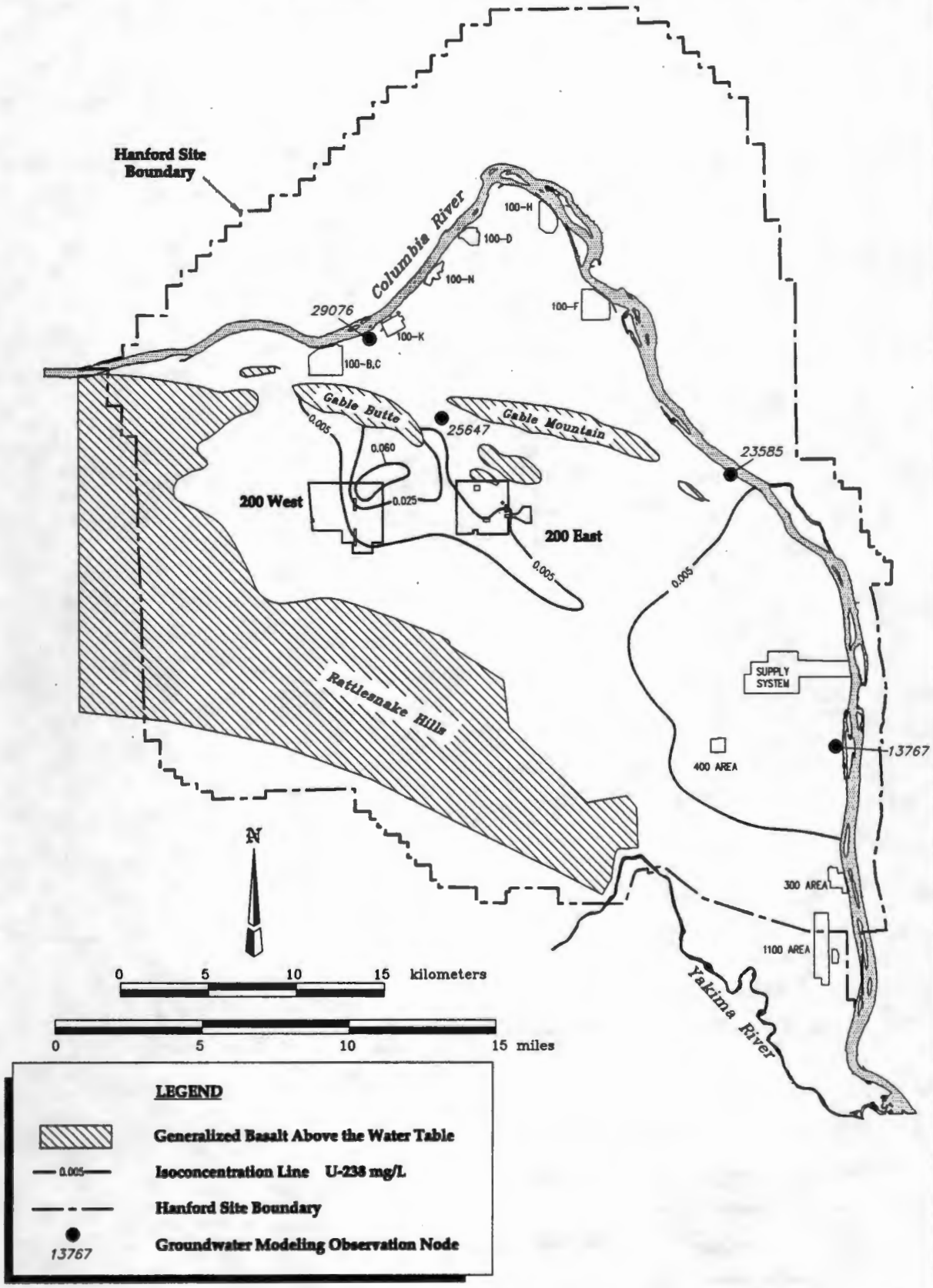

Figure F.3.7.1 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ Extensive Separations Alternative (Tank and LAW Vault Sources Combined)

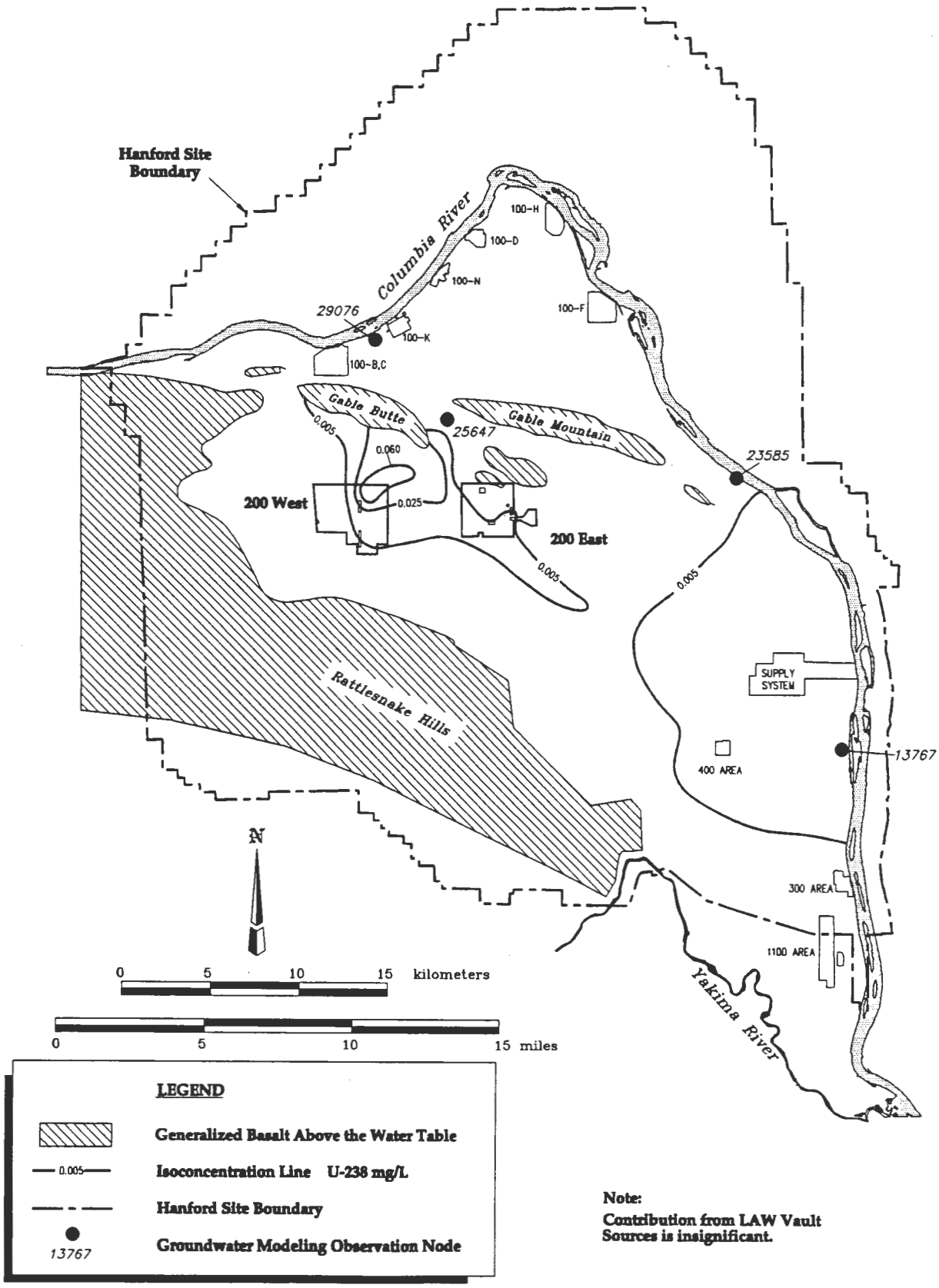

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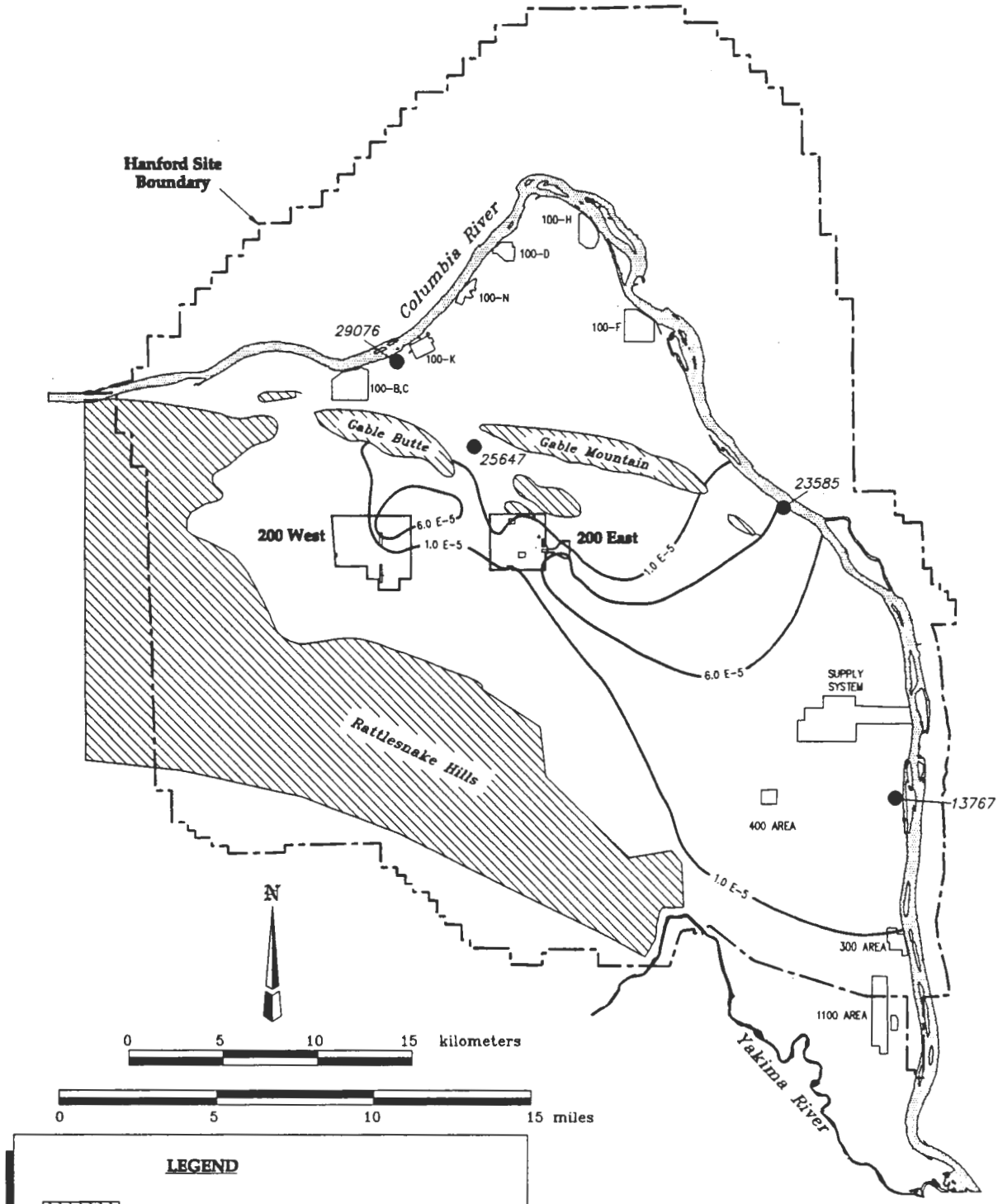
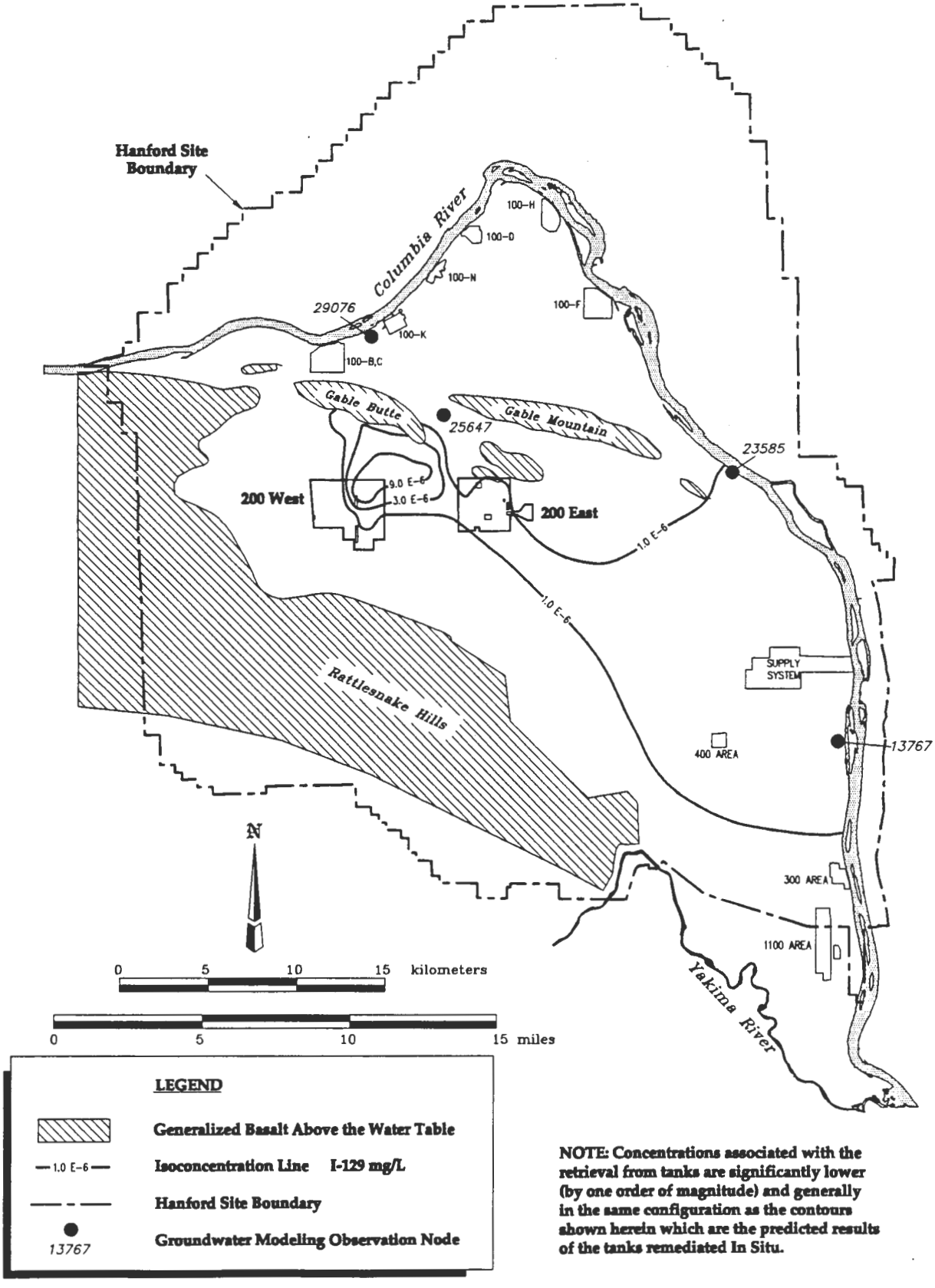
Figure F.3.8.1 Predicted Technetium-99 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination 1 Alternative (Tank Sources Only)



NOTE: Concentrations associated with the retrieval from tanks are significantly lower (by two orders of magnitude) and generally in the same configuration as the contours shown herein which are the predicted results of the tanks remediated In Situ.

Figure F.3.8.2 Predicted Iodine-129 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination 1 Alternative (Tank Sources Only)



NOTE: Concentrations associated with the retrieval from tanks are significantly lower (by one order of magnitude) and generally in the same configuration as the contours shown herein which are the predicted results of the tanks remediated In Situ.

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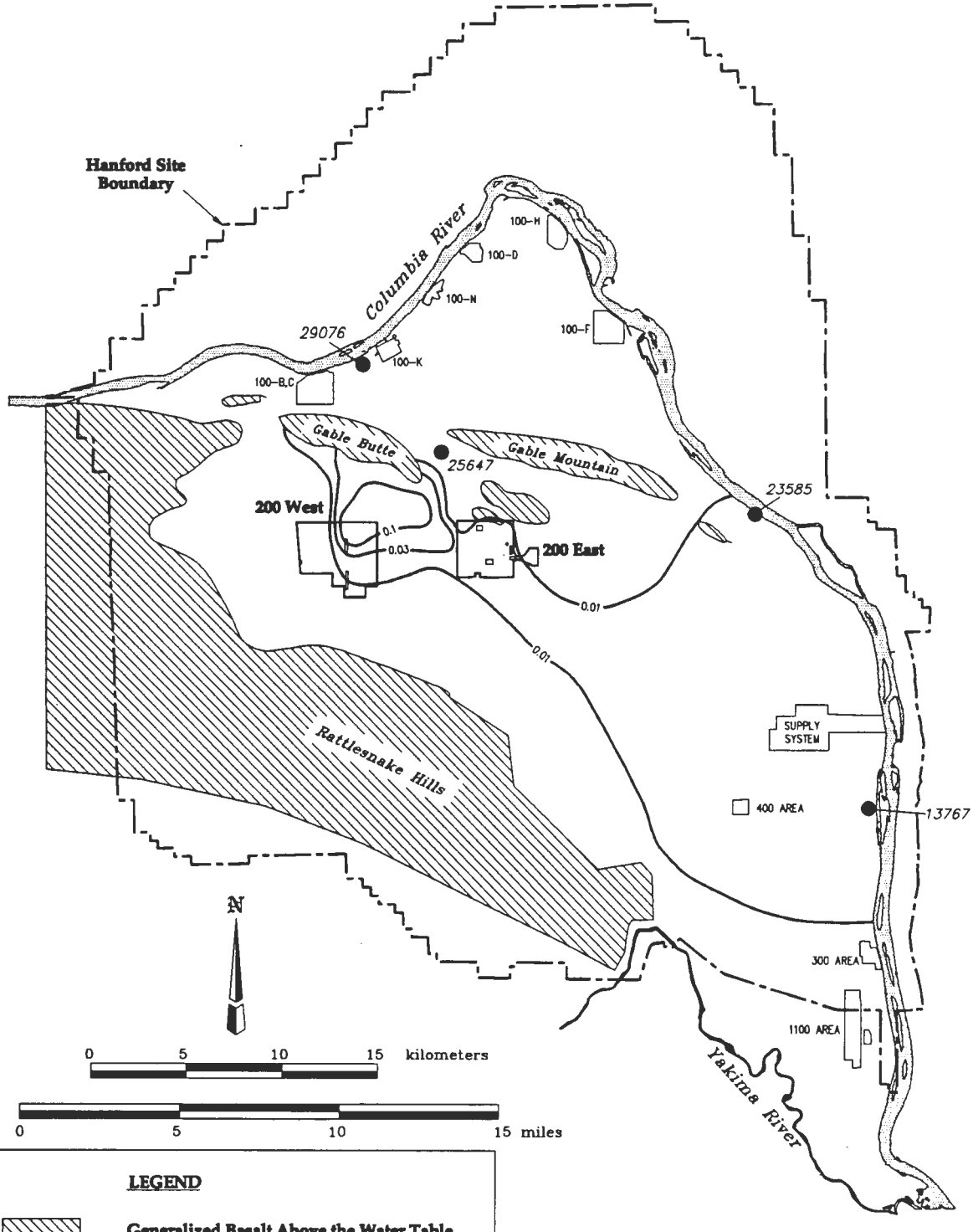
Figure F.3.8.3 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination 1 Alternative (Tank Sources Only)



LEGEND

- Generalized Basalt Above the Water Table
- 0.01 — Isoconcentration Line U-238 mg/L
- Hanford Site Boundary
- 13767 — Groundwater Modeling Observation Node

NOTE: Concentrations associated with the retrieval from tanks are significantly lower (by one to two orders of magnitude) and generally in the same configuration as the contours shown herein which are the calculated results of the tanks remediated In Situ.

Figure F.3.8.4 Predicted Technetium-99 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination 1 Alternative (LAW Vault Sources Only)

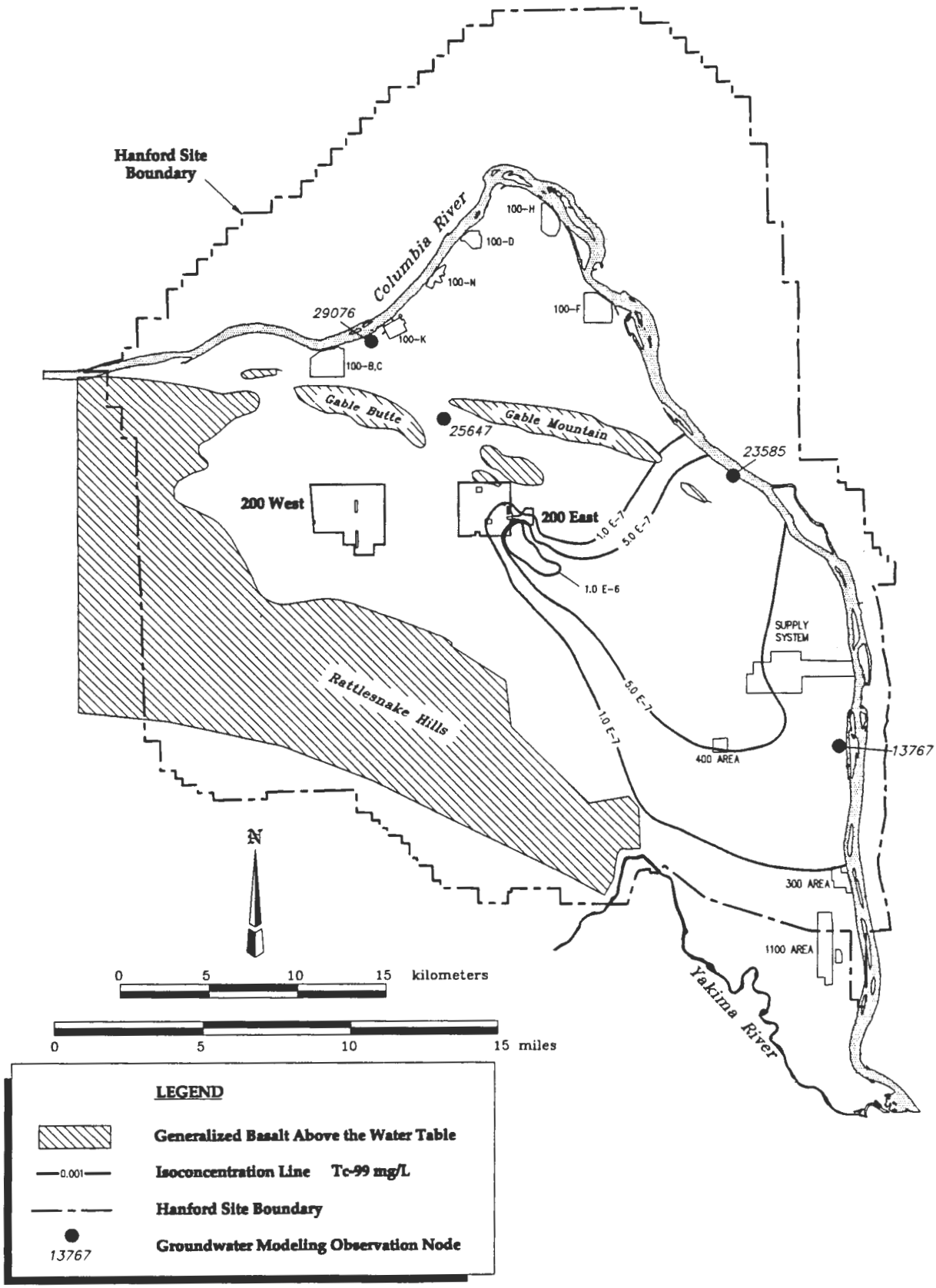


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Figure F.3.8.5 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination 1 Alternative (LAW Vault Sources Only)

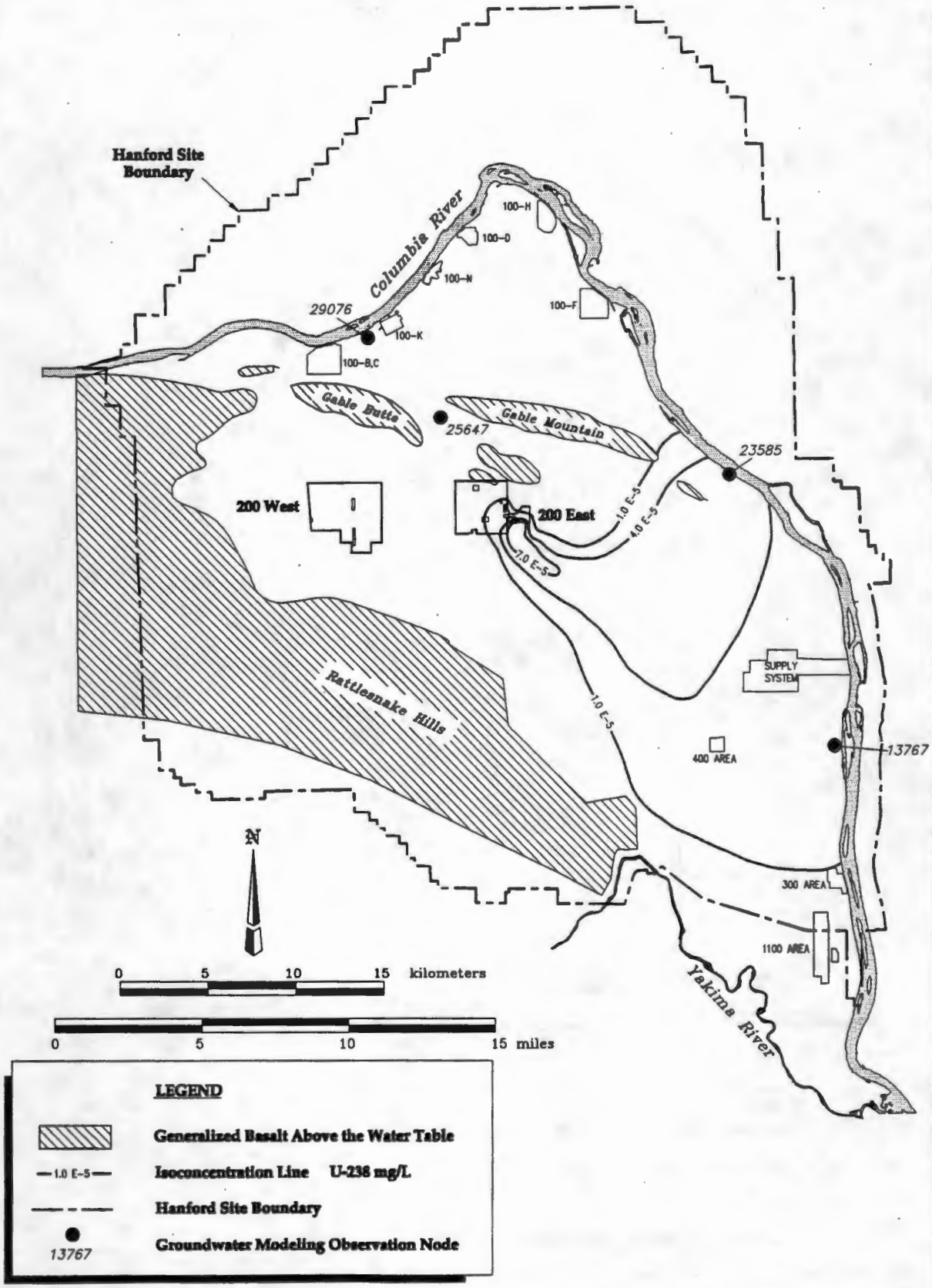

Figure F.3.8.6 Predicted Technetium-99 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination 1 Alternative (Tank Sources Only)

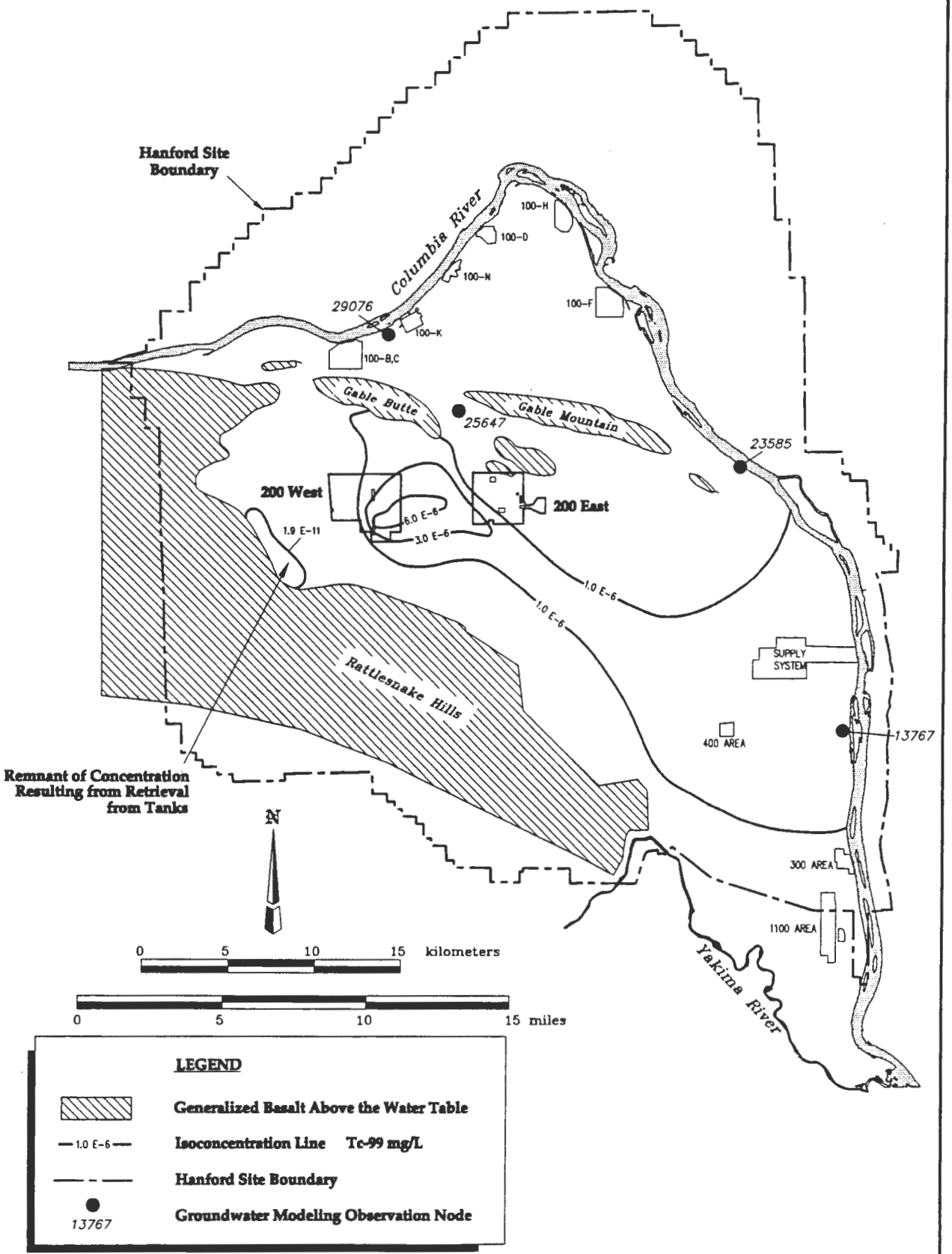

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Figure F.3.8.7 Predicted Iodine-129 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination 1 Alternative (Tank Sources Only)

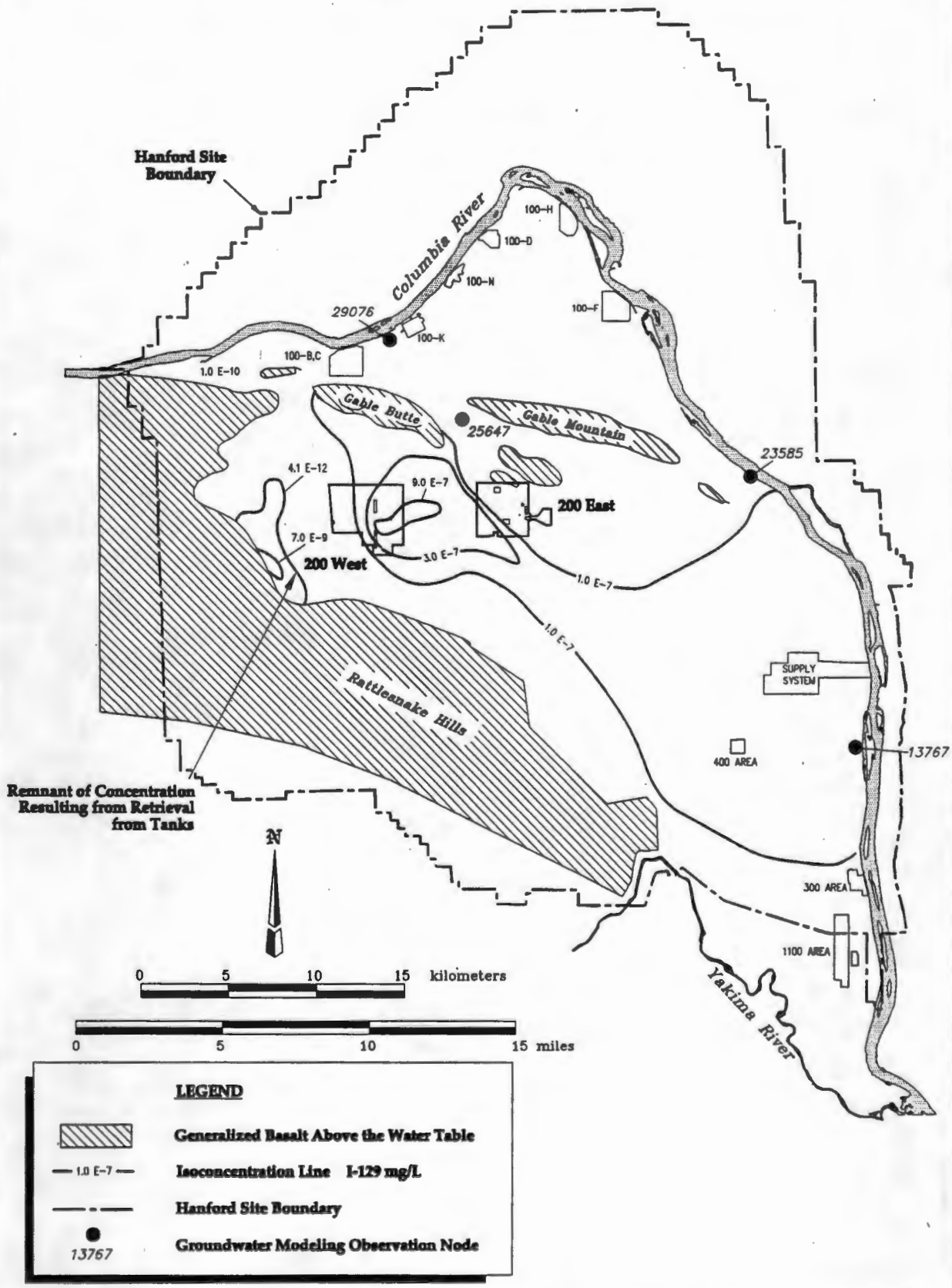
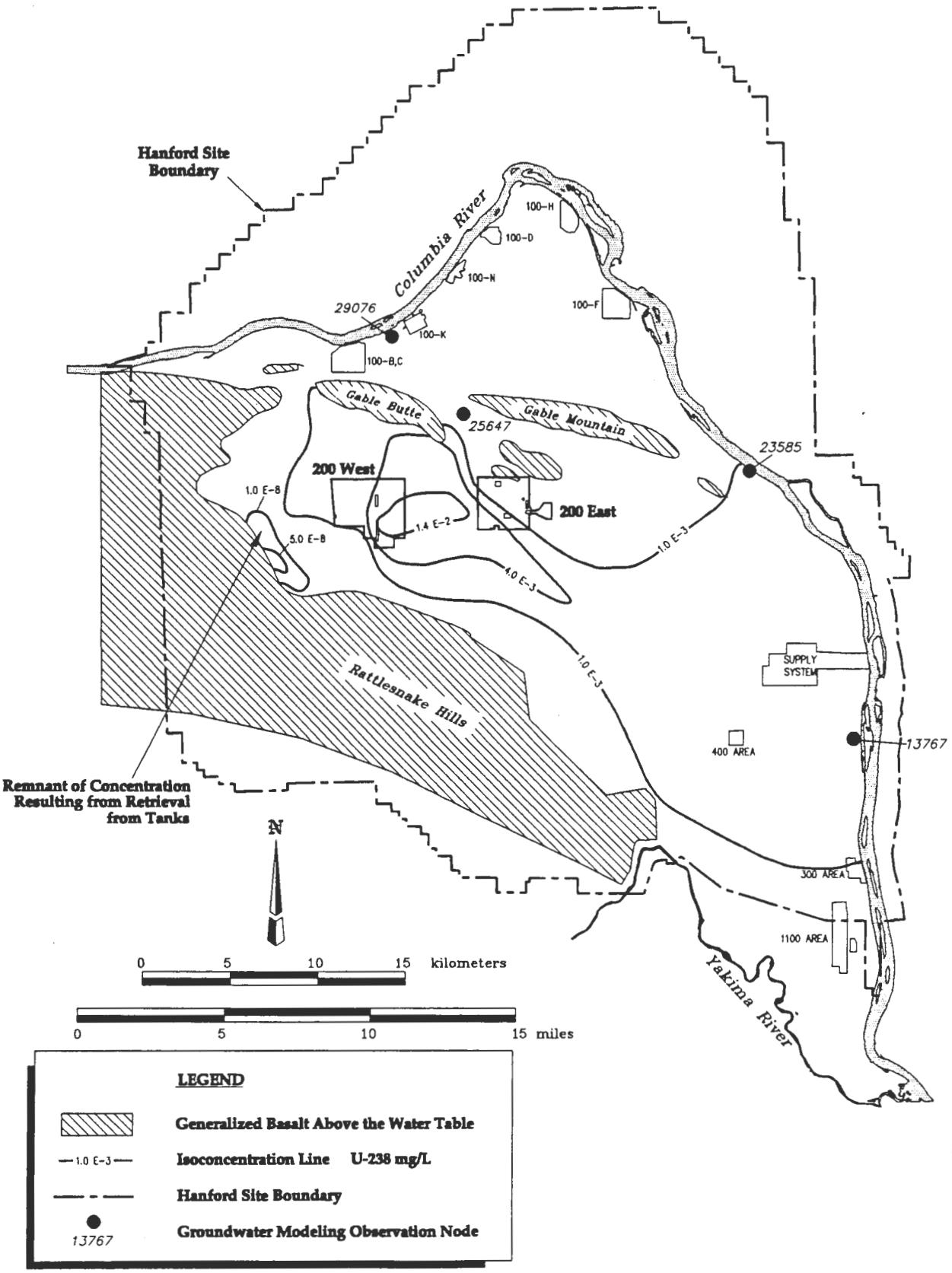


Figure F.3.8.8 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination 1 Alternative (Tank Sources Only)



9613459.1030

Figure F.3.8.9 Predicted Technetium-99 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination 1 Alternative (LAW Vault Sources Only)

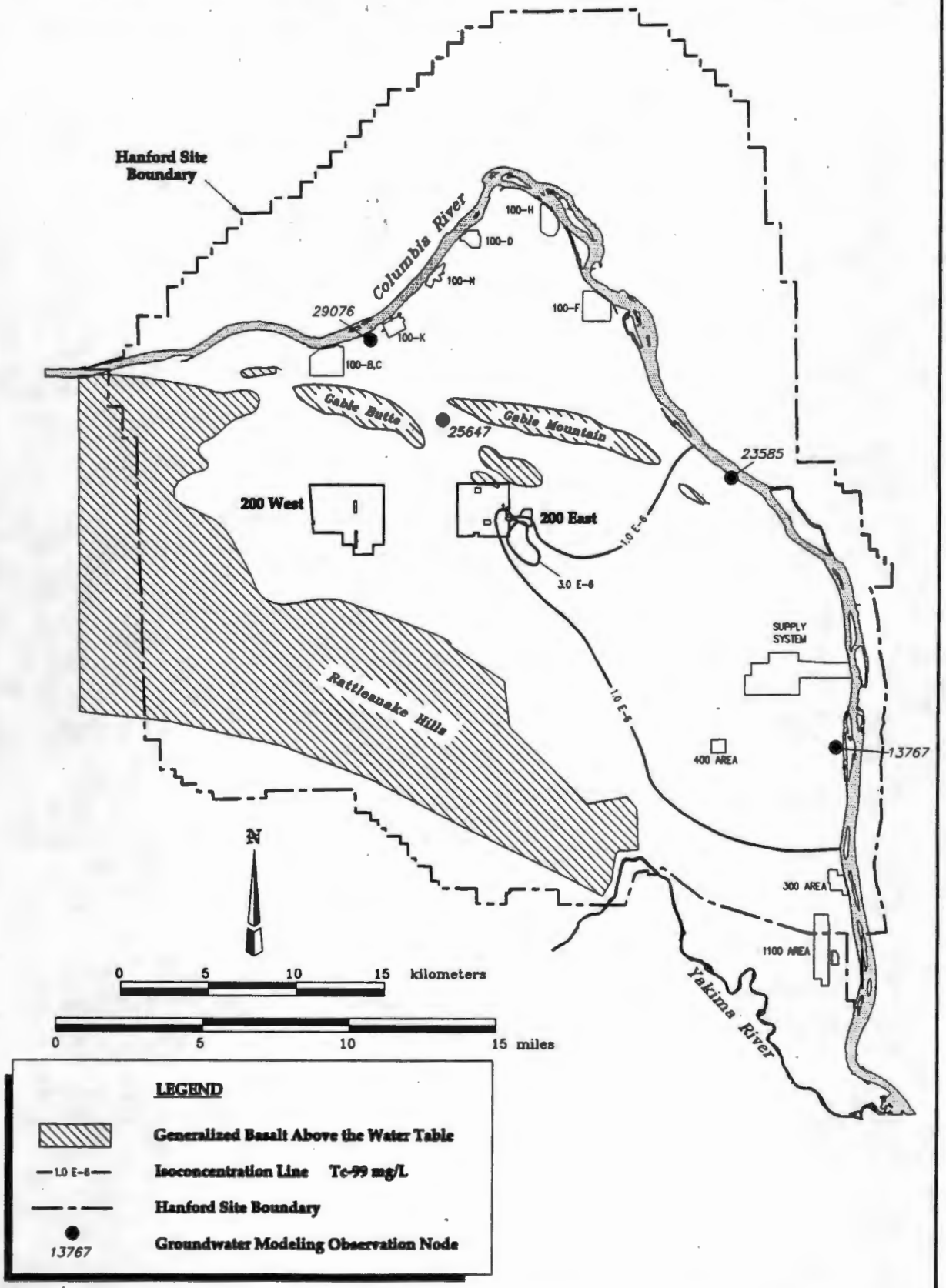
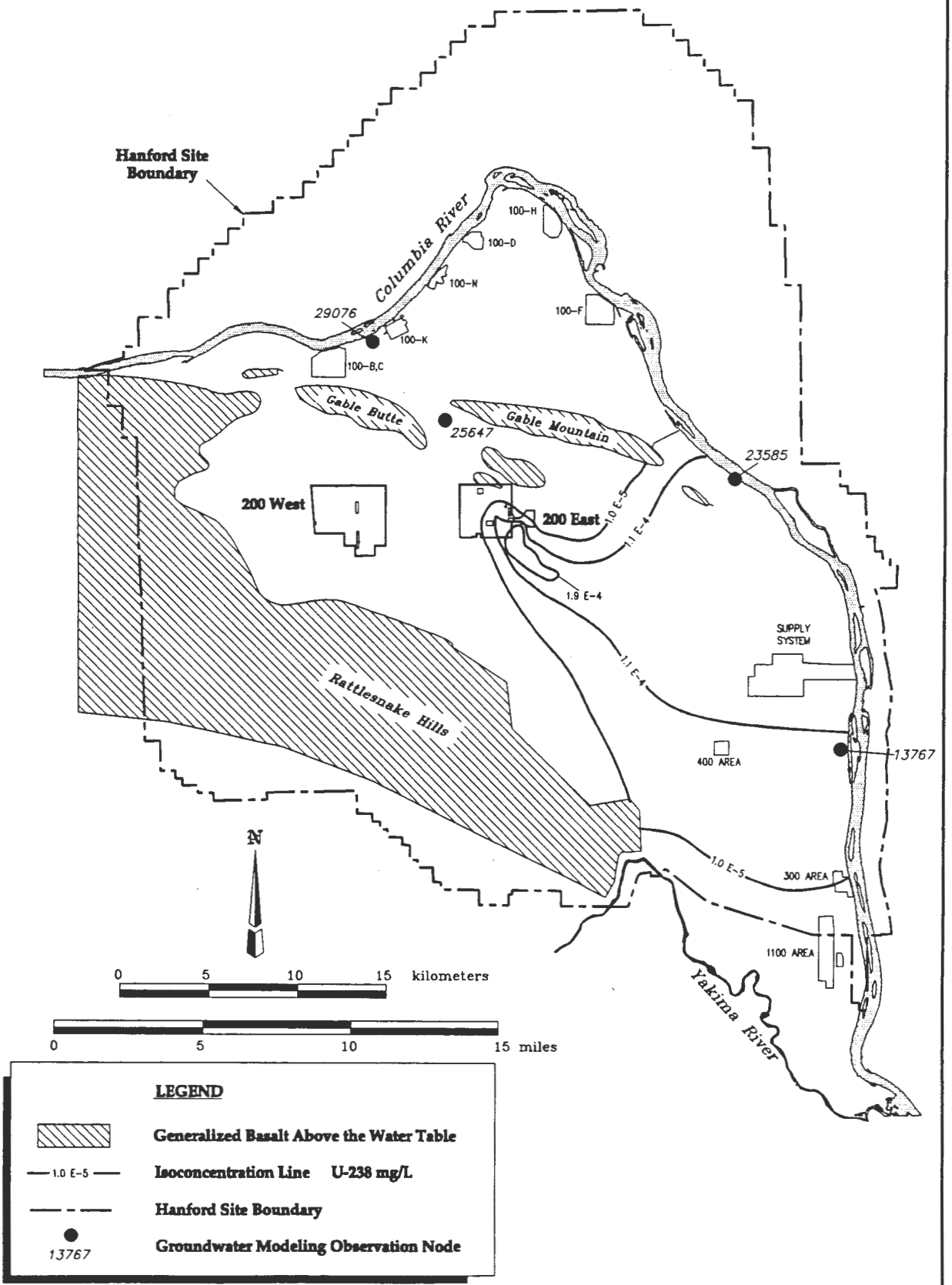
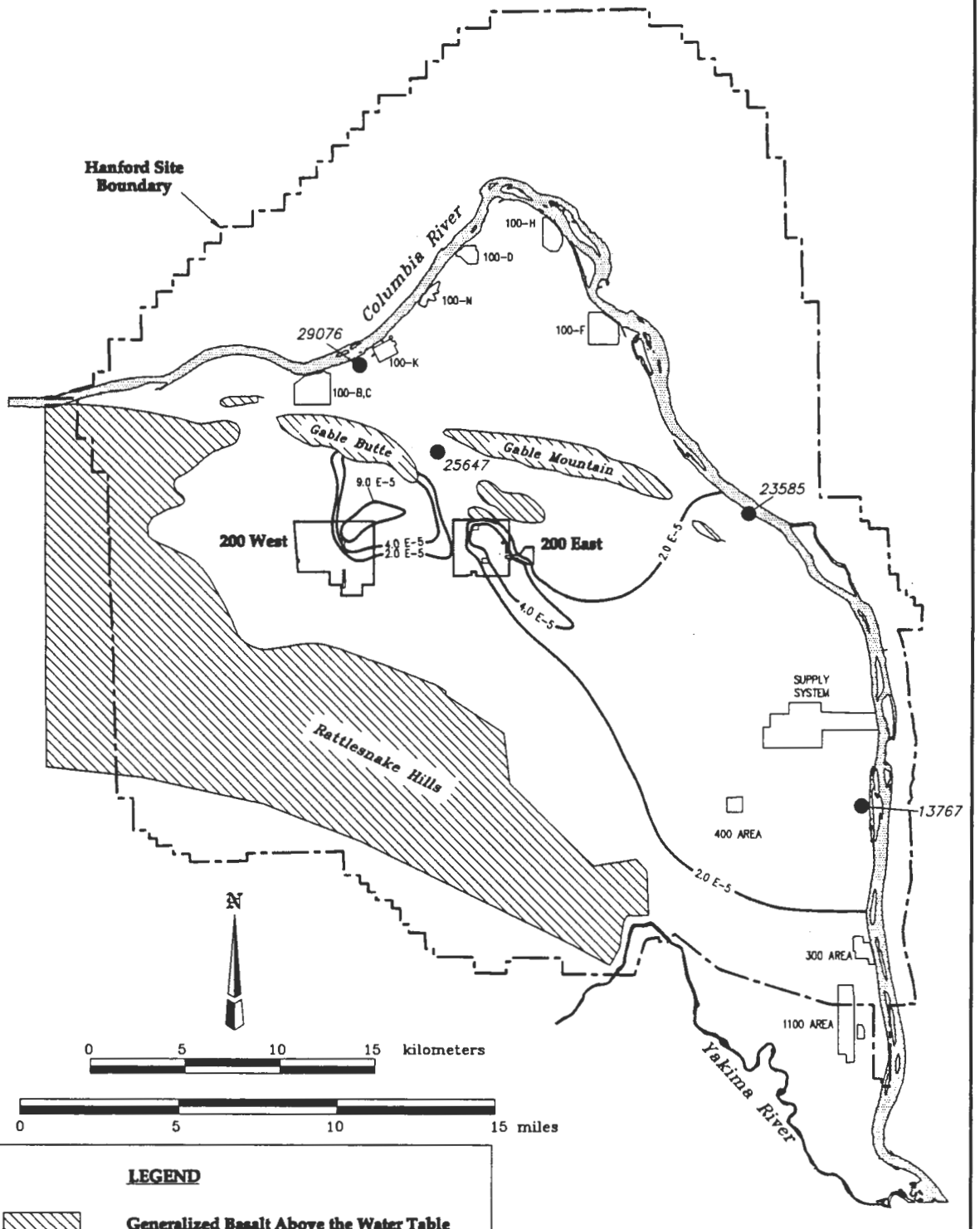


Figure F.3.8.10 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination 1 Alternative (LAW Vault Sources Only)



9613459.1031

Figure F.3.9.1 Predicted Technetium-99 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination 2 Alternative (Tank Sources Only)

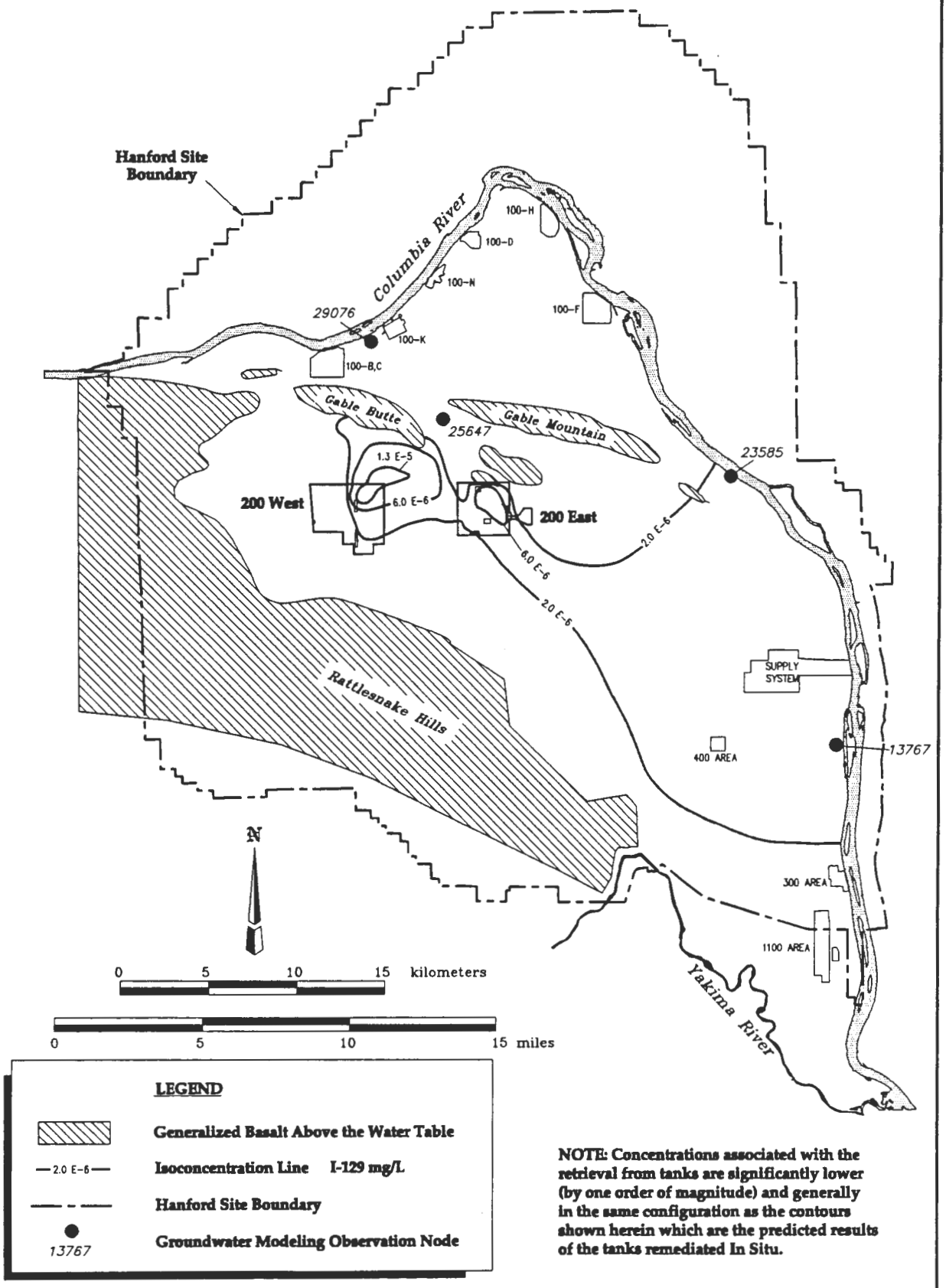


LEGEND

- Generalized Basalt Above the Water Table
- 2.0 E-5 — Isoconcentration Line Tc-99 mg/L
- Hanford Site Boundary
- 13767 — Groundwater Modeling Observation Node

NOTE: Concentrations associated with the retrieval from tanks are significantly lower (by two orders of magnitude) and generally in the same configuration as the contours shown herein which are the predicted results of the tanks remediated In Situ.

Figure F.3.9.2 Predicted Iodine-129 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination 2 Alternative (Tank Sources Only)



NOTE: Concentrations associated with the retrieval from tanks are significantly lower (by one order of magnitude) and generally in the same configuration as the contours shown herein which are the predicted results of the tanks remediated In Situ.

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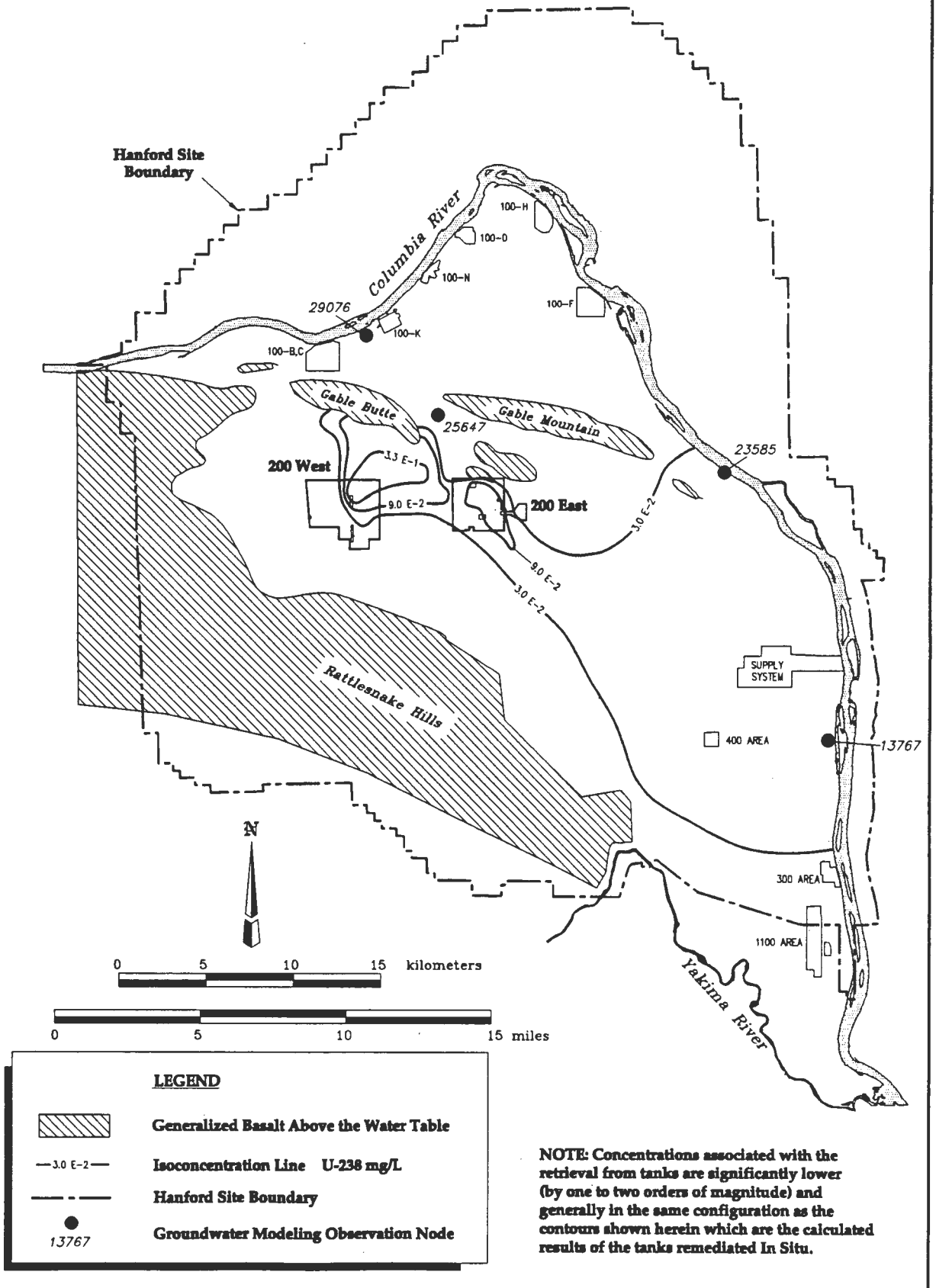
Figure F.3.9.3 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination 2 Alternative (Tank Sources Only)



NOTE: Concentrations associated with the retrieval from tanks are significantly lower (by one to two orders of magnitude) and generally in the same configuration as the contours shown herein which are the calculated results of the tanks remediated In Situ.

Figure F.3.9.4 Predicted Technetium-99 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination 2 Alternative (LAW Vault Sources Only)

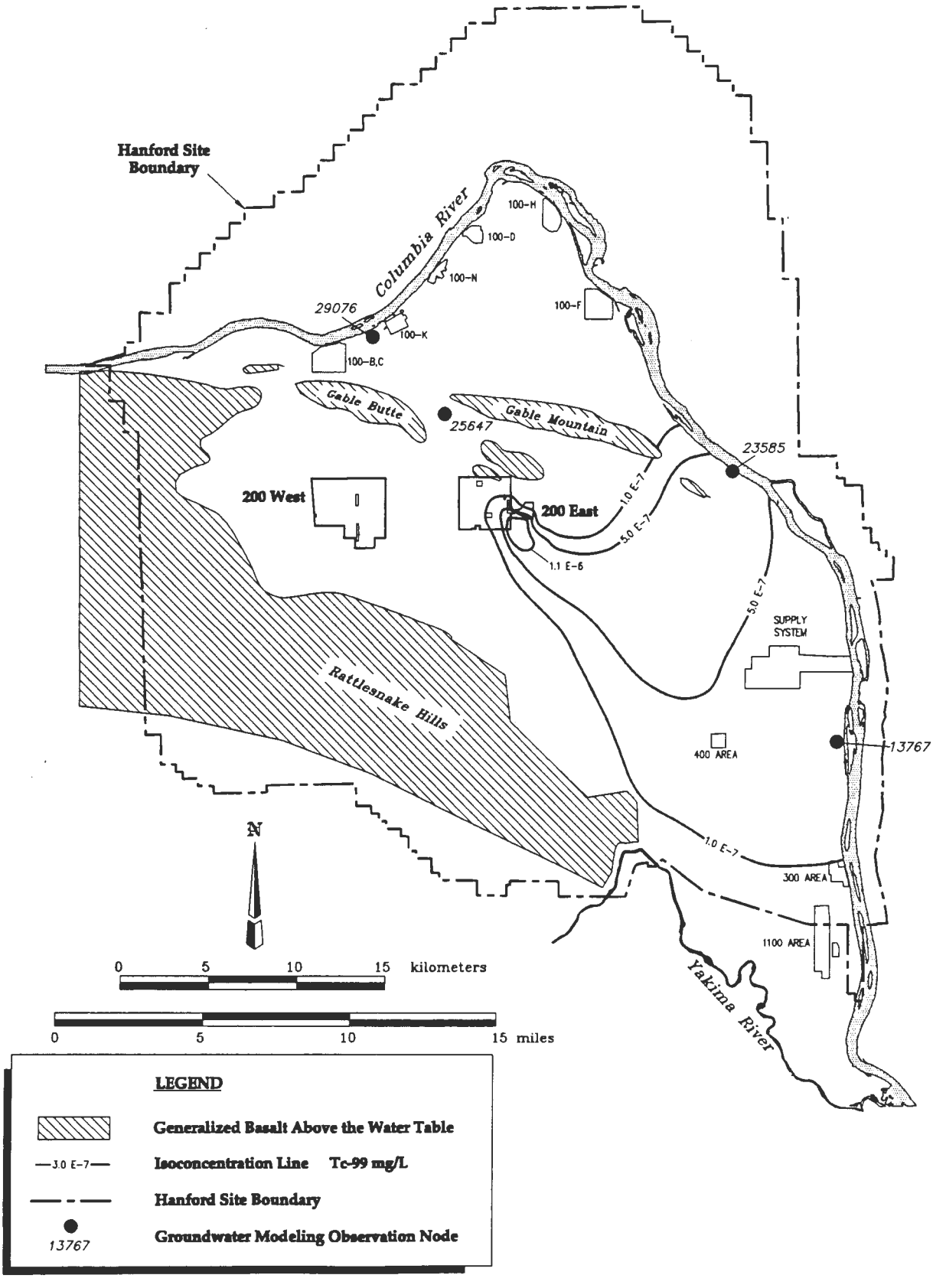


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Figure F.3.9.5 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination 2 Alternative (LAW Vault Sources Only)

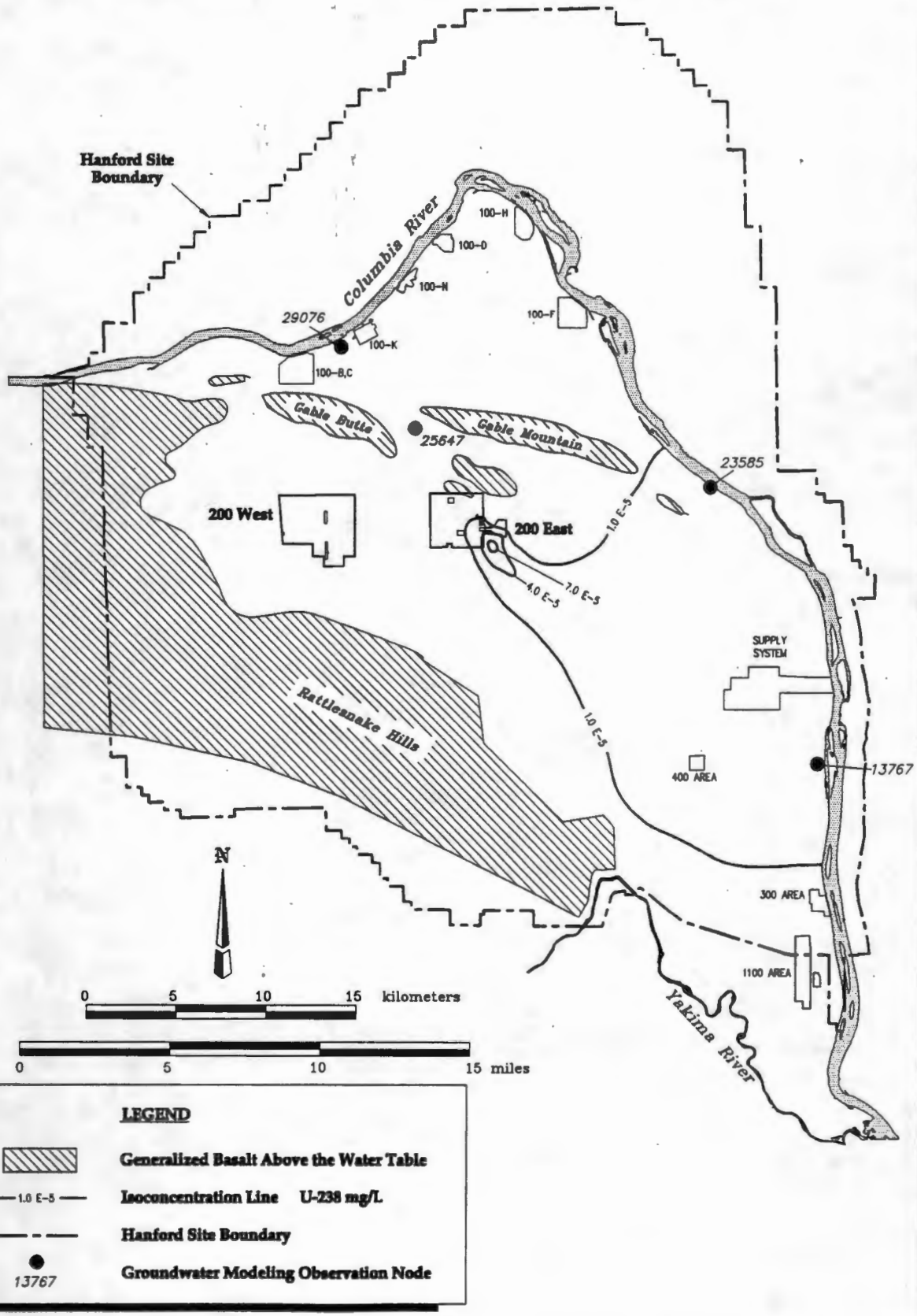
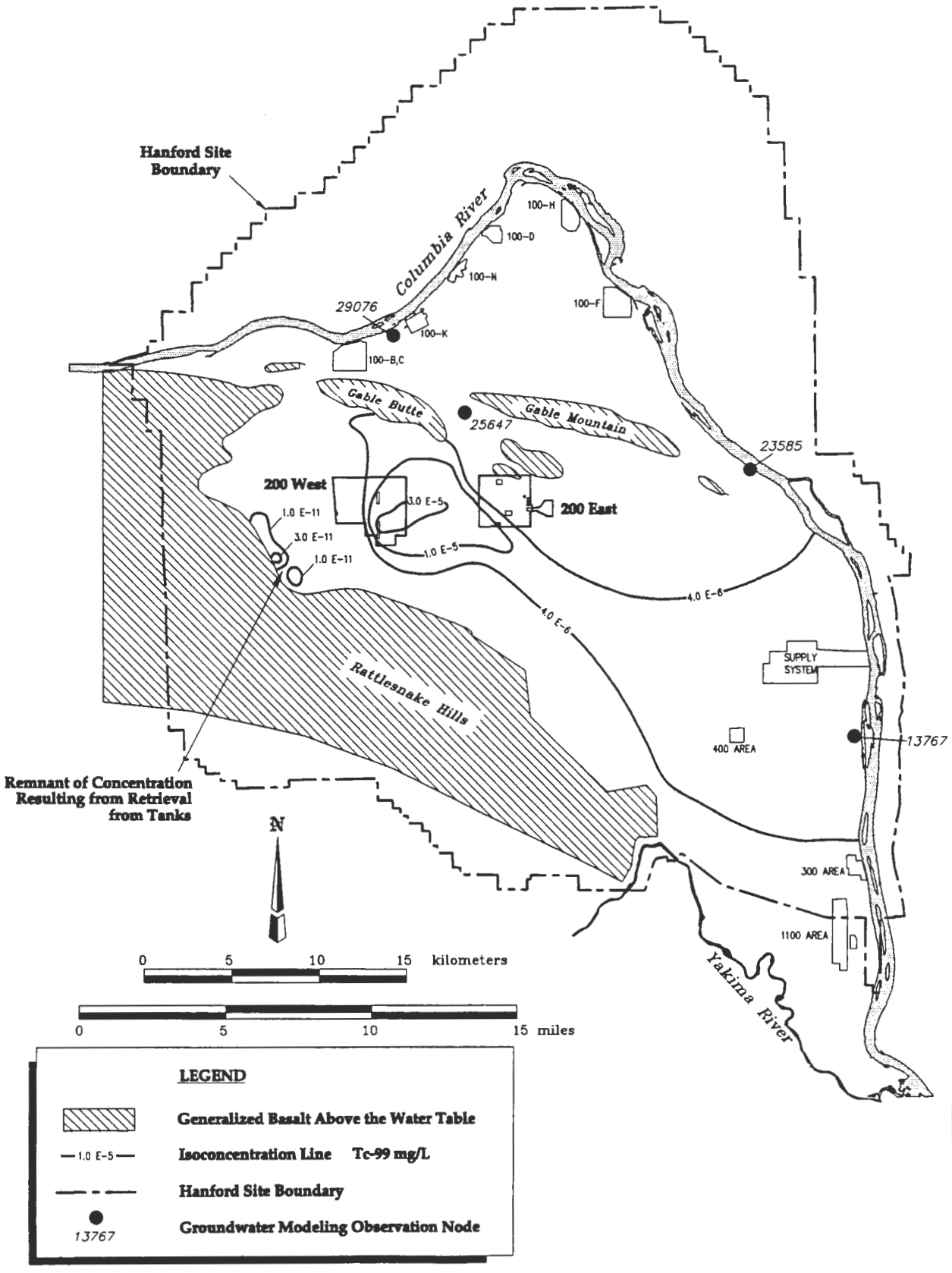


Figure F.3.9.6 Predicted Technetium-99 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination 2 Alternative (Tank Sources Only)



9613459.1034

Figure F.3.9.7 Predicted Iodine-129 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination 2 Alternative (Tank Sources Only)

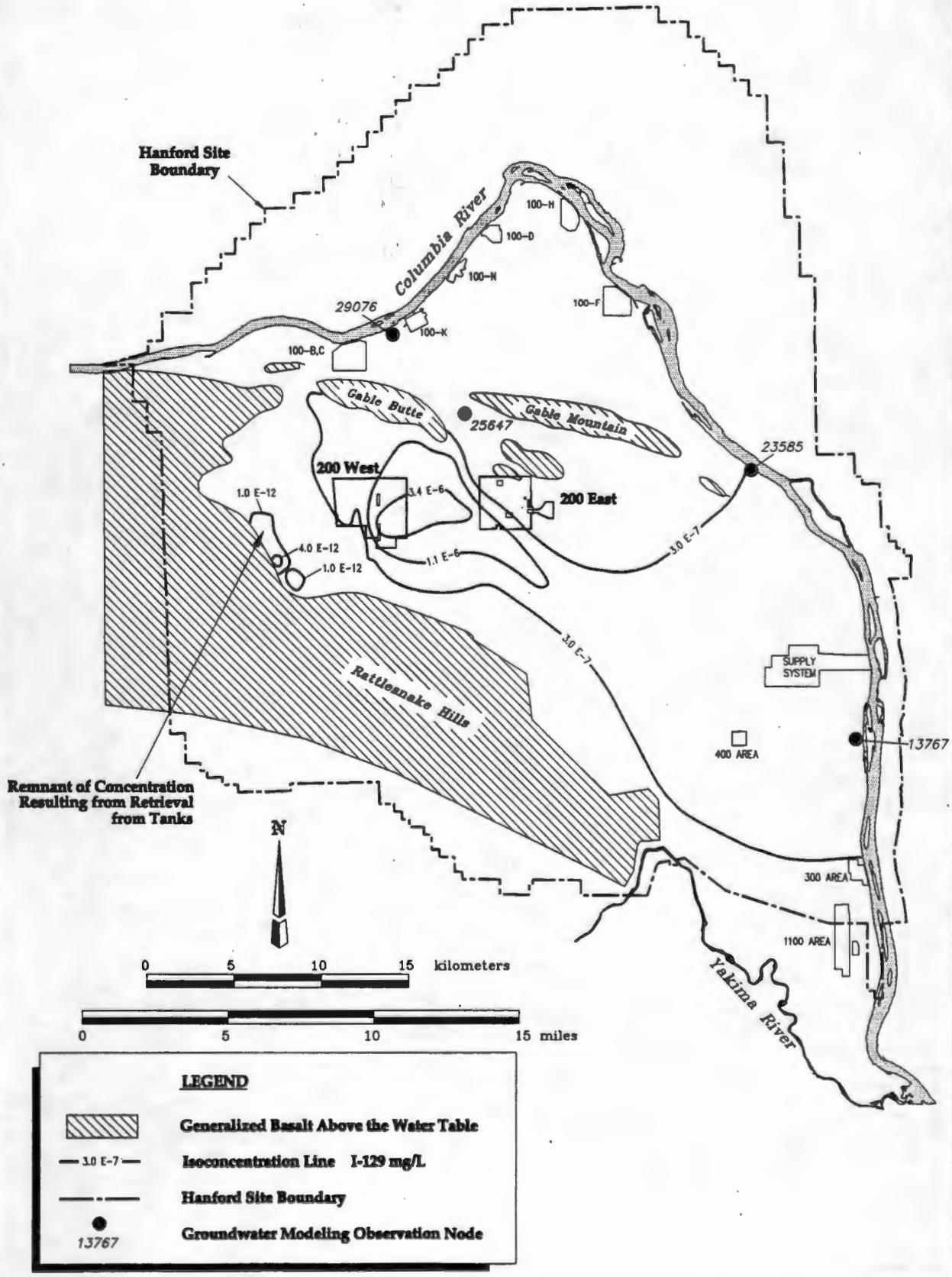
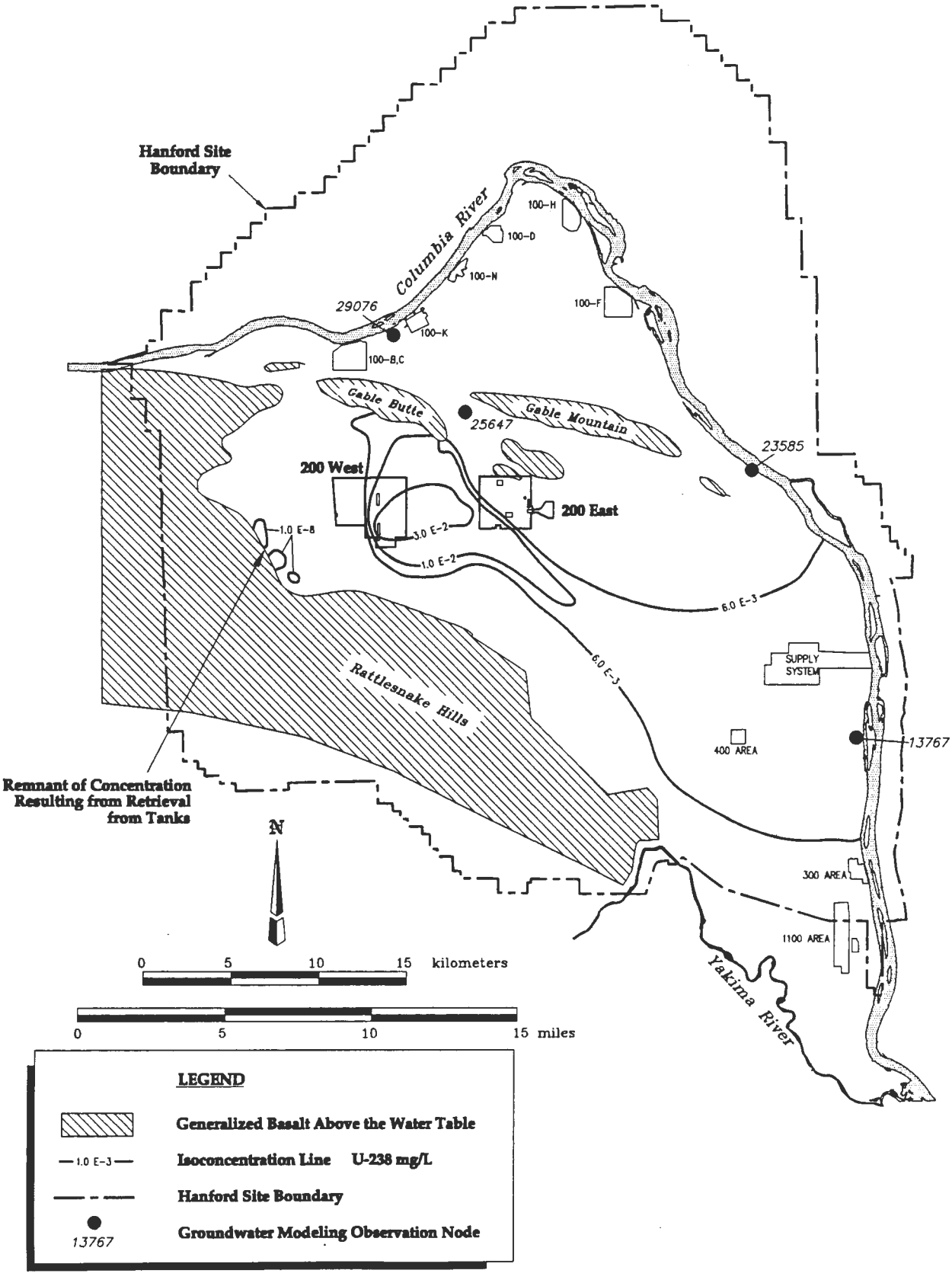


Figure F.3.9.8 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination 2 Alternative (Tank Sources Only)



9613459.1035

Figure F.3.9.9 Predicted Technetium-99 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination 2 Alternative (LAW Vault Sources Only)

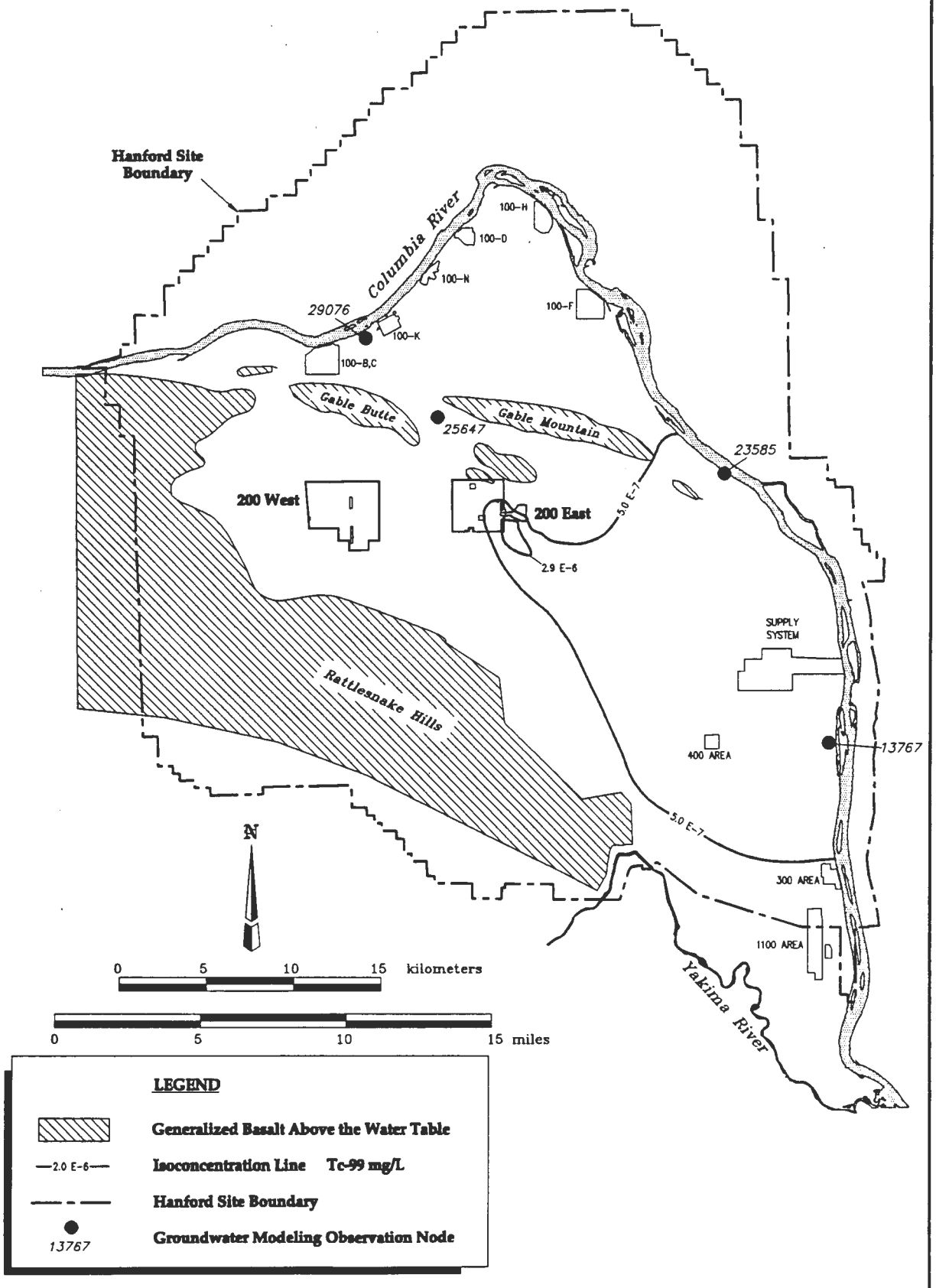
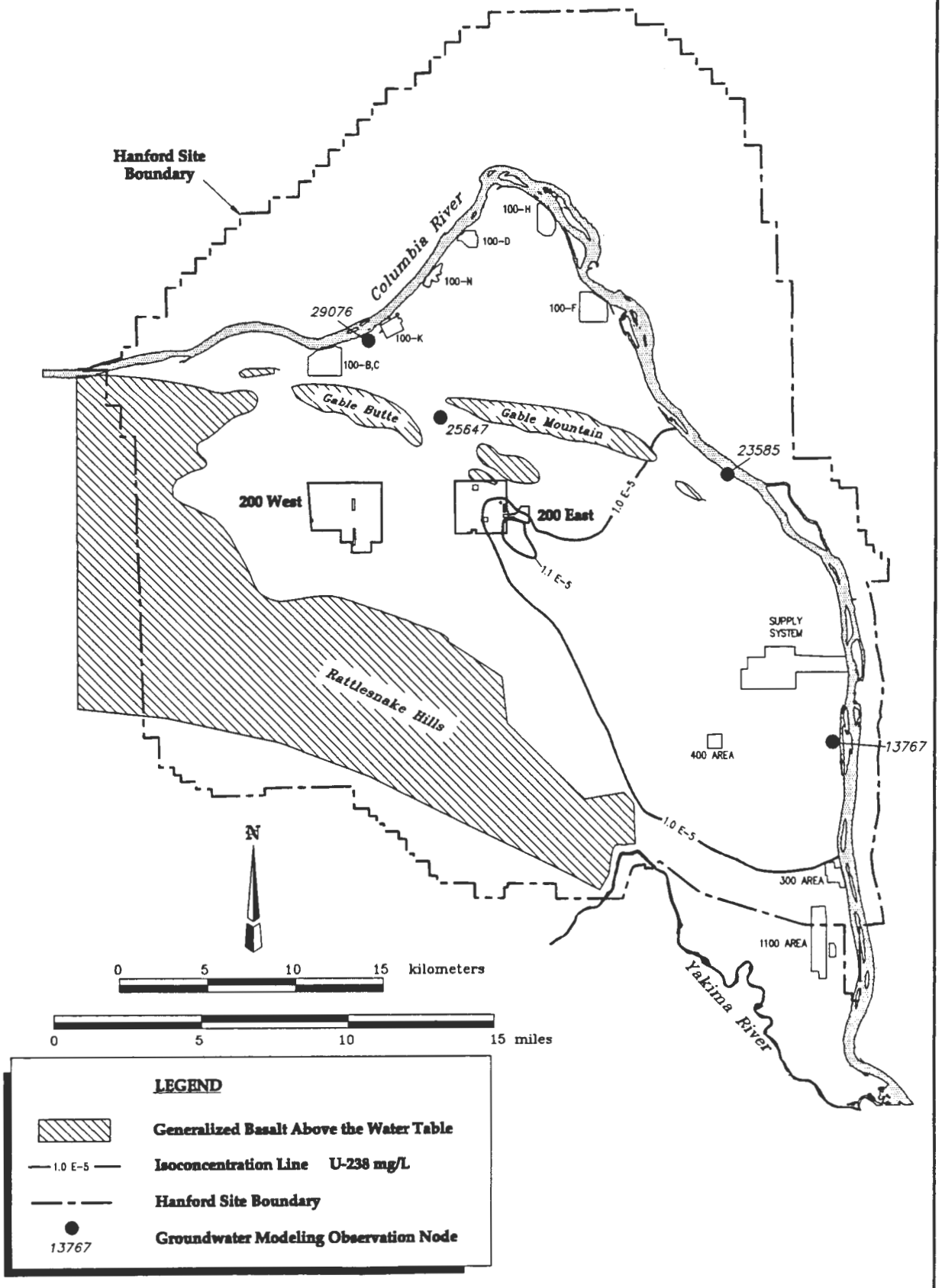
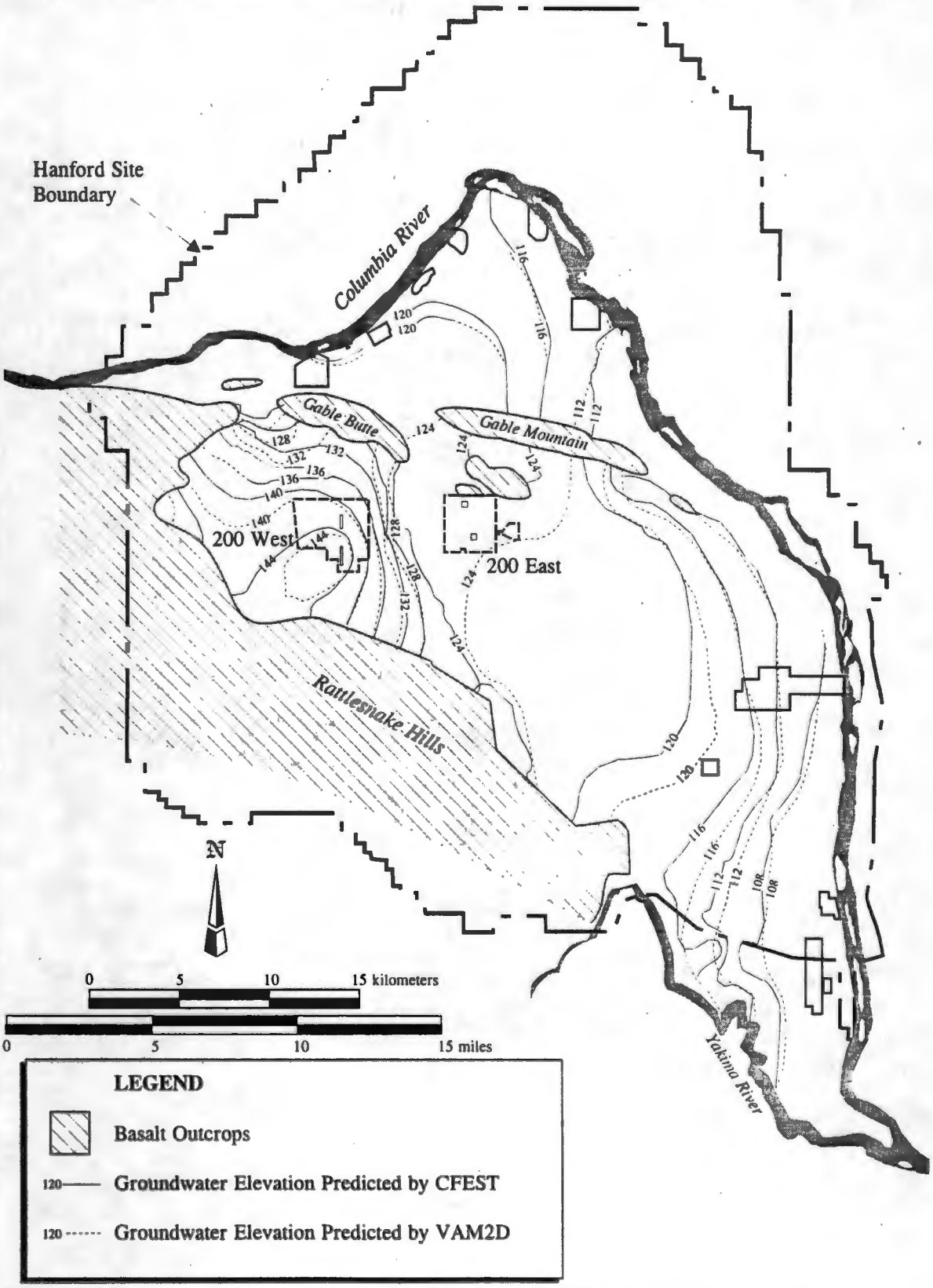


Figure F.3.9.10 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination 2 Alternative (LAW Vault Sources Only)



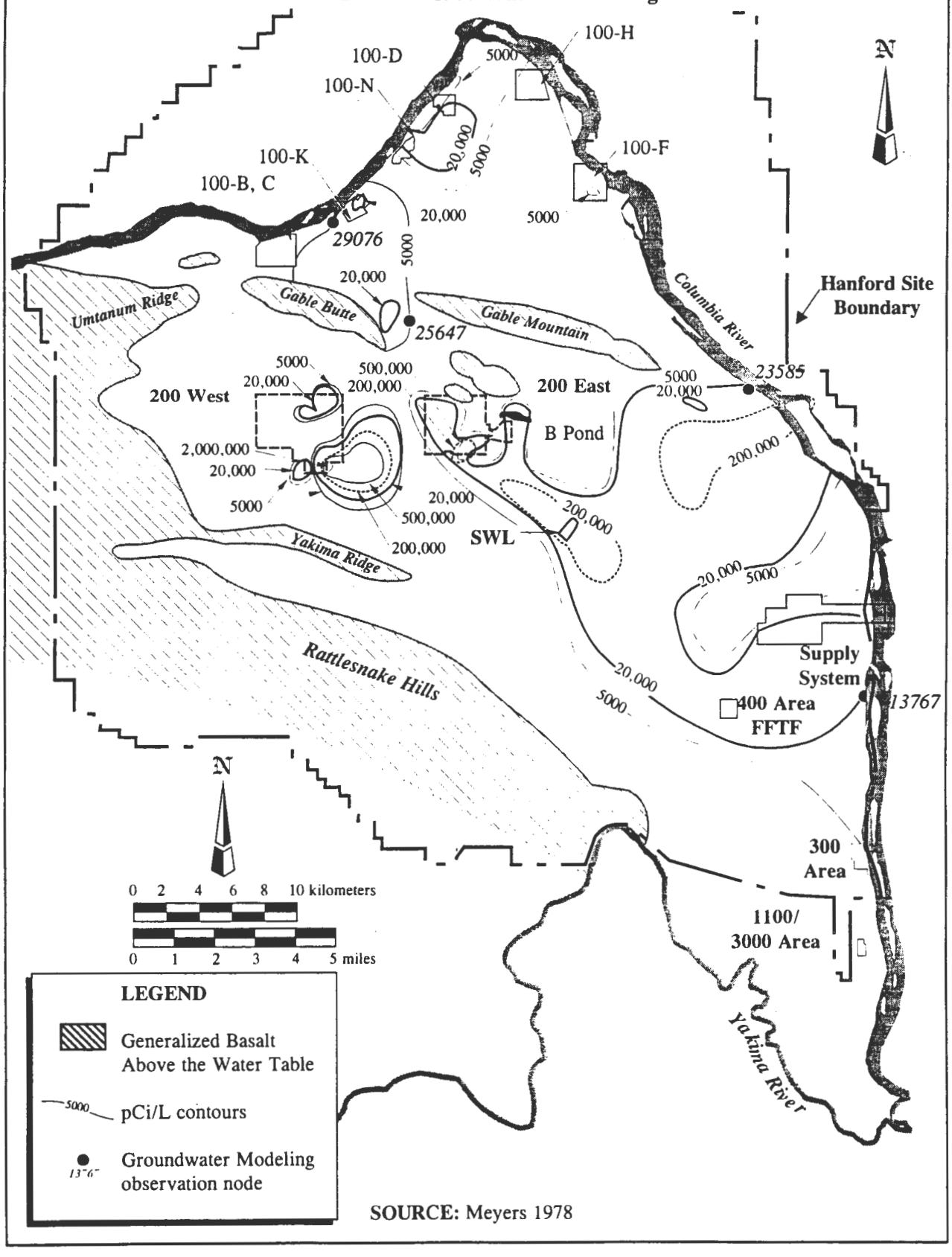
9613459.1036

Figure F.4.3.1 Comparison of Groundwater Elevations Predicted by VAM2D and CFEST



SOURCE: Groundwater elevations predicted by CFEST are from Wurstner and Devary 1993

Figure F.4.3.2 Distribution of Tritium in Unconfined Groundwater Based on 1977 Water Monitoring



SOURCE: Meyers 1978

9613459.1037

Figure F.4.3.3 Predicted Tritium Concentrations in Groundwater at 10, 20, and 30 Years from a B Pond Source

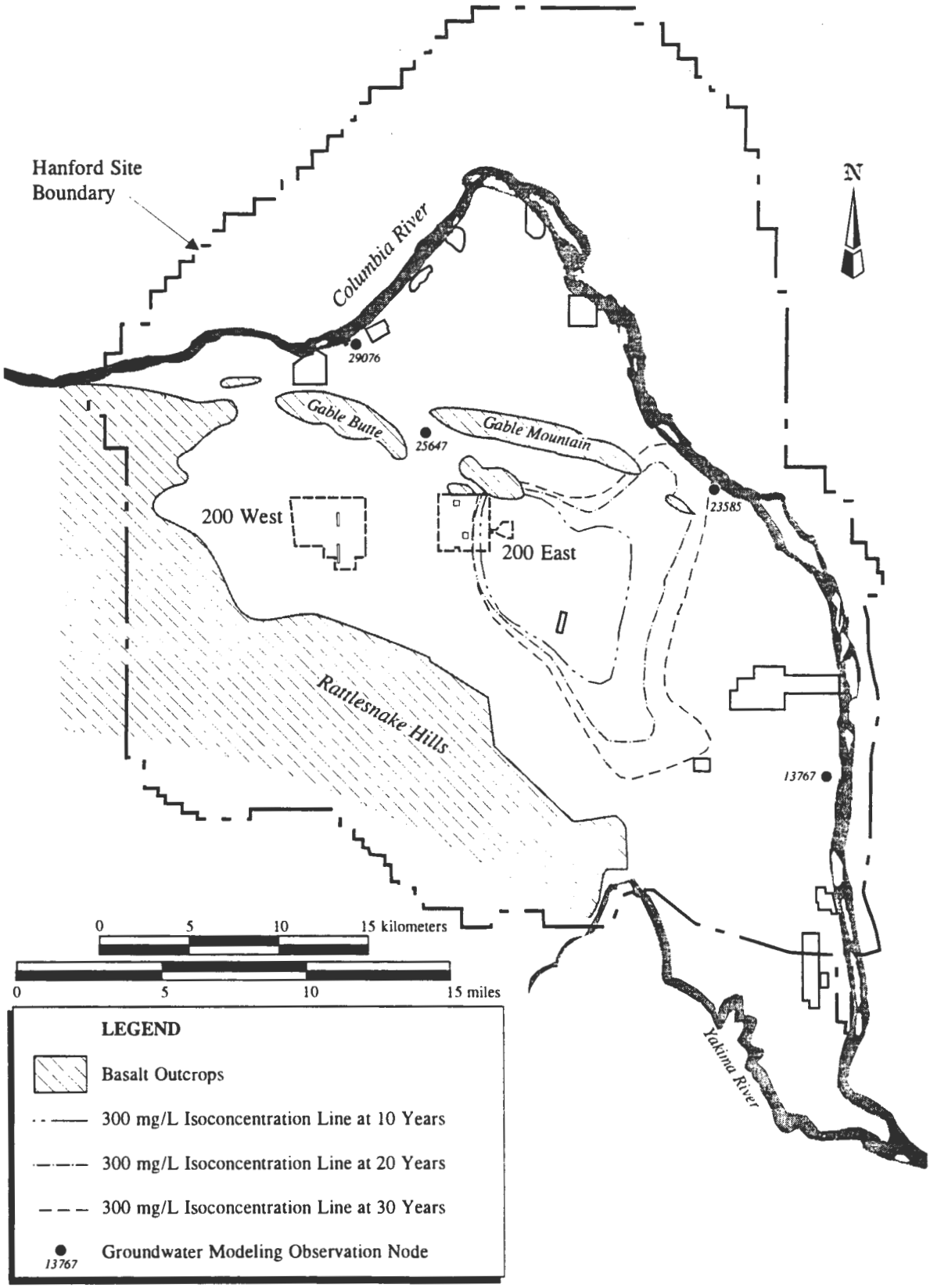


Table F.3.1.1 Maximum Concentrations Calculated for the No Action Alternative

Consti-tuent	300 years		500 years		2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
K_d Group 1 (K_d = 0.0 mL/g)										
C-14	1.55E-05	6.90E+04	4.57E-06	2.03E+04	2.13E-09	9.48E-00	3.18E-11	1.42E-01	0.00E+00	0.00E+00
I-129	2.50E-03	4.40E+02	3.21E-04	5.65E+01	6.53E-07	1.15E-01	1.32E-08	2.32E-03	1.10E-12	1.94E-07
Np-237	2.92E-03	2.06E+03	6.45E-04	4.54E+02	4.18E-07	2.94E-01	8.42E-09	5.93E-03	7.00E-13	4.93E-07
Np-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-219	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-222	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-126m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se-79	4.64E-04	3.23E+04	3.45E-04	2.40E+04	9.18E-08	6.39E+00	1.80E-09	1.25E-01	1.00E-13	6.96E-06
Tc-99	1.87E-02	3.16E+05	7.45E-03	1.26E+05	8.02E-06	1.36E+02	1.58E-07	2.67E-00	1.34E-11	2.26E-04
U-233	3.91E-08	3.77E-01	2.61E-08	2.52E-01	4.70E-12	4.53E-05	1.00E-13	9.64E-07	0.00E+00	0.00E+00
U-234	1.93E-06	1.20E+01	2.84E-07	1.77E-00	1.91E-10	1.19E-03	3.80E-12	2.37E-05	0.00E+00	0.00E+00
U-235	8.03E-01	1.73E+03	9.30E-02	2.01E+02	3.55E-05	7.67E-02	7.15E-07	1.54E-03	6.15E-11	1.33E-07
U-236	8.48E-07	5.48E-02	1.21E-07	7.82E-03	1.69E-10	1.09E-05	3.40E-12	2.20E-07	0.00E+00	0.00E+00
U-238	1.23E+02	4.13E+04	1.42E+01	4.77E+03	5.04E-03	1.69E+00	1.02E-04	3.43E-02	0.00E+00	0.00E+00
Ag^{+}	1.23E-02	N/A	7.77E-03	N/A	9.07E-07	N/A	1.76E-08	N/A	1.50E-12	N/A
As^{+5}	8.92E-03	N/A	5.54E-03	N/A	3.15E-06	N/A	6.12E-08	N/A	5.20E-12	N/A
B^{+3}	1.09E-02	N/A	6.50E-03	N/A	6.68E-06	N/A	1.30E-07	N/A	1.11E-11	N/A
Be^{+2}	6.14E-04	N/A	4.09E-04	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
Cl^{-}	5.52E+00	N/A	1.23E+00	N/A	1.31E-03	N/A	2.56E-05	N/A	2.19E-09	N/A
CO_3^{-2}	1.69E+02	N/A	1.94E+01	N/A	4.22E-03	N/A	8.51E-05	N/A	7.31E-09	N/A
Cr^{+3}	2.72E+00	N/A	3.80E-01	N/A	8.38E-07	N/A	1.69E-08	N/A	1.50E-12	N/A
CrO_4^{-2}	6.60E-01	N/A	9.20E-02	N/A	1.48E-03	N/A	2.91E-05	N/A	2.49E-09	N/A
F-	3.44E+01	N/A	4.67E+00	N/A	9.31E-04	N/A	1.87E-05	N/A	1.60E-09	N/A
$Fe(CN)_6^{-4}$	1.90E+00	N/A	1.45E+00	N/A	3.58E-05	N/A	7.21E-07	N/A	6.20E-11	N/A
Hg^{+}	5.00E-02	N/A	6.04E-03	N/A	6.29E-06	N/A	1.27E-07	N/A	1.09E-11	N/A
K^{+}	3.40E+00	N/A	2.52E+00	N/A	5.87E-04	N/A	1.14E-05	N/A	9.74E-10	N/A
Li^{+}	2.12E-04	N/A	1.33E-04	N/A	8.76E-08	N/A	1.70E-09	N/A	1.00E-13	N/A
Mo^{+6}	3.72E-02	N/A	2.43E-02	N/A	1.33E-05	N/A	2.59E-07	N/A	2.21E-11	N/A
Na^{+}	3.63E+03	N/A	4.46E+02	N/A	5.86E-01	N/A	1.18E-02	N/A	1.01E-06	N/A
NO_2^{-}	4.25E+02	N/A	4.96E+01	N/A	2.48E-02	N/A	4.98E-04	N/A	4.27E-08	N/A

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Table F.3.1.1 Maximum Concentrations Calculated for the No Action Alternative (cont'd)

Consti-tuent	300 years		500 years		2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
NO_3^-	6.62E+03	N/A	8.22E+02	N/A	1.21E+00	N/A	2.43E-02	N/A	2.09E-06	N/A
OH^-	1.27E+02	N/A	1.79E+01	N/A	6.02E-02	N/A	1.21E-03	N/A	1.04E-07	N/A
SiO_3^{-2}	1.35E+02	N/A	1.57E+01	N/A	6.39E-03	N/A	1.29E-04	N/A	1.11E-08	N/A
SO_4^{-2}	1.53E+02	N/A	1.77E+01	N/A	7.15E-03	N/A	1.44E-04	N/A	1.23E-08	N/A
UO_2^{+2}	2.10E-01	N/A	1.42E-01	N/A	7.00E-13	N/A	0.00E+00	N/A	0.00E+00	N/A
V^{+5}	1.51E-03	N/A	1.12E-03	N/A	2.14E-07	N/A	4.16E-09	N/A	4.00E-13	N/A
W^{+4}	8.01E-01	N/A	9.67E-02	N/A	1.01E-04	N/A	2.03-06	N/A	1.74E-10	N/A
K_d Group 2 (K_d = 1.0 mL/g)										
Bi-210	N/A	N/A	N/A	N/A	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni-63	N/A	N/A	N/A	N/A	5.81E-06	3.42E+05	1.73E-06	1.02E+05	5.58E-08	3.28E+03
Pa-231	N/A	N/A	N/A	N/A	8.20E-09	3.87E-01	5.67E-10	2.68E-02	3.79E-11	1.79E-03
Pa-233	N/A	N/A	N/A	N/A	1.73E-11	3.58E+02	0.00E+00	0.00E+00	1.00E-13	2.07E+00
Pa-234m	N/A	N/A	N/A	N/A	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po-211	N/A	N/A	N/A	N/A	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi^{+3}	N/A	N/A	N/A	N/A	6.86E+00	N/A	4.70E-01	N/A	3.40E-02	N/A
Ca^{+2}	N/A	N/A	N/A	N/A	2.04E-01	N/A	6.48E-02	N/A	1.88E-03	N/A
Cd^{+2}	N/A	N/A	N/A	N/A	3.72E-02	N/A	3.81E-03	N/A	2.14E-04	N/A
Cu^{+2}	N/A	N/A	N/A	N/A	2.21E-03	N/A	3.88E-04	N/A	1.55E-05	N/A
Fe^{+3}	N/A	N/A	N/A	N/A	7.14E+00	N/A	5.11E-01	N/A	3.77E-02	N/A

Notes:

N/A = Not applicable

Table F.3.2.1 Maximum Concentrations Calculated for the Long-Term Management Alternative

Consti-tuent	300 years		500 years		2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
K_d Group 1 (K_d = 0.0 mL/g)										
C-14	3.15E-06	1.40E+04	3.96E-06	1.76E+04	2.13E-09	9.48E+00	3.18E-11	1.42E-01	0.00E+00	0.00E+00
I-129	2.50E-03	4.40E+02	3.21E-04	5.60E+01	6.54E-07	1.15E-01	1.32E-08	2.31E-03	1.10E-12	1.94E-07
Np-237	2.92E-03	2.06E+03	6.45E-04	4.54E+02	4.19E-07	2.95E-01	8.46E-09	5.96E-03	7.00E-13	4.93E-07
Np-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-219	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-222	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-126m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se-79	2.12E-04	1.48E+04	3.45E-04	2.40E+04	9.18E-08	6.39E+00	1.80E-09	1.25E-01	1.00E-13	6.96E-06
Tc-99	5.40E-03	9.13E+04	6.48E-03	1.10E+05	8.44E-06	1.43E+02	1.71E-07	2.89E+00	1.45E-11	2.45E-04
U-233	1.53E-08	1.47E-01	2.89E-08	2.79E-01	4.70E-12	4.53E-05	1.00E-13	9.64E-07	0.00E+00	0.00E+00
U-234	3.82E-05	2.38E+02	3.20E-05	2.00E+02	1.91E-10	1.19E-03	3.80E-12	2.37E-05	0.00E+00	0.00E+00
U-235	1.20E-01	2.59E+02	9.30E-02	2.01E+02	5.28E-06	1.14E-02	1.06E-07	2.29E-04	6.33E-11	1.37E-07
U-236	1.36E-07	8.79E-03	1.27E-07	8.20E-03	2.52E-11	1.63E-06	5.00E-13	3.23E-08	0.00E+00	0.00E+00
U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-238	1.83E+01	6.15E+03	1.42E+01	4.77E+03	7.50E-04	2.52E-01	1.51E-05	5.07E-03	9.00E-09	3.02E-06
Ag^{+}	8.52E-03	N/A	9.19E-03	N/A	1.02E-06	N/A	2.11E-08	N/A	1.80E-12	N/A
As^{+5}	6.19E-03	N/A	6.37E-03	N/A	3.54E-06	N/A	7.32E-08	N/A	6.30E-12	N/A
B^{+3}	7.73E-03	N/A	6.84E-03	N/A	7.52E-06	N/A	1.55E-07	N/A	1.34E-11	N/A
Be^{+2}	4.39E-04	N/A	4.84E-04	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
Cl^{-}	1.4E+00	N/A	1.27E+00	N/A	1.46E-03	N/A	3.01E-05	N/A	2.59E-09	N/A
CO_3^{-2}	2.50E+01	N/A	1.94E+01	N/A	4.22E-03	N/A	8.51E-05	N/A	7.31E-09	N/A
Cr^{+3}	5.87E-01	N/A	4.45E-01	N/A	8.39E-07	N/A	1.69E-08	N/A	1.50E-12	N/A
CrO_4^{-2}	1.10E-01	N/A	9.20E-02	N/A	1.60E-03	N/A	3.27E-05	N/A	2.82E-09	N/A
F^{-}	5.10E+00	N/A	4.04E+00	N/A	9.49E-04	N/A	1.92E-07	N/A	1.65E-09	N/A
$Fe(CN)_6^{-4}$	8.73E-01	N/A	1.49E+00	N/A	5.32E-06	N/A	1.07E-07	N/A	6.39E-11	N/A
Hg^{+}	3.06E-04	N/A	3.30E-04	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
K^{+}	2.38E+00	N/A	2.69E+00	N/A	6.60E-04	N/A	1.36E-05	N/A	1.18E-09	N/A
Li^{+}	1.47E-04	N/A	1.50E-04	N/A	9.86E-08	N/A	2.04E-09	N/A	2.00E-13	N/A
Mo^{+6}	2.69E-02	N/A	2.81E-02	N/A	1.50E-05	N/A	3.10E-07	N/A	2.67E-11	N/A
Na^{+}	5.70E+02	N/A	4.44E+02	N/A	5.90E-01	N/A	1.19E-02	N/A	1.03E-06	N/A

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Table F.3.2.1 Maximum Concentrations Calculated for the Long-Term Management Alternative (cont'd)

Consti-tuent	300 years		500 years		2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
NO_2^-	6.38E+01	N/A	4.94E+01	N/A	2.53E-02	N/A	5.12E-04	N/A	4.41E-08	N/A
NO_3-	1.05E+03	N/A	8.21E+02	N/A	1.21E+00	N/A	2.44E-02	N/A	2.10E-06	N/A
OH^-	2.26E+01	N/A	1.79E+01	N/A	6.02E-02	N/A	1.21E-03	N/A	1.04E-07	N/A
SiO_3^{-2}	2.02E+01	N/A	1.56E+01	N/A	6.40E-03	N/A	1.29E-04	N/A	1.11E-08	N/A
SO_4^{-2}	2.28E+01	N/A	1.77E+01	N/A	7.23E-03	N/A	1.46E-04	N/A	1.26E-08	N/A
UO_2^{+2}	1.26E-01	N/A	1.49E-01	N/A	3.80E-12	N/A	0.00E+00	N/A	0.00E+00	N/A
V^{+5}	1.06E-03	N/A	1.20E-03	N/A	2.41E-07	N/A	4.98E-09	N/A	4.00E-13	N/A
W^{+4}	3.92E-03	N/A	4.22E-03	N/A	2.00E-13	N/A	0.00E+00	N/A	0.00E+00	N/A
K_d Group 2 (K_d = 1.0 mL/g)										
Bi-210	N/A	N/A	N/A	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
Ni-63	N/A	N/A	N/A	N/A	2.00E-13	N/A	0.00E+00	N/A	0.00E+00	N/A
Pa-231	N/A	N/A	N/A	N/A	8.20E-09	N/A	5.67E-10	N/A	3.79E-11	N/A
Pa-233	N/A	N/A	N/A	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
Pa-234m	N/A	N/A	N/A	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
Po-211	N/A	N/A	N/A	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
Bi^{+3}	N/A	N/A	N/A	N/A	6.86E+00	N/A	4.70E-01	N/A	3.40E-02	N/A
Ca^{+2}	N/A	N/A	N/A	N/A	2.04E-01	N/A	6.48E-02	N/A	1.88E-03	N/A
Cd^{+2}	N/A	N/A	N/A	N/A	3.72E-02	N/A	3.81E-03	N/A	2.14E-04	N/A
Cu^{+2}	N/A	N/A	N/A	N/A	6.00E-06	N/A	1.24E-07	N/A	1.07E-11	N/A
Fe^{+3}	N/A	N/A	N/A	N/A	7.14E+00	N/A	5.11E-01	N/A	3.77E-02	N/A
Mg^{+2}	N/A	N/A	N/A	N/A	2.63E-02	N/A	5.36E-03	N/A	2.04E-04	N/A
Ni^{+2}	N/A	N/A	N/A	N/A	2.13E-01	N/A	8.37E-02	N/A	2.31E-03	N/A

Notes:
N/A = Not applicable

Table F.3.3.1 Maximum Concentrations Calculated for the In Situ Fill and Cap Alternative

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
C-14	1.40E-12	6.23E-03	2.99E-07	1.33E+03	1.93E-08	8.59E+01
I-129	1.76E-08	3.10E-03	4.55E-05	8.00E+00	1.63E-06	2.87E+01
Rn-219	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-222	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	0.00E+00	0.00E+00	1.00E-13	3.34E-01	0.00E+00	0.00E+00
Sb-126m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se-79	1.35E-11	9.40E-04	6.51E-06	4.53E+02	1.91E-06	1.33E+02
Tc-99	2.72E-09	4.60E-02	8.70E-04	1.47E+04	1.03E-04	1.74E+03
U-233	0.00E+00	0.00E+00	5.84E-10	5.63E-03	1.03E-10	9.93E-04
U-234	1.00E-13	6.24E-07	3.70E-08	2.31E-01	4.41E-09	2.75E-02
U-235	2.02E-08	4.36E-05	1.57E-02	3.39E+01	1.61E-03	3.48E+00
U-236	1.00E-13	6.46E-09	1.62E-08	1.05E-03	3.81E-09	2.46E-04
U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-238	3.00E-06	1.01E-03	2.40E+00	8.06E+02	2.44E-01	8.20E+01
Ag^{+}	5.40E-10	N/A	5.53E-04	N/A	1.68E-07	N/A
As^{+5}	6.70E-11	N/A	3.00E-04	N/A	5.79E-07	N/A
B^{+3}	1.72E-10	N/A	4.12E-04	N/A	1.23E-06	N/A
Be^{+2}	5.76E-11	N/A	3.61E-05	N/A	7.80E-09	N/A
Cl	1.41E-07	N/A	1.09E-01	N/A	9.95E-03	N/A
CO_3^{-2}	1.47E-06	N/A	3.31E+00	N/A	3.19E-01	N/A
Cr^{+3}	2.20E-11	N/A	8.83E-05	N/A	1.86E-05	N/A
CrO_4^{-2}	7.22E-10	N/A	6.19E-02	N/A	1.21E-02	N/A
F^{-}	5.96E-06	N/A	6.75E-01	N/A	6.44E-02	N/A
$Fe(CN)_6^{-4}$	1.16E-06	N/A	1.93E-01	N/A	1.14E-03	N/A
Hg^{+}	2.40E-12	N/A	1.61E-05	N/A	6.68E-09	N/A
K^{+}	9.74E-07	N/A	3.47E-01	N/A	1.08E-04	N/A
Li^{+}	0.00E+00	N/A	6.63E-06	N/A	1.61E-08	N/A
Mo^{+6}	2.06E-09	N/A	1.73E-03	N/A	2.45E-06	N/A
Na^{+}	4.43E-05	N/A	7.00E+01	N/A	1.24E+01	N/A
NO_2^{-}	3.66E-06	N/A	8.31E+00	N/A	8.64E-01	N/A
NO_3^{-}	3.17E-05	N/A	1.27E+02	N/A	2.68E+01	N/A
Np-237	2.02E-10	1.42E-04	6.87E-05	4.84E+01	9.19E-06	6.47E+00
Np-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

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Table F.3.3.1 Maximum Concentrations Calculated for the In Situ Fill and Cap Alternative (cont'd)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
OH^-	1.94E-05	N/A	2.34E+00	N/A	1.35E+00	N/A
Rh-106	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
SO_4^{-2}	2.43E-06	N/A	2.98E+00	N/A	3.04E-01	N/A
UO_2^{+2}	6.95E-08	N/A	2.27E-02	N/A	3.46E-07	N/A
V^{+5}	4.28E-10	N/A	1.54E-04	N/A	3.94E-08	N/A
W^{+4}	0.00E+00	N/A	2.00E-04	N/A	8.67E-08	N/A

Notes:
N/A = Not applicable

Table F.3.4.1 Maximum Concentrations Calculated for the In Situ Vitrification Alternative

Constituents	5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
Tc_2O_7	1.72E-06	2.91E+01	2.21E-06	3.73E+01
U-233	1.40E-12	1.35E-05	1.80E-12	1.74E-05
U-234	3.92E-11	2.45E-04	4.99E-11	3.11E-04
U-235	1.25E-05	2.70E-02	1.61E-05	3.48E-02
U-236	4.51E-11	2.91E-06	5.82E-11	3.76E-06
U-238	1.84E-03	6.18E-01	2.37E-03	7.96E-01
Ag_2O	1.90E-06	N/A	2.45E-06	N/A
As_2O_5	1.42E-06	N/A	1.83E-06	N/A
B_2O_3	4.86E-06	N/A	6.27E-06	N/A
BeO	1.01E-07	N/A	1.31E-07	N/A
Cr_2O_3	7.11E-05	N/A	9.18E-05	N/A
Li_2O	3.38E-08	N/A	4.36E-08	N/A
Na_2O	7.39E-02	N/A	9.54E-02	N/A
MoO_3	6.31E-06	N/A	8.14E-06	N/A
NpO_2	1.63E-07	N/A	2.10E-07	N/A
V_2O_5	2.78E-07	N/A	3.59E-07	N/A
WO_2	5.63E-07	N/A	7.26E-07	N/A
WO_3	1.12E-06	N/A	1.45E-06	N/A

Notes:
N/A = Not applicable

Table F.3.5.1 Maximum Concentrations Calculated for the Ex Situ Intermediate Separations Alternative - Tank Sources

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
C-14	3.42E-10	1.52E+00	6.80E-09	3.03E+01	2.00E-13	8.90E-04
I-129	5.32E-08	9.36E-03	2.01E-06	3.54E-01	1.31E-10	2.13E-05
Rn-219	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-222	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-126	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se-79	7.49E-09	5.21E-01	2.75E-07	1.91E+01	1.71E-11	1.19E-03
Tc-99	3.78E-07	6.39E+00	1.50E-05	2.54E+02	1.55E-09	2.62E-02
U-233	7.00E-13	6.75E-06	2.32E-11	2.24E-04	0.00E+00	0.00E+00
U-234	2.45E-11	1.53E-04	1.42E-09	9.96E-03	0.00E+00	0.00E+00
U-235	7.44E-06	1.61E-02	5.82e-04	1.26E+00	7.16E-09	1.55E-05
U-236	4.57E-11	2.95E-06	6.63E-10	4.28E-05	N/A	0.00E+00
U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-238	1.11E-03	3.73E-01	8.89E-02	2.99E+01	1.02E-06	3.43E-04
Ag^{+}	3.24E-10	N/A	1.94E-05	N/A	1.72E-10	N/A
As^{+5}	4.02E-11	N/A	1.39E-05	N/A	5.95E-10	N/A
B^{+3}	1.03E-10	N/A	1.82E-05	N/A	1.26E-09	N/A
Be^{+2}	3.46E-11	N/A	9.15E-07	N/A	0.00E+00	N/A
Cl^{-}	1.71E-05	N/A	4.06E-03	N/A	2.50E-07	N/A
CrO_4^{-2}	2.57E-06	N/A	3.16E-03	N/A	2.87E-07	N/A
F^{-}	1.80E-03	N/A	2.47E-02	N/A	1.86E-07	N/A
$Fe(CN)_6^{-4}$	4.47E-04	N/A	4.27E-03	N/A	7.22E-09	N/A
Hg^{+}	1.5E-12	N/A	7.64E-07	N/A	0.00E+00	N/A
Li^{+}	0.00E+00	N/A	3.29E-07	N/A	1.66E-11	N/A
Na^{+}	1.61E-03	N/A	2.78E+00	N/A	1.18E-04	N/A
NO_2^{-}	2.10E-03	N/A	3.10E-01	N/A	4.96E-06	N/A
NO_3^{-}	2.18E-02	N/A	5.13E+00	N/A	2.44E-04	N/A
SO_4^{-2}	9.07E-04	N/A	1.11E-01	N/A	1.44E-06	N/A
UO_2^{+2}	4.23E-08	N/A	8.93E-05	N/A	0.00E+00	N/A
V^{+5}	2.57E-10	N/A	1.23E-06	N/A	4.05E-11	N/A
W^{+6}	0.00E+00	N/A	9.90E-06	N/A	0.00E+00	N/A
Np-237	7.19E-08	5.06E-02	2.22E-06	1.56E+00	8.42E-11	5.93E-05

Table F.3.5.1 Maximum Concentrations Calculated for the Ex Situ Intermediate Separations Alternative - Tank Sources (cont'd)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
Np-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO_3^{-2}	6.66E-04	N/A	1.21E-01	N/A	8.51E-07	N/A
Cr^{+3}	1.52E-08	N/A	3.56E-06	N/A	1.69E-10	N/A
K^+	5.85E-07	N/A	2.68E-03	N/A	1.11E-07	N/A
Mo^{+6}	1.24E-09	N/A	5.51E-05	N/A	2.52E-09	N/A
OH^-	6.53E-03	N/A	1.14E-01	N/A	1.22E-05	N/A
SiO_3^{-2}	1.11E-03	N/A	9.80E-02	N/A	1.29E-06	N/A

Notes:
N/A = Not applicable

Table F.3.5.2 Maximum Concentrations Calculated for the LAW Vaults - Ex Situ Intermediate Separations Alternative

Constituent	5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
Tc-99	4.56E-06	7.71E+01	1.23E-05	2.08E+02
U-233	2.00E-13	1.93E-06	6.00E-13	5.78E-06
U-234	6.60E-12	4.12E-05	1.76E-11	1.10E-04
U-235	2.06E-06	4.45E-03	5.56E-06	1.20E-02
U-236	7.60E-12	4.91E-07	2.05E-11	1.32E-06
U-238	3.09E-04	1.04E-01	8.35E-04	2.81E-01
Ag_2O	1.19E-06	N/A	3.23E-06	N/A
As_2O_5	2.80E-06	N/A	7.57E-06	N/A
B_2O_3	5.46E-06	N/A	1.48E-05	N/A
BeO	2.98E-07	N/A	8.06E-07	N/A
Cr_2O_3	3.52E-06	N/A	9.51E-06	N/A
Li_2O	2.11E-08	N/A	5.71E-08	N/A
MoO_3	1.77E-05	N/A	4.79E-05	N/A
Na_2O	2.66E-01	N/A	7.19E-01	N/A
NpO_2	5.33E-08	N/A	1.44E-07	N/A
V_2O_5	2.27E-07	N/A	6.13E-07	N/A
WO_2	1.22E-10	N/A	3.29E-10	N/A
WO_3	3.66E-06	N/A	9.89E-06	N/A

Notes:
N/A = Not applicable

Table F.3.8.1 Maximum Concentrations Calculated in Groundwater for the Ex Situ/In Situ Combination 1 Alternative (Tank Retrieval Component)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
C-14	2.30E-10	1.02E+00	6.71E-10	2.99E+00	0.00	0.00E+00
I-129	3.91E-08	6.88E-03	1.18E-07	2.08E-02	1.08E-11	1.90E-06
Np-237	5.23E-08	3.68E-02	9.63E-08	6.78E-02	6.20E-12	4.36E-06
Np-238	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
Rh-106	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
Rn-219	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
Rn-222	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
Ru-106	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
Sb-126m	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
Se-79	5.49E-09	3.82E-01	1.59E-08	1.11E+00	1.40E-12	9.74E-05
Tc-99	2.78E-07	4.70E+00	8.15E-07	1.38E+01	7.55E-11	1.28E-03
U-233	4.00E-13	3.86E-06	1.60E-12	1.54E-05	0.00	0.00E+00
U-234	1.01E-11	6.30E-05	9.16E-11	5.72E-04	0.00	0.00E+00
U-235	3.36E-06	7.26E-03	2.59E-05	5.59E-02	5.02E-10	1.08E-06
U-236	1.71E-11	1.10E-06	1.74E-10	1.12E-05	0.00	0.00E+00
U-237	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
U-238	4.99E-04	1.68E-01	3.95E-03	1.33E+00	7.20E-08	2.42E-05
Cl^-	6.63E-06	N/A	1.20E-04	N/A	1.99E-09	N/A
CO_3^{-2}	3.70E-04	N/A	4.22E-03	N/A	6.97E-08	N/A
Cr^{+3}	7.72E-09	N/A	1.35E-07	N/A	8.50E-12	N/A
CrO_4^{-2}	7.90E-07	N/A	5.23E-05	N/A	4.91E-09	N/A
F^-	7.15E-04	N/A	7.25E-03	N/A	1.05E-08	N/A
$Fe(CN)_6^{-4}$	1.75E-04	N/A	1.33E-04	N/A	3.52E-10	N/A
Hg^+	2.94E-07	N/A	2.91E-06	N/A	1.05E-10	N/A
Na^+	7.30E-03	N/A	1.02E-01	N/A	5.42E-06	N/A
NO_2^-	1.33E-03	N/A	1.23E-02	N/A	2.76E-07	N/A
NO_3^-	1.11E-02	N/A	1.95E-01	N/A	1.23E-05	N/A
OH^-	2.39E-03	N/A	2.43E-02	N/A	5.45E-07	N/A
SiO_3^{-2}	2.95E-04	N/A	3.42E-03	N/A	2.27E-08	N/A
SO_4^{-2}	4.05E-04	N/A	3.94E-03	N/A	1.01E-07	N/A
W^{+4}	4.72E-06	N/A	4.67E-05	N/A	1.68E-09	N/A

Note: N/A = Not applicable

Table F.3.8.2 Maximum Concentrations Calculated in Groundwater for the Ex Situ/In Situ Combination 1 Alternative (In Situ Tank Remediation Component)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
C-14	1.0E-13	4.45E-04	5.89E-08	2.62E+02	1.45E-09	6.45E+00
I-129	9.50E-12	1.67E-06	2.16E-05	3.80E+00	1.07E-06	1.88E-01
Np-237	1.48E-11	1.04E-05	2.47E-05	1.74E+01	1.26E-06	8.87E-01
Np-238	0.00	0.00	0.00	0.00	0.00	0.00
Rh-106	0.00	0.00	0.00	0.00	0.00	0.00
Rn-219	0.00	0.00	0.00	0.00	0.00	0.00
Rn-222	0.00	0.00	0.00	0.00	0.00	0.00
Ru-106	0.00	0.00	0.00	0.00	0.00	0.00
Sb-126m	0.00	0.00	0.00	0.00	0.00	0.00
Se-79	1.30E-12	9.05E-05	2.98E-06	2.07E+02	1.38E-07	9.60E+00
Tc-99	1.21E-10	2.04E-03	1.64E-04	2.77E+03	7.49E-06	1.27E+02
U-233	0.00	0.00	4.96E-10	4.78E-03	4.06E-11	3.91E-04
U-234	0.00	0.00	1.33E-08	8.30E-02	1.32E-09	8.24E-03
U-235	1.04E-09	2.25E-06	2.03E-03	4.38E+00	1.47E-04	3.18E-01
U-236	0.00	0.00	2.18E-09	1.41E-04	6.99E-10	4.52E-05
U-237	0.00	0.00	0.00	0.00	0.00	0.00
U-238	1.49E-07	5.01E-05	3.07E-01	1.03E+02	1.99E-02	6.69E+00
Ag^{+}	1.10E-10	N/A	2.80E-03	N/A	3.59E-08	N/A
As^{+5}	4.11E-11	N/A	4.92E-04	N/A	1.25E-07	N/A
B^{+3}	1.05E-10	N/A	1.91E-03	N/A	4.07E-08	N/A
Be^{+2}	3.45E-11	N/A	9.49E-06	N/A	1.00E-13	N/A
Cl^{-}	5.19E-08	N/A	8.49E-02	N/A	5.69E-04	N/A
CO_3^{-2}	1.51E-06	N/A	1.94E+00	N/A	6.18E-03	N/A
Cr^{+3}	9.40E-12	N/A	5.44E-05	N/A	6.38E-06	N/A
CrO_4^{-2}	1.84E-08	N/A	2.60E-02	N/A	4.82E-03	N/A
F^{-}	5.63E-07	N/A	2.99E-01	N/A	3.68E-03	N/A
$Fe(CN)_6^{-4}$	1.86E-07	N/A	5.64E-02	N/A	2.93E-04	N/A
Hg^{+}	3.52E-10	N/A	1.03E-03	N/A	8.35E-06	N/A
K^{+}	3.19E-07	N/A	3.20E-02	N/A	5.09E-06	N/A
Li^{+}	0.00	N/A	1.37E-05	N/A	3.48E-09	N/A
Mo^{+6}	8.81E-10	N/A	3.33E-04	N/A	2.62E-08	N/A
Na^{+}	9.14E-06	N/A	4.38E+01	N/A	4.54E+00	N/A
NO_2^{-}	1.71E-06	N/A	3.15E+00	N/A	1.02E-01	N/A
NO_3^{-}	1.35E-05	N/A	7.83E+01	N/A	9.19E+00	N/A
OH^{-}	1.42E-06	N/A	2.84E+00	N/A	5.38E-01	N/A
SiO_3^{-2}	9.51E-08	N/A	1.45E+00	N/A	9.01E-02	N/A

Table F.3.8.2 Maximum Concentrations Calculated in Groundwater for the Ex Situ/In Situ Combination 1 Alternative (In Situ Tank Remediation Component) (cont'd)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
SO_4^{-2}	4.31E-07	N/A	1.92E+00	N/A	1.65E-02	N/A
UO_2^{+2}	4.17E-08	N/A	8.61E-03	N/A	4.56E-11	N/A
V^{+5}	2.63E-10	N/A	3.35E-05	N/A	8.50E-09	N/A
W^{+4}	5.65E-09	N/A	1.74E-02	N/A	1.34E-04	N/A

Notes:
N/A = Not applicable

Table F.3.8.3 Maximum Concentrations Calculated in Groundwater for the Ex Situ/In Situ Combination 1 Alternative (LAW Vault Component)

Constituent	5,000 years		10,000 year	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
Tc-99	2.34E-06	3.95E+01	6.30E-06	1.06E+02
U-233	1.00E-13	9.64E-07	3.00E-13	2.89E-06
U-234	3.40E-12	2.12E-05	9.00E-12	5.62E-05
U-235	1.05E-06	2.27E-03	9.00E-12	1.94E-08
U-236	3.90E-12	2.52E-07	1.05E-11	6.78E-07
U-238	1.58E-04	5.31E-02	4.28E-04	1.44E-01
Ag^+	6.12E-07	N/A	1.65E-06	N/A
As^{+5}	1.43E-06	N/A	3.88E-06	N/A
B^+	2.80E-06	N/A	7.56E-06	N/A
Be^{+2}	1.53E-07	N/A	4.13E-07	N/A
Cr^{+3}	1.80E-06	N/A	4.87E-06	N/A
K^+	4.11E-07	N/A	1.11E-06	N/A
Li^+	1.08E-08	N/A	2.92E-08	N/A
Mo^{+6}	9.08E-06	N/A	2.46E-05	N/A
Na^+	1.36E-01	N/A	3.68E-01	N/A
NpO_2	2.73E-08	N/A	7.39E-08	N/A
SiO_3^{-2}	1.20E-01	N/A	5.40E-01	N/A
V^+	1.16E-07	N/A	3.14E-07	N/A
WO_3	1.87E-06	N/A	5.07E-06	N/A
WO_2	6.23E-11	N/A	1.69E-10	N/A

Notes:
N/A = Not applicable

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Table F.3.10.1 Maximum Concentrations Calculated in Groundwater for the Phased Implementation Total Alternative (Tank Sources)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
C-14	3.42E-10	1.52E+00	6.80E-09	3.03E+01	2.00E-13	8.90E-04
I-129	5.32E-08	9.36E-03	2.01E-06	3.54E-01	1.31E-10	2.13E-05
Rn-219	0.00	0.00	0.00	0.00	0.00	0.00
Rn-222	0.00	0.00	0.00	0.00	0.00	0.00
Ru-106	0.00	0.00	0.00	0.00	0.00	0.00
Sb-126	0.00	0.00	0.00	0.00	0.00	0.00
Se-79	7.49E-09	5.21E-01	2.75E-07	1.91E+01	1.71E-11	1.19E-03
Tc-99	3.78E-07	6.39E+00	1.50E-05	2.54E+02	1.55E-09	2.62E-02
U-233	7.00E-13	6.75E-06	2.32E-11	2.24E-04	0.00	0.00
U-234	2.45E-11	1.53E-04	1.42E-09	8.86E-03	0.00	0.00
U-235	7.44E-06	1.61E-02	5.82E+04	1.26E+06	7.16E-09	1.55E-05
U-236	4.57E-11	2.95E-06	6.63E-10	4.28E-05	0.00	0.00
U-237	0.00	0.00	0.00	0.00	0.00	0.00
U-238	1.11E-03	3.73E-01	8.89E-02	2.99E+02	1.02E-06	3.43E-04
Ag^{+}	3.24E-10	N/A	1.94E-05	N/A	1.72E-10	N/A
As^{+5}	4.02E-11	N/A	1.39E-05	N/A	5.95E-10	N/A
B^{+3}	1.03E-10	N/A	1.82E-05	N/A	1.26E-09	N/A
Be^{+2}	3.46E-11	N/A	9.15E-07	N/A	0.00	N/A
Cl^{-}	1.71E-05	N/A	4.06E-03	N/A	2.50E-07	N/A
CrO_4^{-2}	2.57E-06	N/A	3.16E-03	N/A	2.87E-07	N/A
F^{-}	1.80E-03	N/A	2.47E-02	N/A	1.86E-07	N/A
$Fe(CN)_6^{-4}$	4.47E-04	N/A	4.27E-03	N/A	7.22E-09	N/A
Hg^{+}	1.50E-12	N/A	7.64E-07	N/A	0.00	N/A
Li^{+}	0.00	N/A	3.29E-07	N/A	1.66E-11	N/A
Na^{+}	1.62E-02	N/A	2.78E+00	N/A	1.18E-04	N/A
NO_2	2.11E-03	N/A	3.09E-01	N/A	4.96E-06	N/A
NO_3	2.18E-02	N/A	5.13E+00	N/A	2.44E-04	N/A
SO_4^{-2}	9.07E-04	N/A	1.11E-01	N/A	1.44E-06	N/A
UO_2^{+2}	4.23E-08	N/A	8.93E-05	N/A	0.00	N/A
V^{+5}	2.57E-10	N/A	1.23E-06	N/A	4.05E-11	N/A
W^{+6}	0.00	N/A	9.90E-06	N/A	0.00	N/A
Np-237	7.19E-08	5.06E-02	2.22E-06	1.56E+00	8.42E-11	5.93E-05
Np-238	0.00	0.00	0.00	0.00	0.00	0.00
Rh-106	0.00	0.00	0.00	0.00	0.00	0.00
CO_3^{-2}	6.66E-04	N/A	1.21E-01	N/A	8.51E-07	N/A
Cr^{+3}	1.52E-08	N/A	3.56E-06	N/A	1.69E-10	N/A

Table F.3.10.1 Maximum Concentrations in Groundwater Calculated for the Phased Implementation Total Alternative (Tank Sources) (cont'd)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
K^+	5.85E-07	N/A	2.68E-03	N/A	1.11E-07	N/A
Mo^{+6}	1.24E-09	N/A	5.51E-05	N/A	2.52E-09	N/A
OH^-	6.53E-03	N/A	1.14E-01	N/A	1.22E-05	N/A
SO_4^{-2}	9.07E-04	N/A	1.11E-01	N/A	1.44E-06	N/A

Notes
N/A = Not applicable

Table F.3.10.2 Maximum Concentration Calculated in Groundwater for the Phased Implementation Total Alternative (LAW Vaults)

Constituent	5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
Tc-99	4.56E-06	7.71E+01	1.23E-05	2.08E+02
U-233	2.00E-13	1.93E-06	6.00E-13	5.78E-06
U-234	6.60E-12	4.12E-05	1.76E-11	1.10E-04
U-235	2.06E-06	4.45E-03	5.56E-06	1.20E-02
U-236	7.60E-12	4.91E-07	2.05E-11	1.32E-06
U-238	3.09E-04	1.04E-01	8.35E-04	2.81E-01
Ag_2O	1.19E-06	N/A	3.23E-06	N/A
As_2O_5	2.80E-06	N/A	7.57E-06	N/A
B_2O_3	5.46E-06	N/A	1.48E-05	N/A
BeO	2.98E-07	N/A	8.06E-07	N/A
Cr_2O_3	3.52E-06	N/A	9.51E-06	N/A
Li_2O	2.11E-08	N/A	5.71E-08	N/A
MoO_3	1.77E-05	N/A	4.79E-05	N/A
Na_2O	2.66E-01	N/A	7.19E-01	N/A
NpO_2	5.33E-08	N/A	1.44E-07	N/A
V_2O_5	2.27E-07	N/A	6.13E-07	N/A
WO_2	1.22E-10	N/A	3.29E-10	N/A
WO_3	3.66E-06	N/A	9.89E-06	N/A

Notes
N/A = Not applicable

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Table F.3.12.1 Comparison of Maximum Contaminant Concentrations Calculated in Groundwater for Each Alternative

Constituent	Alternative	Drinking Water Standards	Maximum concentration Observed in Groundwater at the Specified Time				
			300 Years (mg/L)	500 Years (mg/L)	2,500 Years (mg/L)	5,000 Years (mg/L)	10,000 Years (mg/L)
Carbon-14	No Action	2,000 pCi/L (4.49E-7 mg/L)	1.55E-05*	4.57E-06*	2.13E-09	3.18E-11	0.00
	Long-Term Management		3.15E-06*	3.96E-06*	2.13E-09	3.18E-11	0.00
	In Situ Fill and Cap		0.0	0.0	1.40E-12	2.99 E-07	1.93E-08
	In Situ Vitrification		0.0	0.0	0.0	0.0	0.0
	Ex Situ Intermediate Separations Ex Situ-Tank Sources[1]		0.0	0.0	3.42E-10	6.80E-09	2.00E-13
	Ex Situ Intermediate Separations Ex Situ-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ No Separations		0.0	0.0	3.42E-10	6.80E-09	2.00E-13
	Ex Situ Extensive Separations-Tank Sources[1]		0.0	0.0	3.42E-10	6.80E-09	2.00E-13
	Ex Situ Extensive Separations-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ/In Situ Combination 1-Tank Sources[1]		0.0	0.0	2.30E-10	5.89E-08	1.45E-09
	Ex Situ/In Situ Combination 1-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ/In Situ Combination 2 - Tank Sources		0.0	0.0	7.78E-11	5.87E-8	8.10E-9
	Ex Situ/In Situ Combination 2 - SAW Vaults		0.0	0.0	0.0	0.0	0.0
	Phased Implementation (Phase 1)		0.0	0.0	0.0	0.0	0.0
	Phased Implementation (Total) Tank Sources [1]		0.0	0.0	3.42E-10	6.80E-09	2.00E-13
	Phased Implementation (Total) LAW Vaults [1]		0.0	0.0	0.0	0.0	0.0

Table F.3.12.1 Comparison of Maximum Contaminant Concentrations Calculated for Each Alternative (cont'd)

Constituent	Alternative	Drinking Water Standards	Maximum Concentration Observed in Groundwater at the Specified Time				
			300 Years (mg/L)	500 Years (mg/L)	2,500 Years (mg/L)	5,000 Years (mg/L)	10,000 Years (mg/L)
Iodine-129	No Action	1 pCi/L (5.68E-06 mg/L)	2.50E-03*	3.21E-04*	6.53E-07	1.32E-08	1.10E-12
	Long-Term Management		2.50E-03*	3.21E-04*	6.54E-07	1.32E-08	1.10E-12
	In Situ Fill and Cap		0.0	0.0	1.76E-08	4.55E-05*	1.63E-06
	In Situ Vitrification		0.0	0.0	0.0	0.0	0.0
	Ex Situ Intermediate Separations Ex Situ-Tank Sources[1]		0.0	0.0	5.32E-08	2.01E-06	1.32E-10
	Ex Situ Intermediate Separations Ex Situ-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ No Separations		0.0	0.0	5.32E-08	2.01E-06	1.32E-10
	Ex Situ Extensive Separations-Tank Sources[1]		0.0	0.0	5.32E-08	2.01E-06	1.32E-10
	Ex Situ Extensive Separations-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ/In Situ Combination 1-Tank Source[1]		0.0	0.0	3.91E-08	2.17E-05*	1.07E-06
	Ex Situ/In Situ Combination 1-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ/In Situ Combination 2 -Tank Sources		0.0	0.0	1.26E-08	2.40E-05*	5.57E-06
	Ex Situ/In Situ Combination 2 - LAW Vaults		0.0	0.0	0.0	0.0	0.0
	Phased Implementation (Phase 1)		0.0	0.0	0.0	0.0	0.0
	Phased Implementation (Total) Tank Sources [1]		0.0	0.0	5.32E-08	2.01E-06	1.32E-10
	Phased Implementation (Total) LAW Vaults [1]		0.0	0.0	0.0	0.0	0.0

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Table F.3.12.1 Comparison of Maximum Containment Contaminant Calculated in Groundwater for Each Alternative (cont'd)

Constituent	Alternative	Drinking Water Standards	Maximum Concentration Observed in Groundwater at the Specified Time				
			300 Years (mg/L)	500 Years (mg/L)	2,500 Years (mg/L)	5,000 Years (mg/L)	10,000 Years (mg/L)
Technetium-99	No Action	900 pCi/L (5.33E-05 mg/L)	1.87E-02*	7.45E-03*	8.02E-06	1.58E-07	1.34E-11
	Long-Term Management		5.40E-03*	6.48E-03*	8.44E-06	1.71E-07	1.45E-11
	In Situ Fill and Cap		0.0	0.0	2.72E-09	8.70E-04*	1.03E-04*
	In Situ Vitrification		0.0	0.0	0.0	1.72E-06	2.21E-06
	Ex Situ Intermediate Separations Ex Situ Tank Sources[1]		0.0	0.0	3.78E-07	1.50E-05	1.55E-09
	Ex Situ Intermediate Separations Ex Situ-LAW Vaults[1]		0.0	0.0	0.0	4.56E-06	1.23E-05
	Ex Situ No Separations		0.0	0.0	3.78E-07	1.50E-05	1.55E-09
	Ex Situ Extensive Separations - Tank Sources[1]		0.0	0.0	3.78E-07	1.50E-05	1.55E-09
	Ex Situ Extensive Separations - LAW Vaults[1]		0.0	0.0	0.0	3.36E-08	9.05E-08
	Ex Situ/In Situ Combination 1-Tank Sources[1]		0.0	0.0	2.78E-07	1.65E-04*	7.49E-06
	Ex Situ/In Situ Combination 1-LAW Vaults[1]		0.0	0.0	0.0	2.34E-06	6.30E-06
	Ex Situ/In Situ Combination 2-Tank Sources		0.0	0.0	8.91E-08	1.70E-04*	3.90E-05
	Ex Situ/In Situ Combination 2-LAW Vaults		0.0	0.0	0.0	2.02E-06	5.45E-06
	Phased Implementation (Phase 1)		0.0	0.0	0.0	0.0	0.0
	Phased Implementation (Total) Tank Sources [1]		0.0	0.0	3.78E-07	1.50E-05	1.55E-09
	Phased Implementation (Total) LAW Vaults [1]		0.0	0.0	0.0	4.56E-06	1.23E-05

Table F.3.12.1 Comparison of Maximum Contaminant Concentrations Calculated in Groundwater for each Alternative (cont'd)

Constituent	Alternative	Drinking Water Standards	Maximum Concentrations Observed in groundwater at the Specified Time				
			300 Years (mg/L)	500 Years (mg/L)	2,500 Years (mg/L)	5,000 Years (mg/L)	10,000 Years (mg/L)
Uranium-238	No Action	0.02 mg/L (Total)	1.23E+02*	1.42E+01*	5.04E-03	1.02E-04	0.0
	Long-Term Management		1.83E+01*	1.42E+01*	7.50E-04	1.51E-05	9.00E-09
	In Situ Fill and Cap		0.0	0.0	3.00E-06	2.40E+00*	2.44E-01*
	In Situ Vitrification		0.0	0.0	0.0	1.84E-03	2.37E-03
	Ex Situ Intermediate Separations Ex Situ-Tank Sources[1]		0.0	0.0	1.11E-03	8.90E-02*	1.02E-06
	Ex Situ Intermediate Separations Ex Situ-LAW Vaults[1]		0.0	0.0	0.0	3.08E-04	8.35E-04
	Ex Situ No Separations		0.0	0.0	1.11E-03	8.90E-02*	1.02E-06
	Ex Situ Extensive Separations - Tank Sources[1]		0.0	0.0	1.11E-03	8.90E-02*	1.02E-06
	Ex Situ Extensive Separations - LAW Vaults[1]		0.0	0.0	0.0	1.13E-06	3.06E-06
	Ex Situ/In Situ Combination 1-Tank Sources[1]		0.0	0.0	4.99E-04	3.11E-01*	1.99E-02
	Ex Situ/In Situ Combination 1-LAW Vaults[1]		0.0	0.0	0.0	1.58E-04	4.28E-04
	Ex Site/In Situ Combination 2-tank Sources		0.0	0.0	9.62E-05	8.22E-01*	5.53E-02*
	Ex Situ/In Situ Combination 2-LAW Vaults		0.0	0.0	0.0	7.78E-05	2.10E-04
	Phased Implementation (Phase 1)		0.0	0.0	0.0	0.0	0.0
	Phased Implementation (Total) Tank Sources [1]		0.0	0.0	1.11E-03	8.90E-02*	1.02E-06
	Phased Implementation (Total) LAW Vaults [1]		0.0	0.0	0.0	3.08E-04	8.35E-04

Table F.3.12.1 Comparison of Maximum Contaminant Concentrations Calculated in Groundwater for each Alternative (cont'd)

Constituent	Alternative	Drinking Water Standards	Maximum Concentration Observed in Groundwater at the Specified Time				
			300 Years (mg/L)	500 Years (mg/L)	2,500 Years (mg/L)	5,000 Years (mg/L)	10,000 Years (mg/L)
Nitrate	No Action	45 mg/L	6.62E+03*	8.22E+02*	1.21E+00	2.43-02	2.90E-06
	Long-Term Management		1.05E+03*	8.21E+02*	1.21E+00	2.44E-02	2.10E-06
	In Situ Fill and Cap		0.0	0.0	3.17E-05	1.27E+02*	2.68E+01
	In Situ Vitrification		0.0	0.0	0.0	0.0	0.0
	Ex Situ Intermediate Separations Ex Situ-Tank Sources[1]		0.0	0.0	2.19E-02	5.13E+00	2.44E-04
	Ex Situ Intermediate Separations Ex Situ-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ No Separations		0.0	0.0	2.19E-02	5.13E+00	2.44E-04
	Ex Situ Extensive Separations - Tank Sources[1]		0.0	0.0	2.19E-02	5.13E+00	2.44E-04
	Ex Situ Extensive Separations - LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ/In Situ Combination 1-Tank Sources[1]		0.0	0.0	1.11E-02	7.85E+01*	9.19E+00
	Ex Situ/In Situ Combination 1-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ/In Situ Combination 2-Tank Sources		0.0	0.0	2.91E-03	8.00E-01*	1.59E+01
	Ex Situ/In Situ Combination 2-LAW Vaults		0.0	0.0	0.0	0.0	0.0
	Phased Implementation		0.0	0.0	0.0	0.0	0.0

Table F.3.12.1 Comparison of Maximum Contaminant Concentrations Calculated in Groundwater for each Alternative (cont'd)

Constituent	Alternative	Drinking Water Standards	Maximum Concentration Observed in Groundwater at the Specified Time				
			300 Years (mg/L)	500 Years (mg/L)	2,500 Years (mg/L)	5,000 Years (mg/L)	10,000 Years (mg/L)
Nitrate (cont'd)	Phased Implementation (Total) Tank Sources [1]		0.0	0.0	2.19E-02	5.13E+00	2.44E-04
	Phased Implementation (Total) LAW Vaults [1]		0.0	0.0	0.0	0.0	0.0

Notes:
[1] Maximum concentrations from the tank source and LAW vaults are additive, but not on a one-to-one basis because the source locations are not coincident and the time of release is not the same.
* Calculated value exceeds drinking water standard (40 CFR 141.16) based on a calculated dose equivalent to 4 millirem/year to an internal organ.

Table F.4.4.1 Estimated Mass of Selected Contaminants Released During Retrieval and as Residual for the Ex Situ Alternatives

Contaminant	Mass Released for Nominal Case Retrieval Scenario (g)	Mass Released for Lower Bounding Retrieval Scenario (g)	Mass Released as Residual Remaining in all Tanks (g)
Iodine-129	1.97E+03	3.94E+02	9.08E+02
Carbon-14	2.26E+01	4.52E+00	1.20E+01
Technetium-99	1.37E+04	2.74E+03	1.93E+04
Uranium-238	7.63E+08	1.53E+07	1.43E+07
Nitrate	8.12E+08	1.62E+08	1.03E+09

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Table F.4.5.1 Summary of Tank Leak Estimates from Single-Shell Tanks

Tank Number	Date Declared confirmed or Assumed Leaker [3]	Volume [1,2] (gallons)	Associated Kilocuries 137 Cs [8]	Interim Stabilized Date [9]
241-A-103	1987	5,500 [7]		6/88
241-A-104	1975	500 to 2,500	0.8 to 1.8	9/78
241-A-105	1963	10,000 to 277,000	85 to 760	7/79
241-AX-102	1988	3,000 [7]	--	9/88
241-AX-104	1977	---[5]	--	8/81
241-B-101	1974	---[5]	--	3/81
241-B-103	1978	---[5]	--	2/85
241-B-105	1978	---[5]	--	12/84
241-B-107	1980	8,000 [7]	--	3/85
241-B-110	1981	10,000 [7]	--	3/85
241-B-111	1978	---[5]	--	6/85
241-B-112	1978	2,000	--	5/85
241-B-201	1980	1,200 [7]	--	8/81
241-B-203	1983	300 [7]	--	6/84
241-B-204	1984	400 [7]	--	6/84
241-BX-101	1972	---[5]	--	9/78
241-BX-102	1971	70,000	50	11/78
241-BX-108	1974	2,500	0.5	7/79
241-BX-110	1976	---[5]	--	8/85
241-BX-111	1984	---[5]	--	3/95 [4]
241-BY-103	1973	<5,000	--	N/A
241-BY-105	1984	---[5]	--	N/A
241-BY-106	1984	---[5]	--	N/A
241-BY-107	1984	15,100 [7]	--	7/79
241-BY-108	1972	<5000	--	2/85
241-C-101	1980	20,000 [7]	--	11/83
241-C-110	1984	2,000	--	5/95
241-C-111	1968	5,500 [7]	--	3/84
241-C-201	1988	550	--	3/82
241-C-202	1988	450	--	8/81
241-C-203	1984	400 [7]	--	3/82
241-C-204	1988	350	--	9/82
241-S-104	1968	24,000 [7]		12/84
241-SX-104	1988	6,000 [7]	--	N/A
241-SX-107	1964	<5,000	--	10/79
241-SX-108	1962	2,400 to 35,000	17 to 140	8/79
241-SX-109	1965	<10,000	<40	5/81
241-SX-110	1976	5,500 [7]		8/79
241-SX-111	1974	500 to 2,000	0.6 to 2.4	7/79
241-SX-112	1969	30,000	40	7/79
241-SX-113	1962	15,000	8	11/78
241-SX-114	1972	---[5]	--	7/79
241-SX-115	1965	50,000	21	9/78

Table F.4.5.1 Summary of Tank Leak Estimates from Single-Shell Tanks (cont'd)

Tank Number	Date Declared confirmed or Assumed Leaker [3]	Volume [1,2] (gallons)	Associated Kilocuries 137 Cs [8]	Interim Stabilized Date [9]
241-T-101	1992	7,500 [7]	--	4/93
241-T-103	1974	<1,000 [7]	--	11/83
241-T-106	1973	115,000 [7]	40	8/81
241-T-107	1984	---[5]	--	N/A
241-T-108	1974	<1,000 [7]	--	11/78
241-T-109	1974	<1,000 [7]	--	12/84
241-T-111	1979,1994[10]	<1,000 [7]	--	2/95
241-TX-105	1977	---[5]	--	4/83
241-TX-107	1984	2500	--	10/79
241-TX-110	1977	---[5]	--	4/83
241-TX-113	1974	---[5]	--	4/83
241-TX-114	1974	---[5]	--	4/83
241-TX-115	1977	---[5]	--	9/83
241-TX-116	1977	---[5]	--	4/83
241-TX-117	1977	---[5]	--	3/83
241-TY-101	1973	<1,000 [7]	--	4/83
241-TY-103	1973	3,000	0.7	2/83
241-TY-104	1981	1,400 [7]	--	11/83
241-TY-105	1960	35,000	4	2/83
241-TY-106	1959	20,000	2	11/78
241-U-101	1959	30,000	20	9/79
241-U-104	1961	55,000	0.09	10/78
241-U-110	1975	5,000 to 8,100 [7]	0.05	12/84
241-U-112	1980	8,500 [7]	--	9/79
67 Tanks		<600,000-900,000 [6]		

Source: Hanlon 1996

Notes:

- = No data provided

N/A = Not applicable (not yet interim stabilized)

[1] One gallon is equal to 3.788 L.

[2] These leak volume estimates do not include (with some exceptions) such things as 1) cooling/raw water leaks; 2) intrusions (rain infiltration) and subsequent leaks; 3) leaks inside the tank farm but not through the tank liner (surface leaks, pipeline leaks, leaks at the joint for the overflow or fill lines, etc.); and 4) leaks from catch tanks, diversion boxes, encasements, etc.

[3] In many cases, a leak was suspected long before it was identified or confirmed. For example, tank 241-U-104 was suspected of leaking in 1956. The leak was confirmed in 1961. This report lists the assumed leaker date as 1961. Using present standards, tank 241-U-104 would have been declared as assumed leaker in 1956. In 1984, the criteria designations of "suspected leaker," "questionable integrity," "confirmed leaker," "declared leaker," "borderline," and "dormant" were merged into one category now reported as "assumed leaker." It is highly likely that there have been undetected leaks from SSTs because of the nature of their design and instrumentation.

[4] Tank BX-111 was declared an assumed re-leaker in April 1993. Preparations for pumping were delayed, following an administrative hold placed on all tank farm operations in August 1993. Pumping resumed and the tank was declared interim stabilized on March 15, 1995.

[5] The total leak volume estimate for these tanks is 570,000 L (150,000 gal) [rounded to the nearest 38,000 L (10,000 gal)], for an average of approximately 30,400 L (8,000 gal) for each of the 19 tanks.

[6] The total has been rounded to the nearest 190,000 L (50,000 gal). Upperbound values were used in many cases in developing these estimates. It is likely that some of these tanks have not actually leaked.

[7] Leak volume estimate is based solely on observed liquid level decreases in these tanks. This is considered to be the most accurate method for estimating leak volumes.

[8] The curie content list is not decayed to a consistent date; therefore, a cumulative total is inappropriate.

[9] These dates indicate when the tanks were declared to be interim stabilized. In some cases, the official interim stabilization documents were issued at a later date. Also, in some cases, the field work associated with interim stabilization was completed at an earlier date.

[10] Tank 241-T-111 was declared an assumed re-leaker on February 28, 1994, due to a decreasing trend in surface level measurement. This tank was pumped and interim stabilized on February 22, 1995.

Table F.4.5.2 Estimated Past-Practice and Projected Future Waste Disposed Quantities Compared to Tank Waste Quantity

Waste Source / Contaminant	Tc-99 (Ci)	I-129 (Ci)	C-14 (Ci)	Uranium [3] (Ci)	Nitrate (Metric tons)
Waste Tanks (177)	32,700	38	5,330	480	103,500
Estimated Past-Practice Liquid Disposal [1]	254	2	[2]	36	50,000
Estimates Past Waste Tank Leaks [12]	847 [13]	8[13]	1,000 [10]	121 [13]	1230 [11]
Estimated Past-Practice Solid Waste Disposal [1]	[2]	[2]	6,300	560	[2]
Projected Low-Level Waste Disposal in 200 West Burial Grounds [4]	0.0025 [5] 1.6 [6]	0.014 [5] 0.17 [6]	1.3E-04 [5] 5.26 [6]	3.6E-04 [5] 206 [6]	[2]
Projected Low-Level Waste Disposal in ERDF [7] Burial Grounds	0.2	3.0E-05	118.7	115 [9]	[2]
Projected Low-Level Waste Disposal in US Ecology Burial Grounds [8]	65.5	5.77	3880.7	10,938	

Notes:
[1] Source: Wodrich 1991
[2] Indicates contaminant not provided in inventory
[3] Isotopic distribution of uranium is unknown and assumed to consist of U-238
[4] Source: Wood et al. 1995
[5] Waste disposed of as a Category 1 waste. Disposal does not include a cap.
[6] Waste disposed of as a Category 3 waste. Disposal includes a cap.
[7] Source: Wood et al. 1995a
[8] Source: Jacobs 1996
[9] Reported in Wood et al. 1995a as uranium. Assumed here to be U-238.
[10] Estimate based on maximum reported leak volumes of 3,420,000 L (900,000 gal) and maximum C-14 concentration in a SST of 6.74E-05 g/L in source area 2E55.
[11] Estimate based on maximum reported leak volume of 3,420,000 L (900,000 gal) and nitrate concentration of 3.60E+02 g/l.
[12] Potential leaks from tanks associated with cooling water sprays are not included in estimated past tank leaks.
[13] Source: Wodrich 1991. Adjusted for more recent estimate of tank leak volume.

Table F.4.5.3 Potential Maximum Groundwater Contaminant Concentrations Associated with Post Leak from Waste Tanks Solid Waste Disposal in the Central Plateau

Contaminant/ Waste Source	Tc-99 mg/L (pCi/L)	I-129 mg/L (pCi/L)	C-14 mg/L (pCi/L)	Uranium [3] mg/L (pCi/L)
Past Waste Tank Leaks[10]	4.8E-04[11] (8,190)	5.3E-04[11] (93)	2.91E-06 (12,900)	31[11] (10,400)
Estimated Past-Practice Solid Waste Disposal [1]	[2]	[2]	1.42E-06 (6,300)	1.67E+00 (560)
Projected Low-Level Waste Disposal in 200 West Burial Grounds [4]	1.54E-07 [5] 9.98E-05 [6] (2.6 [5] 1686 [6])	3.86E-07 [5] 4.72E-06 [6] (0.068 [5] 0.83 [6])	1.91E-11 [5] 7.62E-07 [6] (0.085 [5] 3392 [6])	6.25E-07 [5] 3.39E-01 [6] (2.1E-04 [5] 114 [6])
Projected Low-Level Waste Disposal in ERDF [7] Burial Grounds	4.37E-07 (7.38)	5.56E-09 (9.78E-04)	5.01E-08 (223)	5.06E-04 (0.17 [9])
Projected Low-Level Waste Disposal in US Ecology Burial Grounds [8]	1.95E-07 (3.3)	3.83E-08 (6.74E-03)	1.22E-09 (5.41)	1.01E-03 (3.4E-01)

Notes:
[1] Source: Wodrich 1991
[2] Indicates not provided in inventory.
[3] Isotopic distribution of uranium is unknown and assumed to consist of U-238.
[4] Source: Wood et al. 1995
[5] Waste disposed of as a Category 1 waste. Disposal does not include a cap.
[6] Waste disposed of as a Category 3 waste. Disposal includes a cap.
[7] Source: Wood et al. 1995a
[8] Source: Jacobs 1996
[9] Reported in Wood et al 1995a as uranium. Assumed here to be U-238.
[10] Source Jacobs 1996
[11] Calculated value exceeds drinking water standard (40 CFR 141.6) based on a calculated dose equivalent to 4 million/year to an internal organ.

Table F.4.6.1 Inventory of Contaminants Released During Retrieval - Nominal Case (Tank Waste)

Constituent	Inventory(grams)[2]							
	1WSS	2WSS	3WDS[1]	1ESS	2ESS	3EDS[1]	4ESS	5EDS[1]
K_d Group 1 (K_d = 0.0 mL/g)								
C-14	3.53E-01	3.78E-01		3.16E+00	1.09E+01		3.04E-01	
I-129	5.34E+01	8.53E+01		3.99E+02	7.67E+02		7.20E+00	
Tc-99	3.83E+02	6.16E+02		2.86E+03	5.24E+03		5.05E+01	
U-238	2.83E+06	6.61E+05		3.73E+06	4.33E+07		3.65E+05	

Notes:
[1] There are no retrieval losses from DST sources (i.e. source areas 3WDS, 3EDS, and 5EDS).
[2] Refer to Appendix A for inventory in curies.
Source: Jacobs 1996

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Table F.4.6.2 Concentration of Contaminants Released During Retrieval For Nominal Case (Tank Waste)

Constituent	Concentration (gram/liter)							
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS
K_d Group 1 (K_d = 0.0 mL/g)								
C-14	5.82E-07	5.81E-07	4.18E-08	5.22E-06	4.49E-05	5.70E-05	2.01E-06	6.34E-08
I-129	8.80E-05	1.31E-04	0.00E+00	6.59E-04	3.15E-03	0.00E+00	4.77E-05	0.00E+00
Tc-99	6.31E-04	9.40E-04	4.99E-02	4.72E-03	2.16E-02	1.02E-01	3.33E-04	5.10E-03
U-238	4.67E+01	1.01E+00	0.00E+00	6.16E+00	1.78E+02	0.00E+00	2.41E+00	0.00E+00

Source: Jacobs 1996

Table F.4.6.3 Inventory of Residual Contaminants Released - Nominal Case

Constituent	Inventory(grams)[1]							
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS
K_d Group 1 (K_d = 0.0 mL/g)								
C-14	6.38E-02	1.10E-01	2.00E-04	4.11E-01	4.83E-02	5.23E-01	4.09E-02	1.20E-03
I-129	9.66E+00	2.49E+01	1.29E+01	5.19E+01	3.39E+00	9.28E+01	9.72E-01	2.11E+01
Tc-99	6.92E+01	1.79E+02	2.17E+02	3.72E+02	2.33E+01	9.37E+02	6.80E+00	9.46E+01
U-238	5.12E+06	1.93E+06	0.00E+00	4.85E+06	1.92E+06	0.00E+00	4.91E+05	0.00E+00

Notes:
[1] Refer to Appendix A for inventory in curies.
Source: Jacobs 1996

Table F.4.6.4 Concentration of Residual Tank Waste Releases - Nominal Case

Constituent	Concentration (gram/liter)							
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS
K_d Group 1 (K_d = 0.0 mL/g)								
C-14	8.74E-07	8.71E-07	6.27E-08	7.82E-06	6.72E-05	8.56E-05	3.01E-06	9.52E-08
I-129	1.32E-04	1.97E-04	4.46E-05	9.88E-04	4.71E-03	1.52E-04	7.15E-05	1.71E-05
Tc-99	9.48E-04	1.42E-03	7.49E-02	7.08E-03	3.23E-02	1.54E-01	5.01E-04	7.66E-03
U-238	7.00E+00	1.52E+00	0.00E+00	9.24E+00	2.68E+02	0.00E+00	3.61E+00	0.00E+00

Source: Jacobs 1996

Table F.4.6.5 Contaminant Releases Modeled for Nominal Case

Site	Releases from Retrieval Operations		1 Percent Residual Releases	
	Duration of Contaminant Release	Mass Released [1] (grams)	Duration of Contaminant Release	Mass Released [1] (grams)
1WSS	15 years	1.61E+08	9 years	2.63E+07
2WSS	15 years	1.74E+08	14 years	4.55E+07
3WDS	No Release	0.00	4 years	1.04E+06
1ESS	15 years	1.61E+08	6 years	1.89E+07
2ESS	15 years	6.46E+07	93 days	2.59E+05
3EDS	No Release	0.00	2.5 years	2.20E+06
4ESS	15 years	4.04E+07	6 years	4.89E+06
5EDS	No Release	0.00	4 years	4.45E+06
LAW Vaults	N/A	0.00	9,461 years[2]	2.10E+10

Notes:
[1] Mass released is based on the unit concentration modeled (e.g., 400 g/L for the tank sources and 100 g/L for the LAW vaults). For the LAW vaults, release reported is vitrified waste rather than the 1 percent residual left in the tank.
[2] During 10,000-year period of interest. Mass remains after 10,000-year period of interest.
LAW = Low-activity waste
N/A = Not applicable

Table F.4.6.6 Maximum Concentration Calculated for the Nominal Case - Tank Sources

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
C-14	2.27E-10	1.01E+00	1.55E-09	6.92E+00	0.00E+00	0.00E+00
I-129	3.53E-08	6.22E-03	3.35E-07	5.90E-02	1.30E-11	2.29E-06
Tc-99	2.51E-07	4.25E+00	2.44E-06	4.12E+01	9.00E-11	1.52E-03
U-238	3.30E-04	1.11E-01	1.41E-02	4.73E+00	9.93E-08	3.34E-05
NO3	1.46E-02	N/A	8.30E-01	N/A	2.35E-05	N/A

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APPENDIX F
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