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Revision 0

GROUNDWATER FLOW AND MIGRATION CALCULATIONS TO SUPPORT ASSESSMENT OF THE WMA S-SX MONITORING NETWORK

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

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APPROVED
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Terms

API	American Petroleum Institute
CHPRC	CH2M HILL Plateau Remediation Company
CPGWM	Central Plateau Groundwater Model
CY	calendar year
DWMU	dangerous waste management unit
ECF	environmental calculation file
EMMA	Environmental Model Management Archive
FY	fiscal year
HISI	Hanford Information Systems Inventory
MT3DMS	Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems
NAVD88	North American Vertical Datum of 1988
OU	operable unit
P&T	pump and treat
SALDS	State-Approved Land Disposal Site
SSM	Sink/Source Mixing
SST	single-shell tank
SSP&A	S.S. Papadopulos and Associates, Inc.
WMA	waste management area

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1 Purpose

This environmental calculation file (ECF) is a facility-specific calculation file that supplements the ECF developed for the 200 West Area, ECF-200W-17-0070, *Groundwater Flow and Migration Calculations to Support Assessment of the Hanford Central Plateau 200 West Area Facilities Monitoring Network.* This facility-specific ECF describes calculations made to evaluate monitoring well locations for Waste Management Area (WMA) S-SX groundwater monitoring network. The monitoring network is designed to detect significant increases in groundwater contamination that would result from hypothetical releases from single-shell tanks (SSTs) within the regulated unit. The calculations evaluate the suitability of the WMA S-SX interim status groundwater monitoring network (Figure 1-1) for detecting releases from SSTs and liquid handling structures within WMA S-SX and determine whether additional monitoring locations are required. The interim status groundwater monitoring for WMA S-SX is described in DOE/RL-2009-73, *Interim Status Groundwater Quality Assessment Plan for the Single Shell Tank Waste Management Area S-SX.* Changes to the monitoring well network have been made over time; the interim status groundwater monitoring network evaluated herein is documented in Table 3-11 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016.*

The 200 West Area ECF, ECF-200W-17-0070, presents a regional-scale evaluation of eight dangerous waste management units (DWMUs) located in or near the 200 West Area of the Hanford Central Plateau near Richland, Washington, hereinafter referred to as the 200 West Facilities. ECF-200W-17-0070 provides the conceptual basis and details the specific methods and codes used for all calculations performed in support of the evaluation, including general 200 West Area-wide results. Calculations completed that are specific to WMA S-SX are detailed in this facility-specific ECF.

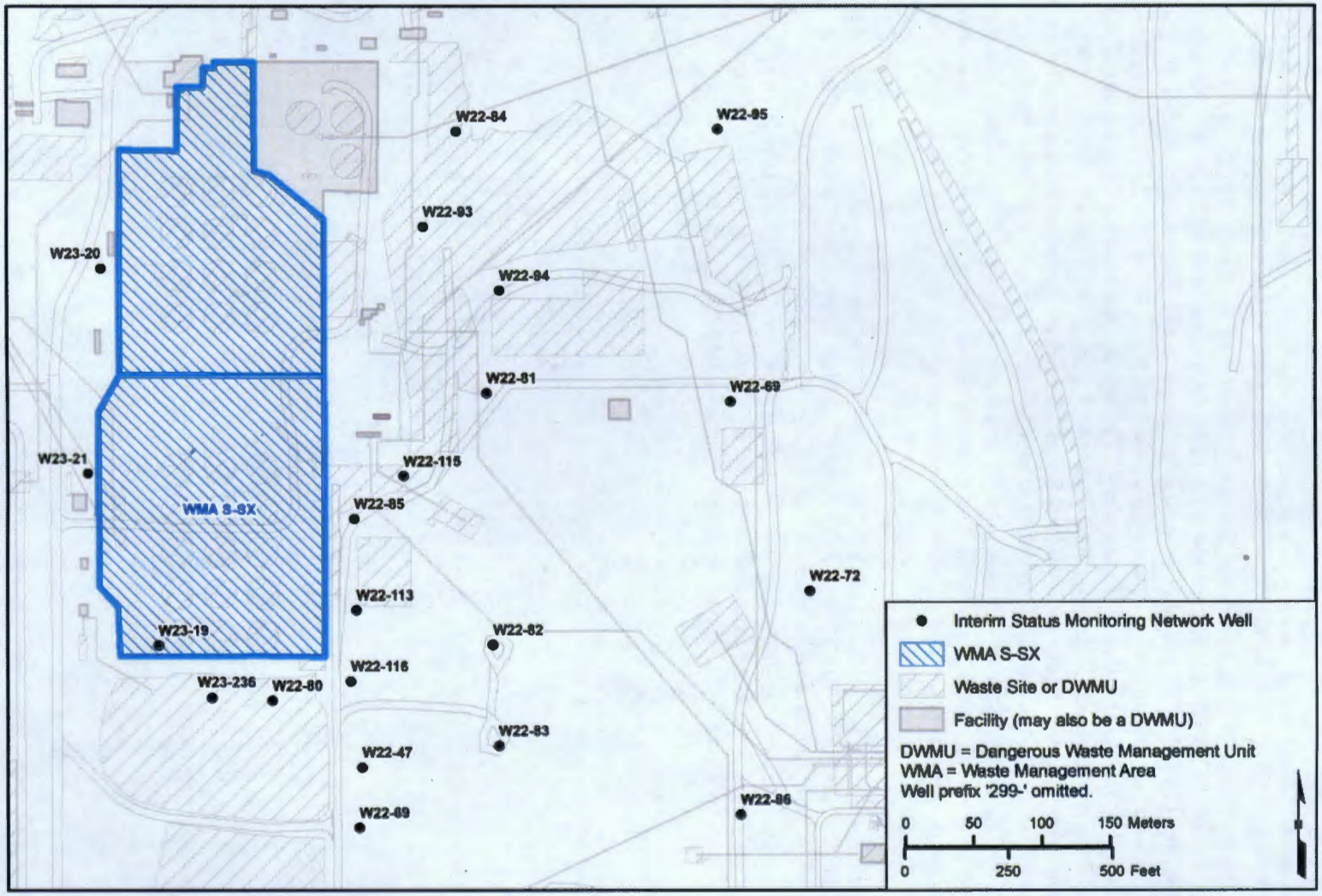


Figure 1-1. Map Showing Locations of Interim Status Groundwater Monitoring Wells at WMA S-SX

1-2

2 Background

WMA S-SX, located in the southern part of the 200 West Area, consists of two tanks farms; the 241-S Tank Farm and the 241-SX Tank Farm. Together, the tanks farms comprise 27 SSTs, and ancillary liquid handling equipment including catch and receiver tanks, diversion boxes, piping, valve pits, and pumps. The 241-S Tank Farm contains 12 SSTs and the 241-SX Tank Farm contains 15 SSTs. WMA S-SX was used for disposal of waste from the Reduction Oxidation Plant in the 1950s and 1960s. Most drainable liquid was removed from the SSTs and moved to double-shell tanks to reduce the likelihood and severity of future leaks.

A groundwater quality assessment program for WMA S-SX was put in place in 1996 (later revised) due to elevated specific conductance detected in downgradient monitoring wells. During the groundwater quality assessment, groundwater was found to have elevated chromium concentrations originating from multiple sources within the WMA, including a 91,000 L overfill of tank 241-S-104 in the 241-S Farm, and a 190,000 L leak from tank 241-SX-115 in the 241-SX Farm during 1965. Until incorporation into the Hanford Facility Dangerous Waste Permit, groundwater monitoring is ongoing at WMA S-SX to assess the extent and concentration of the dangerous waste constituent chromium in the groundwater and determine its rate of movement.

In the area of WMA S-SX, groundwater pump and treat (P&T) technology is an element of the interim groundwater remedy devised for the 200-UP-1 Groundwater Operable Unit (OU). P&T is also an element of the selected final groundwater remedy for the 200-ZP-1 OU, located north of the 200-UP-1 OU on the Hanford Site Central Plateau. The groundwater extracted by the 200-ZP-1 and 200-UP-1 P&T remedies ultimately is combined and treated at a single facility. The combination of the 200-ZP-1 and 200-UP-1 P&T remedies is referred to herein as the 200 West P&T system. As part of the 200 West P&T system, 28 injection wells and 37 extraction wells have operated at various times since January 2012. No active injection wells are located near WMA S-SX. Two active extraction wells (299-W22-90 and 299-W22-91) are located just east of the eastern edge of WMA S-SX.

The interim status groundwater monitoring well network has changed over time. Groundwater currently flows generally east-northeast beneath WMA S-SX. Groundwater flow is affected by groundwater extraction from the 200 West P&T system. A decline in groundwater elevation from the groundwater extraction operations have caused various monitoring network wells to go dry requiring the installation of replacement wells.

The groundwater P&T system influences groundwater flow directions and rates and potentially influences the migration of hypothetical releases of contaminants from SSTs and liquid handling structures within the WMA S-SX boundary. As a result, groundwater modeling is used to evaluate the effects of groundwater extraction and treated water injection at monitoring locations. The groundwater model used is the Central Plateau Groundwater Model (CPGWM) Version 8.3.4 (CP-47631, *Model Package Report: Central Plateau Groundwater Model Version 8.3.4*, Rev. 3). Details of the model are included in Chapter 2 of ECF-200W-17-0070.

The interim status monitoring network for WMA S-SX (Figure 2-1) consists of 2 upgradient wells (299-W23-20 and 299-W23-21) and 19 downgradient wells (299-W22-47, 299-W22-69, 299-W22-72, 299-W22-80, 299-W22-81, 299-W22-82, 299-W22-83, 299-W22-84, 299-W22-85, 299-W22-86, 299-W22-89, 299-W22-93, 299-W22-94, 299-W22-95, 299-W22-113, 299-W22-115, 299-W22-116, 299-W23-19, and 299-W23-236), which are screened at the top of the unconfined aquifer (DOE/RL-2016-66). This ECF presents calculations that evaluate the efficacy of the groundwater monitoring network, including consideration of the possible impact of treated water injection at the 200 West P&T system injection wells on the ability to detect hypothetical releases from WMA S-SX at existing and potential new monitoring wells.

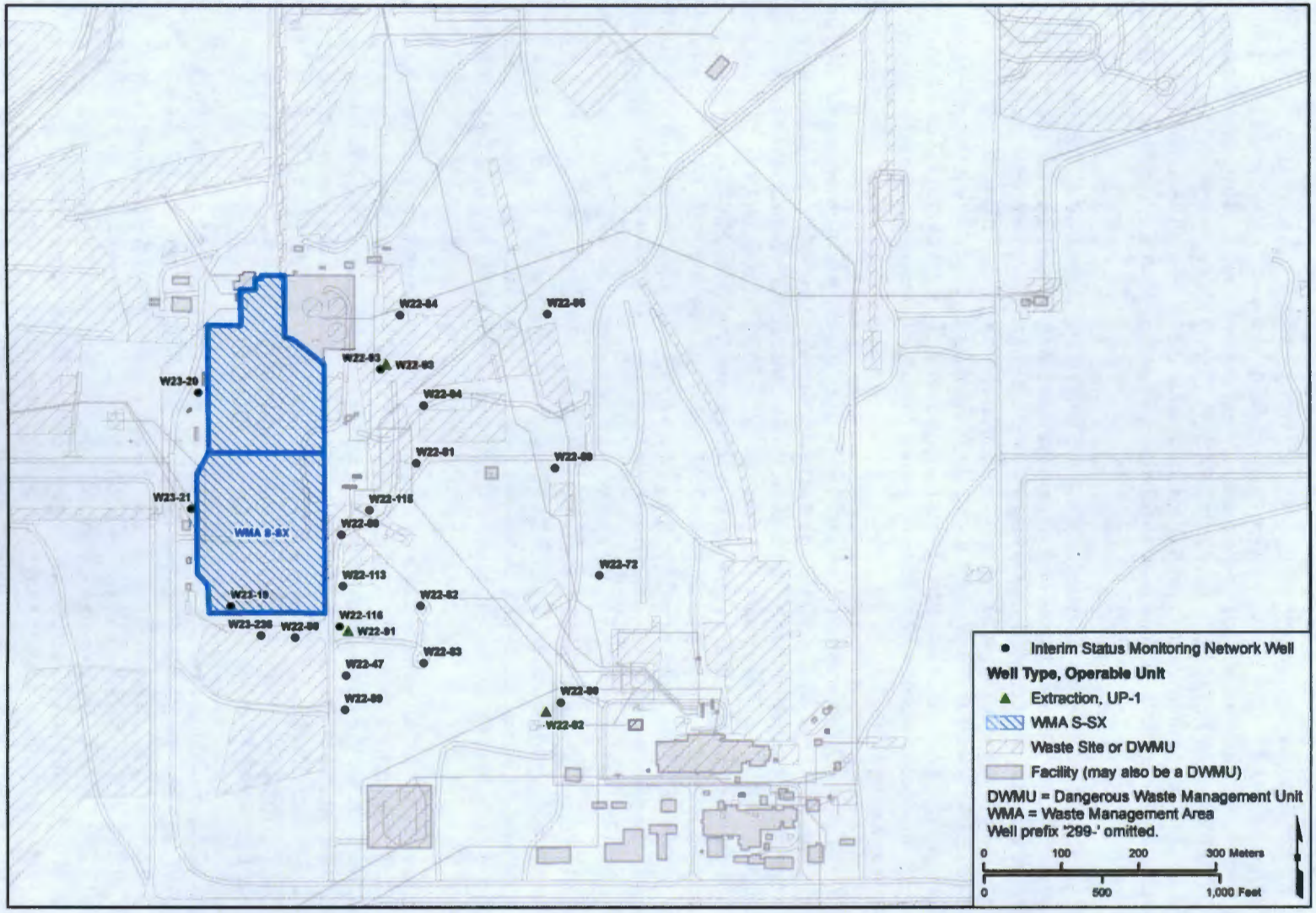


Figure 2-1. Map Showing Locations of Monitoring Wells and 200 West Pump and Treat System Wells at WMA S-SX

3 Calculation Methods

This chapter describes the calculation methods used to support this ECF. Simulations were conducted to evaluate the efficacy of the groundwater monitoring network for detecting significant increases in groundwater contamination that might occur from a hypothetical release at WMA S-SX, while accounting for the influence of the 200 West P&T system extraction and injection wells.

The 200 West Area ECF, ECF-200W-17-0070, describes the methods used for, and presents the results of, the area-wide groundwater modeling using CPGWM Version 8.3.4 (CP-47631, Rev. 3). ECF-200W-17-0070 describes the general calculations that were completed that are applicable to the eight 200 West Facilities that are evaluated in that ECF.

Details about the structure of the CPGWM, including time discretization and updates to model input, are included in ECF-200W-17-0070 and not repeated herein. The following sections briefly summarize the facility-specific model calibration, the determination of the simulation scenarios to be implemented, and the facility-specific calculations that were performed.

3.1 Groundwater Flow Model Calibration

Calibration of the CPGWM on a regional and site-specific scale was evaluated prior to performing simulations. To provide correspondence between simulated and measured groundwater elevations, the flow model component of the CPGWM was previously calibrated to groundwater elevation data collected from 1944 through 2009 (CP-47631, *Model Package Report: Central Plateau Groundwater Model Version 3.3*, Rev. 0). Since that time, the outputs of the CPGWM have been compared with measured groundwater elevations to ensure that the simulated values still reasonably correspond with measured data. ECF-200W-17-0070 presented water-level hydrographs for wells throughout the 200 West Area to illustrate correspondence between simulated and measured groundwater elevations after the calibration period.

In this facility-specific ECF, the 200 West Area analysis is repeated using a subset of the wells selected in the vicinity of WMA S-SX to illustrate correspondence of the simulated elevations to measured elevations in the specific region of interest. The locations of selected wells are shown on Figure 3-1, and the hydrographs are presented as Figure 3-2.

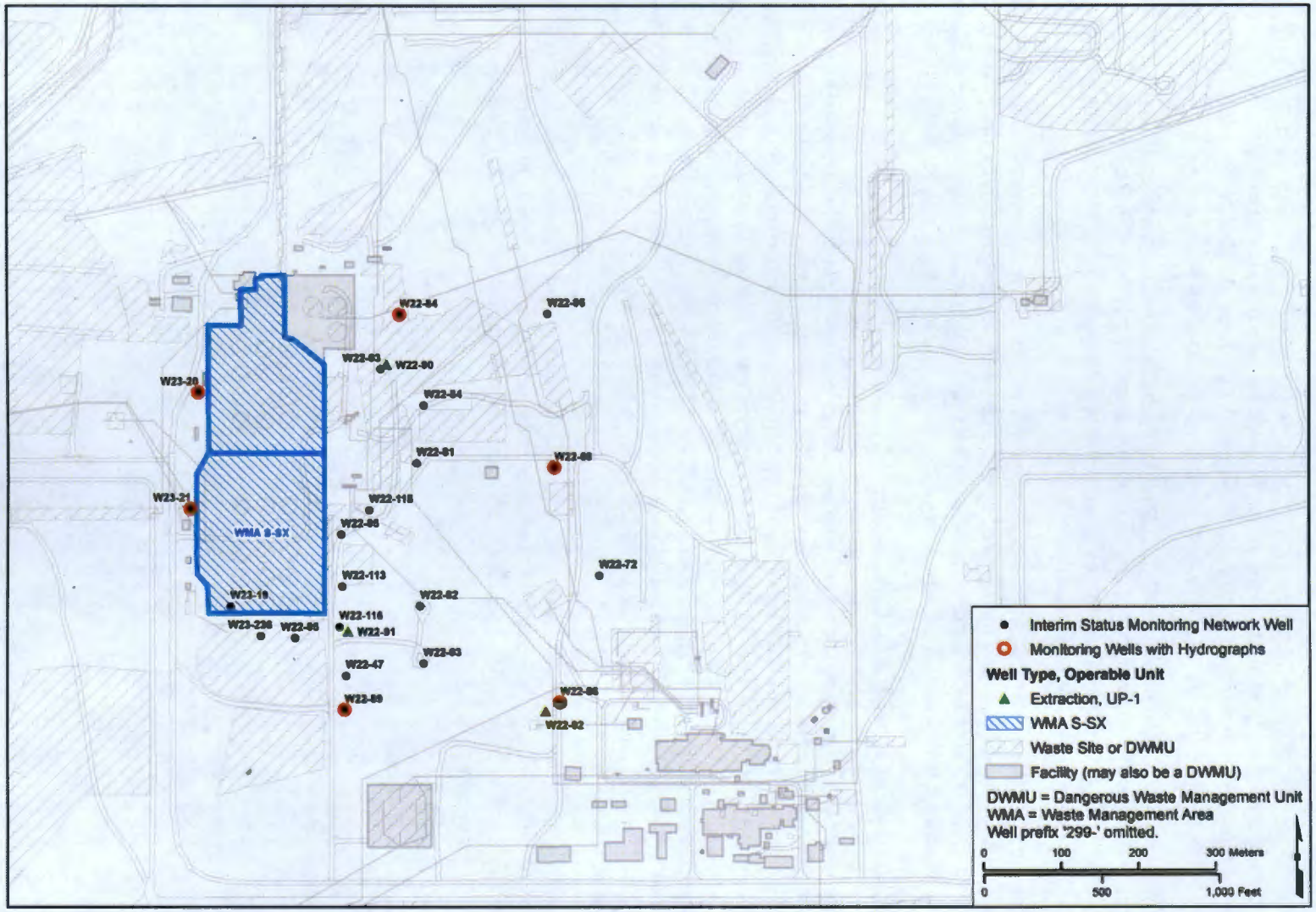
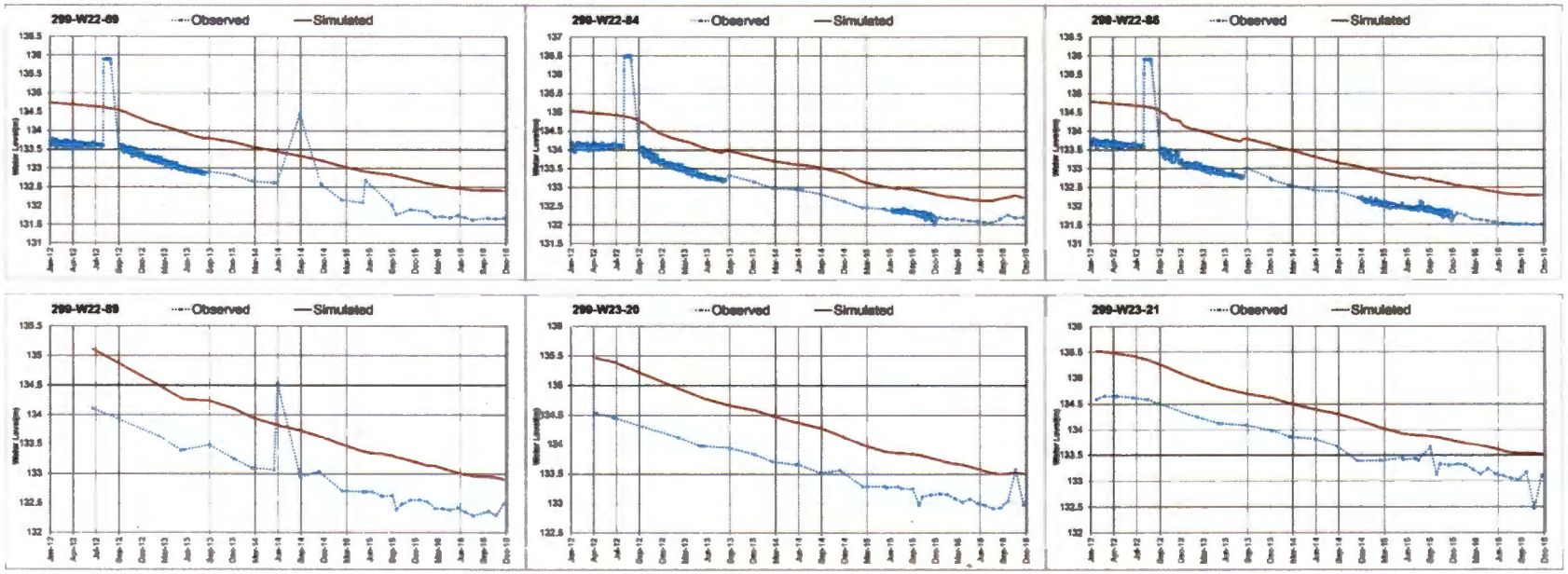


Figure 3-1. Well Locations for Selected Water-Level Hydrographs



NAVD88, *North American Vertical Datum of 1988*

Figure 3-2. Selected Water-Level Hydrographs throughout the Study Area Illustrating the Correspondence Between Simulated and Measured Groundwater Elevations (Elevations in NAVD88)

3.2 Simulated Scenarios

The CPGWM is updated each year as part of annual P&T reporting; therefore, the CPGWM always represents actual conditions through the end of the previous calendar year. However, future operating conditions cannot be known with certitude. The calculations herein were performed to evaluate a range of potential future operating conditions, predominantly focused upon alternative patterns of injection rates for the 200 West P&T system injection wells. These potential operating conditions, referred to as "scenarios," were developed to reflect the potential range of influence on groundwater flow and contaminant migration directions that could result from varying the operating conditions of the nearby injection wells.

Table 3-1 identifies the simulated scenarios and provides a general description of each. As described in ECF-200W-17-0070, some scenarios were selected to examine conditions under typical or likely operating conditions, whereas others were selected to represent more extreme and consequently unlikely operating conditions. Those extreme operating conditions, or bounding scenarios, are included to provide a bounding set of operating conditions that can be used to evaluate the locations of the interim status monitoring wells for each individual 200 West Facility and to assist in determining whether adjustments to the monitoring networks (including additional wells) are justified. Inputs for the simulations, including the actual simulated injection rate at each well under various scenarios, are detailed in Section 4.2 in ECF-200W-17-0070. Scenario 1, sub-scenario A is defined as the "current," or most likely, injection well operating conditions. The injection rates in sub-scenario A were determined by considering historical injection rates for the existing 200 West P&T injection wells and projected injection rates for new injection wells.

In sub-scenarios where a subset of wells have reduced rates or are non-operational, increased flow rates are redistributed among the wells that remain active. This process of rebalancing ensures that the total system-wide operating rate remains unchanged, with groundwater extraction (or treated water injection) rates adjusted proportionately at the operational wells. A similar process of adjusting the rates proportionately at the wells was implemented to rebalance injection rates due to the increase in the total 200 West P&T system capacity between scenarios 1 and 2. The simulated flow rates at each extraction and injection well for each of the predictive scenarios are listed in Table A-4 of Appendix A in ECF-200W-17-0070.

Table 3-1. Simulation Scenarios

Scenario	P&T System Capacity[a]	Sub-Scenario	Description	Scenario Weight (%)
1	2,305 gal/min (8,725 L/min)	A	Current conditions[b].	55
		B	Injection well 299-W10-35 operating at 50%.	5
		C	Injection well 299-W10-35 not operating.	3
		D	Injection well 299-W15-226 operating at 50%.	3
		E	Injection well 299-W15-226 not operating.	3
		F	Injection wells 299-W10-35 and 299-W15-226 not operating.	1
		G	Injection well 299-W10-36 not operating.	2
		H	Injection wells 299-W10-36, 299-W10-35, and 299-W15-226 not operating.	1
		I	Injection well 299-W6-14 not operating.	3
		J	Injection well 299-W6-16 not operating.	3
		K	Injection wells 299-W6-14 and 299-W6-16 operating at 50%.	3
		L	Injection wells 299-W6-14 and 299-W6-16 not operating.	1
		M	Injection wells 299-W18-41 and 299-W15-229 not operating.	2
		N	Injection wells 299-W15-29, 299-W18-36, 299-W18-38, and 299-W18-39 not operating.	3
		O	Injection wells 299-W15-228, 299-W15-229, 299-W15-29, 299-18-44, 299-W18-36, and 299-W15-29 operating at 50%.	5
		P	Injection wells 299-W18-41, 299-W18-39, 299-W18-38, 299-18-42, and 299-18-43 operating at 50%.	5
		Q	Injection wells 299-W15-229, 299-W15-29, 299-18-44, and 299-W18-36 not operating.	1
		R	Injection wells 299-W18-41, 299-W18-39, 299-W18-38, 299-18-42, and 299-18-43 not operating.	1
2	2,500 gal/min (9,464 L/min)	A	2,500 gal/min, injection rates rebalanced.	55
		B	Injection well 299-W10-35 operating at 50%.	5
		C	Injection well 299-W10-35 not operating.	3
		D	Injection well 299-W15-226 operating at 50%.	3
		E	Injection well 299-W15-226 not operating.	3
		F	Injection wells 299-W10-35 and 299-W15-226 not operating.	1
		G	Injection well 299-W10-36 not operating.	2

Table 3-1. Simulation Scenarios

Scenario	P&T System Capacity[a]	Sub-Scenario	Description	Scenario Weight (%)
2 (cont.)	2,500 gal/min (9,464 L/min)	H	Injection wells 299-W10-36, 299-W10-35, and 299-W15-226 not operating.	1
		I	Injection well 299-W6-14 not operating.	3
		J	Injection well 299-W6-16 not operating.	3
		K	Injection wells 299-W6-14 and 299-W6-16 operating at 50%.	3
		L	Injection wells 299-W6-14 and 299-W6-16 not operating.	1
		M	Injection wells 299-W18-41 and 299-W15-229 not operating.	2
		N	Injection wells 299-W15-29, 299-W18-36, 299-W18-38, and 299-W18-39 not operating.	3
		O	Injection wells 299-W15-228, 299-W15-229, 299-W15-29, 299-18-44, 299-W18-36, and 299-W15-29 operating at 50%.	5
		P	Injection wells 299-W18-41, 299-W18-39, 299-W18-38, 299-18-42, and 299-18-43 operating at 50%.	5
		Q	Injection wells 299-W15-229, 299-W15-29, 299-18-44, and 299-W18-36 not operating.	1
		R	Injection wells 299-W18-41, 299-W18-39, 299-W18-38, 299-18-42, and 299-18-43 not operating.	1
3	0		System shutdown following active P&T.	100

Notes: For injected treated water dilution calculations, unit concentrations released at injection wells correspond with initiation of each injection well (i.e., using actual dates/timing).

For release calculations, unit concentrations released at the facility assumed a late 2017 release date for scenarios 1 and 2 and 2037 for scenario 3.

a. Scenario 1 pumping rate = 2,305 gal/min (comprised of 305 gal/min from 200-UP-1 extraction wells and 2,000 gal/min from 200-ZP-1 extraction wells); Scenario 2 pumping rate = 2,500 gal/min (comprised of 305 gal/min from 200-UP-1 extraction wells and 2,195 gal/min from 200-ZP-1 extraction wells); In both cases, an extraction rate of 60 gal/min at well 299-E33-268, located in the 200-BP-5 operable unit, is included in the extraction total for 200-ZP-1.

b. Current conditions approximate historical injection rates for existing injection wells and projected injection rates for new injection wells.

3.3 Calculations

This section describes the calculations and corresponding outputs that are specific to WMA S-SX. The methods used to perform these calculations are the same as those detailed in ECF-200W-17-0070; however, because some inputs to the calculations are specific to these detailed facility calculations, they are outlined below in this facility-specific ECF. As detailed in ECF-200W-17-0070, particle counts and

unit concentrations are used as a surrogate for relative concentration in order to evaluate the efficacy of the interim monitoring wells and the suitability of any potential additional monitoring wells.

3.3.1 Particle-Tracking "Pathline" Calculations

Particle-tracking calculations were performed for each case (A through R in scenarios 1 and 2). Particles were released annually along the perimeter of all twenty-seven SSTs located in 241-S and 241-SX Tank Farms and tracked forward. This "focused release" reflects a hypothetical tank leak that reaches the water table.

In all cases in scenarios 1 and 2, particles were first released on October 1, 2017 and then released from the same locations every year until October 1, 2036 and tracked through to October 1, 2037, which is the date when the 200-ZP-1 groundwater P&T remedy component is anticipated to cease operation in accordance with EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*. For scenario 3, particles are initially released on October 1, 2037 and are then released every 5 years thereafter until October 1, 2132 and tracked until October 1, 2137.

Particle tracking was simulated using both advection and dispersion, with the latter simulating the effect of mechanical dispersion of contaminants during transport in groundwater. The facility-specific calculations and outputs are based upon post-processing of advective-dispersive particle-tracking calculations undertaken using a greater number of particle releases from the facility than were used for the regional-scale calculations described in Chapter 3 of the 200 West Area ECF, ECF-200W-17-0070. This approach produces local-scale advective-dispersive particle-tracking calculations that provide a large number of "pathlines," each of which depicts the hypothetical path of a particle of water or dissolved contaminant released at the water table beneath the facility.

Dispersion was simulated in the particle-tracking calculations using a random-walk option implemented in the ModPath3DU particle-tracking simulator developed by S.S. Papadopulos & Associates, Inc. (SSP&A) (Lichtner et al., 2002, "New Form of Dispersion Tensor for Axisymmetric Porous Media with Implementation in Particle Tracking"; CHPRC-00261, *MODFLOW and Related Codes Acceptance Test Report, CHPRC Build 8*; and SSP&A, 2015, *MODPATH-SSPA Build 8: Documentation of a Random-Walk Tracking Option for MODPATH v.5*). The random-walk approach is the most commonly and widely applied method to describe and simulate observed spreading behavior in groundwater transport when using particle-based schemes: it has been demonstrated to be a good alternative to the use of a full contaminant transport model (Salamon et al., 2006, "A Review and Numerical Assessment of the Random Walk Particle-Tracking Method"). As described in the software documentation (CHPRC-00261), for consistency, this random-walk module reads and uses the same dispersion inputs as used in the Hanford version of the mass-conserved contaminant transport simulator Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems (MT3DMS), and has been demonstrated to simulate comparable migration rates and patterns at a fraction of the computational cost. The use of particle tracking with a random-walk dispersion component also facilitates performing calculations on a finer subgrid or locally refined region of the groundwater flow model computational grid than could be accomplished using MT3DMS, without the need to alter or refine the underlying flow model.

3.3.1.1 Calculation of Relative Detectability

In addition to particle pathlines, particle density maps were created on a facility-specific scale. The maps are produced by counting the number of particles that pass through a pre-defined regular calculational grid, enabling creation of a contour map of the particle count for each grid cell. The resulting "relative detectability" maps visually depict areas of relatively higher and lower potential impact from a facility

release that reaches the water table. The grid that is used to calculate these relative detectability maps is a refined subgrid, defined by cells that have a dimension of 20 by 20 m (66 by 66 ft).

3.3.2 Transport Calculations

In addition to influences of advection and dispersion, in the particular case where there is a P&T remedy operating nearby, it is necessary to examine the potential impact of dilution on the future performance of the monitoring well network. Treated water injected at the 200 West P&T system injection wells will mix with ambient groundwater, resulting in dilution of the particles in the ambient groundwater to varying degrees at different locations and times. Likewise, a release of contaminants from the facility that ultimately reaches the underlying water table will be diluted as a result of this mixing process.

The potential effects of dilution were evaluated using a "unit-plume" transport simulation approach. When using a unit-plume approach, the unit concentration can represent a single contaminant, a combination of contaminants, or clean treated water. In any case, for purposes of the analyses performed, this is referred to as a "unit source," and the objective is to use the concept of a unit source to simulate in relative rather than absolute terms the likely fate (i.e., migration and mixing) of the injected treated water or of a particular release of contaminant(s) in the subsurface.

For this analysis, a unit concentration (i.e., C = 1.0) represents either treated water that is injected at the 200 West P&T system injection wells, or water that is impacted by a release from a dangerous waste facility that mixes continuously with groundwater beneath the facility. Consistent with the unit-plume concept, the ascribed value of 1.0 at the unit source – whether an injection well, or the impacted water table beneath the facility – denotes only that at the location of interest, the water comprises 100% of the quantity of interest (i.e., it has not yet undergone any mixing with other water). As water migrates away from the location of the unit source, the effects of mixing and dispersion within the aquifer are simulated. As a result, over time and throughout space, the simulated concentration represents the fraction of the original water that is present from that which was released or injected at the unit source location. For example, a concentration of 0.5 indicates that at that time and location, 50% of the water comprises water that was released at the unit source location, and 50% of the water comprises other water – typically, ambient groundwater with which the water originating from the unit source has mixed and migrated. The simulated concentrations from these calculations can be interpreted in terms of a dilution factor:

- If the unit source represents treated water injection, then the simulated concentration at any point or time represents the fraction of the water at that location that comprises injected treated water and how that fraction has been reduced via the processes of advection and dispersion.
- If the unit source represents a contaminant release or water table impact, then the simulated concentration at any point or time can be interpreted two ways:
  - First, as representing the fraction of the water at that location that comprises the originally impacted groundwater from beneath the facility where the release occurred. The value of (1.0 minus the concentration) then represents the fraction of other water (typically, a combination of ambient groundwater and injected treated water from the P&T system) with which the water originating from the unit source has mixed and migrated.
  - Second, as representing a "dilution factor" or ratio to which the concentration at the source has been reduced via the processes of advection and dispersion.

The following "unit plume" transport calculations were used to illustrate the potential effects of dilution via mixing:

- To represent the migration, mixing, and dilution of treated, injected water, unit concentrations representing injected water were released from the following injection wells:

299-W6-13	299-W10-36	299-W15-229	299-W18-41
299-W6-14	299-W15-29	299-W18-36	299-W18-42
299-W6-16	299-W15-226	299-W18-37	299-W18-43
299-W7-14	299-W15-227	299-W18-38	299-W18-44
299-W10-35	299-W15-228	299-W18-39	

  The unit concentrations were used to simulate the injected treated water migration and transport through fiscal year (FY) 2037. Well locations are shown on Figure 3-3.

- To represent the migration, mixing, and dilution of groundwater impacted by a release at WMA S-SX, unit concentrations representing a hypothetical contaminant release were released at the water table (model layer 2) in four model grid cells representing WMA S-SX to simulate the migration and transport of the release to groundwater through FY 2037.

In each case, two sets of outputs from these dilution calculations were prepared. These outputs comprise time-series plots of concentrations at selected spatial locations, and spatial "snapshots" of concentrations at the water table (model layer 2) throughout the aquifer at certain times.

- The figures that plot the simulated concentration over time at selected spatial locations have a different interpretation and thus descriptor depending on the type of unit source that was simulated:
  - In the case of treated water injection as the unit source, these are referred to as "injected treated water dilution breakthrough curves."
  - In the case of a simulated water table release being the unit source, these are referred to as "release concentration breakthrough curves."
- The figures that depict the simulated concentration at the water table throughout the 200 West Area at a selected time are similarly referred to as:
  - "Injected treated water dilution plumes" for the cases where the unit source is the injected water entering the aquifer via the 200 West P&T system injection wells. As such, these figures indicate the fraction of the water at those locations that comprises treated water injected at the 200 West P&T system injection wells.
  - "Release unit plume maps" for the cases where the unit source is the release to the water table from the facility. As such, these figures indicate the fraction of the water at those locations that comprises the originally impacted groundwater from beneath the facility where the release occurred.

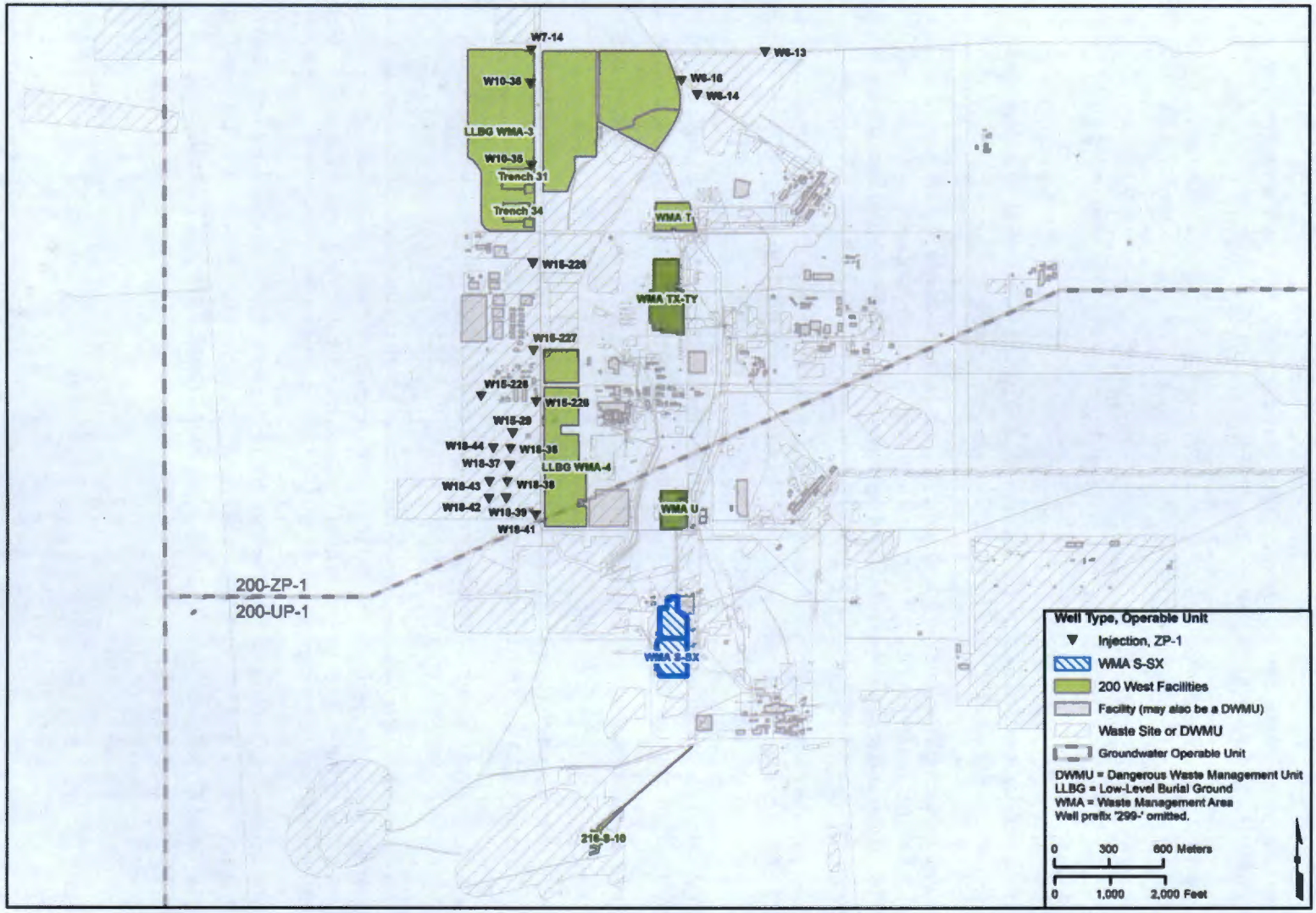


Figure 3-3. Injection Well Locations Used for Evaluation of Injected Treated Water

4 Assumptions and Inputs

This chapter outlines the assumptions and inputs that underlie the calculations.

4.1 Assumptions

Assumptions used for groundwater flow modeling, particle tracking, and transport dilution modeling are discussed in the following subsections.

4.1.1 Groundwater Flow Modeling

The CPGWM is a calibrated and flow-conserved numerical simulator of groundwater and dissolved-phase constituents in the Central Plateau. Since previous efforts were completed to calibrate the flow model parameters, the flow model outputs (i.e., heads and flow fields) in general correspond with measured data throughout the area of interest. However, the accuracy of simulated groundwater elevations and of inferences from those elevations (e.g., as flow rates and directions) are influenced by the structural accuracy of the CPGWM (i.e., how well the model represents actual physical conditions), the accuracy of the groundwater elevation data used for calibration, the magnitude and distribution of validation/calibration residuals, and other factors. These and other potential sources of error in the simulated outputs result in the simulations only approximating actual conditions. As such, the results are interpreted as reasonable approximations that provide value when interpreting the likely directions and rates of groundwater movement.

4.1.2 Particle Tracking

Particle tracking uses and relies upon the outputs (i.e., simulated heads and flow rates) computed using the CPGWM. As a result, the assumptions and limitations that underlie the groundwater flow component of the CPGWM are implicit in the subsequent particle tracking. In addition to these inherited assumptions, particle tracking that considers advection only relies upon the assumption that the value of the mobile (effective) porosity of the aquifer, which is represented as a single best-estimate value, is representative of the bulk conservative transport of water and dissolved constituents; and, particle-tracking calculations that consider dispersion rely upon the assumption that the values of the dispersion coefficients simulated in the three principal directions (longitudinal, transverse, and vertical) are representative of physical processes that act to disperse dissolved constituents in groundwater at the scale of the simulations. Although the particle transport calculations have not been calibrated to match field data, the parameters used in those calculations (i.e., mobile porosity and dispersion coefficients) are equivalent to the parameter values used in the transport (dilution) modeling which, as described below, have been independently qualitatively corroborated.

4.1.3 Transport Modeling

Transport modeling was performed to assess the effect of mixing, recharge, and dispersion on dilution. The transport modeling is based on the groundwater flow model and therefore relies on the accuracy of the outputs of the groundwater flow simulations as well as the accuracy of the parameters, assumptions, and inputs to the transport model. For purposes of the calculations presented in this ECF, it is also assumed that the transport parameters (i.e., for the mass-conserved advective/dispersive calculations, these parameters are limited to mobile [effective] porosity and dispersion) reasonably describe the dominant processes leading to the mixing of water from various sources with groundwater present in the subsurface.

Although the parameters of the groundwater flow component of the CPGWM have been formally calibrated to historical data and conditions, the parameters of the transport component of the CPGWM

have not been formally calibrated to historical data and conditions to date. Unlike flow model parameter calibration, transport model parameter calibration can be a difficult procedure to undertake quantitatively because of the uncertainty regarding the dates and magnitudes of historical sources that would be used as inputs to a calibration process.

However, the parameters of the transport model that are used for the purposes of the calculations described in this ECF have been qualitatively corroborated via simulations conducted as part of the work used to simulate tritium concentrations in monitoring wells adjacent to the State-Approved Land Disposal Site (SALDS), which is an active permitted discharge facility and an ongoing and well-characterized (monitored and documented) source of tritium to groundwater in the 200-ZP-1 OU. Those calculations are detailed, for example, in SGW-56060, *Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State Approved Land Disposal Site, Fiscal Year 2013*. Those simulations suggest that the values of the CPGWM transport parameters that are relevant to the calculations presented in this ECF (i.e., the parameters associated with advection and dispersion) enable the CPGWM to reasonably reproduce the movement and extent of tritium in groundwater that arises from the controlled disposal location at the SALDS.

CH2M HILL Plateau Remediation Company (CHPRC) and its contractors are undertaking an updated calibration of the flow model and, following the flow calibration, will undertake further transport model corroboration analyses to further support or update the transport component of the CPGWM. Any resulting revisions or updates will be reflected in future calculations completed using the CPGWM.

4.1.4 Discretization in Calculation Methods

There are differences in scale and effect that the finite-difference discretization of the CPGWM has on the application and interpretation of particle-tracking and finite-difference transport modeling calculations. In the particle-tracking calculations, particle release locations are defined as discrete points at plausible release locations within a facility, and the particles then move in three-dimensions in a semi-analytical manner by estimating the groundwater velocity at the exact location of the particle from the finite-difference solution of the groundwater flow equation. The particle tracking therefore takes place on a much finer (i.e., largely grid independent) resolution than the flow modeling. In the finite-difference transport modeling, by contrast, transport calculations occur at the same resolution as the flow calculations. Therefore, the unit concentration is released within a single 100 by 100 m (328 by 328 ft) CPGWM grid cell – which is a significantly less refined starting location than possible in particle tracking – and the transport calculations that follow also occur on the same discretization as the CPGWM comprising 100 by 100 m model cells. This can result in some artefacts of discretization: for example, the unit plume maps would have a blocky appearance if they represented only the outputs obtained directly from the model; and, it is possible for monitoring wells to be located within the same grid cell as the release, essentially resulting in the appearance of the release occurring at the well location. These discretization artefacts can be mitigated to some degree by depicting the release plumes produced from transport modeling using a bilinear interpolation process within ArcGIS® to "smooth" the "blocky" modeling results. This graphical interpolation is performed to depict a visually smooth transition between concentrations calculated for the model grid cells that greatly reduces the effect of abrupt cell-to-cell transitions. In some cases, however, this graphical interpolation can increase the spread of the unit plumes, particularly at the margins. Given these effects of discretization on interpretation of the modeling results, the decisions regarding actual and proposed monitoring well locations rely more heavily upon the outputs of the particle-tracking calculations, and the outputs from the finite difference transport

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calculations are used to primarily inform understanding of the potential effects of dilution and other factors of breakthrough concentrations.

4.2 Input Data

This section summarizes input that is specific to the calculations presented in this ECF. Inputs to the CPGWM that do not change for these calculations (e.g., the structure of the CPGWM) are not discussed. The principal inputs to the calculations completed to evaluate the monitoring network for each dangerous waste facility are the assumed extraction and injection rates at P&T wells, model boundary conditions, and the assumed transport parameters.

4.2.1 Extraction and Injection Rates

Historical flow rates for each of the 200 West P&T system extraction and injection wells from calendar year (CY) 2012 through CY 2016 are summarized in ECF-200W-17-0070, Appendix A (Tables A-1 through A-3). Figure 4-1 depicts average pumping rates for December 2016, for the 200 West P&T system (extraction well 299-E33-268, located in the 200 East Area, is outside the figure extent. The well had an average pumping rate of 24 gal/min in December 2016). Simulated flow rates at each extraction and injection well for each of the predictive scenarios are listed in ECF-200W-17-0070, Appendix A (Table A-4).

Some 200-ZP-1 extraction and injection wells are physically located in the 200-UP-1 OU. This is because the well designation, as 200-ZP-1 vs. 200-UP-1, is not dependent upon the well location but is instead dependent upon the function of the well. If the purpose of the well is to extract/control contaminant plumes attributed to 200-ZP-1 OU, it is designated as a 200-ZP-1 well regardless of location. Well designations are listed in Table 2-2 of DOE/RL-2016-69, *Calendar Year 2016 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*.

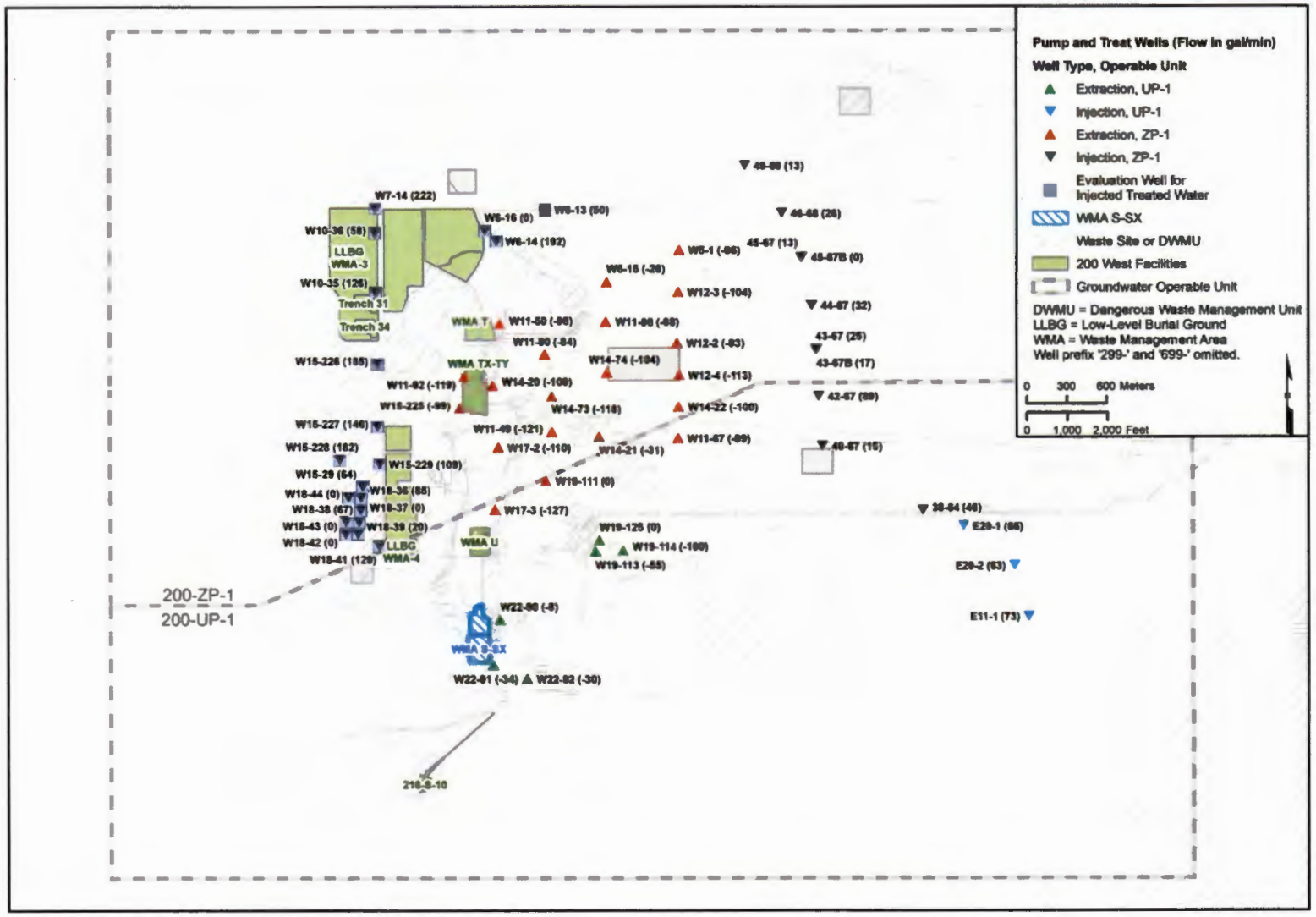

Figure 4-1. Average Pumping Rates for 200 West Pump and Treat System Wells, December 2016

4.2.2 Model Boundary Conditions

Two boundary conditions are updated on an annual basis for the CPGWM as part of the P&T reporting analyses. These are as follows:

- Waste water discharges associated with Hanford Site 200 Area SALDS and 200 Area Treated Effluent Disposal Facility, which are represented via the recharge package for the U.S. Geological Survey modular three-dimensional finite-difference groundwater flow model, MODFLOW. The recharge package used in the model has been updated based on actual discharge data available through December 2016.
- The CPGWM northeastern Constant Head boundary is used to represent historical groundwater elevation changes at the Gable gap. Water levels at monitoring well 699-60-60 are used to set the heads at this boundary. Water-level data acquired from Hanford Environmental Information System through December 2016 have been used to update this boundary using methods consistent with those detailed in the CPGWM model data package reports.

4.2.3 Transport Properties

Transport parameters used in the calculations presented in this ECF are unchanged from the transport parameters used in calculations for previous annual P&T reports. However, since these parameters are fundamental to the calculations, they are listed in Table 4-1 for completeness.

Table 4-1. Properties Assumed for Transport Calculations Using the CPGWM

Assumed Properties for Purposes of Conservative Dilution Calculations					
Distribution Coefficient (mL/g)	**Half-Life (year)**	**Half-Life (day)**	**Degradation Rate (1/d)**	**Reference for Distribution Coefficient**	**Reference for Degradation Rate**
0.0	None assumed	None assumed	None assumed	None assumed	None assumed
Aquifer Dependent Transport Parameter Values for the Central Plateau Model					
Property	**Value**	**Comments**			
Effective porosity	0.15	Approximate central value (Table D-2 of DOE/RL-2007-28)			
Longitudinal dispersivity	3.5 m	Introduced for stability of the transport calculations using recommendation from MT3DMS manual (Zheng and Wang, 1999)			
Transverse dispersivity	0.7 m	20% of longitudinal (DOE/RL-2008-56)			
Vertical dispersivity	0.0 m	DOE/RL-2008-56			
Molecular diffusion constant	0.0 m^2/d	Negligible term			

References: DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit.*

DOE/RL-2008-56, *200 West Area Pre-Conceptual Design for Final Extraction/Injection Well Network: Modeling Analyses.*

Zheng and Wang, 1999, *MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide.*

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5 Software Applications, Descriptions, Installation and Checkout, and Statements of Validity

Software used for this calculation was in accordance with PRC-PRO-IRM-309, *Controlled Software Management*.

5.1 Approved Software

The software used to perform the calculations for this ECF was approved and is compliant with PRC-PRO-IRM-309. The software is managed under the following documents consistent with PRC-PRO-IRM-309:

- CHPRC-00257, *MODFLOW and Related Codes Functional Requirements Document*
- CHPRC-00258, *MODFLOW and Related Codes Software Management Plan*
- CHPRC-00259, *MODFLOW and Related Codes Software Test Plan*
- CHPRC-00260, *MODFLOW and Related Codes Requirements Traceability Matrix-Build 8*
- CHPRC-00261, *MODFLOW and Related Codes Acceptance Test Report-Build 8*

CHPRC-00258 distinguishes between safety software and support software based on whether the software managed calculates reportable results or provides run support, visualization, or other similar functions. Brief descriptions of the software are provided in the following discussion.

5.2 Descriptions

MODFLOW and MT3DMS software that were used for the calculations in this ECF are described in the following subsections.

5.2.1 MODFLOW (Controlled Calculation Software)

- **Software title:** MODFLOW-2000 (Harbaugh et al., 2000, *MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process*) solves transient groundwater flow equations using the finite-difference discretization technique.

- **Software version:** Version 1.19.01, modified by SSP&A to address dry cell issues and to use the Orthomin solver (Vinsome, 1976, "ORTHOMIN, An Iterative Method for Solving Sparse Banded Sets of Simultaneous Linear Equations"); approved as CHPRC Build 8 using a version of the executable "mf2k-mst-chprc08dpv.exe" compiled to default double precision for real variables and optimized for speed.

- **Hanford Information Systems Inventory (HISI) identification number:** 2517 (safety software, graded level C).

- **Workstation type and property number (from which software is run):** SSP&A, FE449.

5.2.2 MT3DMS (Controlled Calculation Software)

- **Software title:** MT3DMS (Zheng and Wang, 1999, *MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide*; Zheng, 2010, *MT3DMS v5.3 Supplemental User's Guide*).

- **Software version:** Version 5.3, modified by SSP&A to address dry cell issues; approved as CHPRC Build 8 using a version of the executable "mt3d-mst-chprc08dpv.exe" compiled to default double precision for real variables and optimized for speed.
- **HISI identification number:** 2518 (safety software, graded level C).
- **Workstation type and property number (from which software is run):** SSP&A, FE449.

5.3 Support Software

The software programs discussed in the following subsections are classified as support software.

5.3.1 MODFLOW Suite Support Software

- **Groundwater Vistas™**: Graphical tools used for model quality assurance and model input/output review (Rumbaugh and Rumbaugh, 2011, *Guide to Using Groundwater Vistas*).
- **ArcGIS®**: Visualization and post-processing tool for assessing simulated plume distributions, identifying extraction/injection well-coordinates, and mapping auxiliary data (Mitchell, 1999, *The ESRI Guide to GIS Analysis, Volume 1: Geographic Patterns & Relationships*).
- **ModPath3DU**: Particle-tracking code for calculating the three-dimensional flow pathlines and travel times of solute particles.

5.4 Software Installation and Checkout

Safety software is checked out in accordance with procedures specified in CHPRC-00258. Executables are obtained from the CHPRC software owner (who maintains the configuration-managed copies in MKS Integrity®), and installation tests identified in CHPRC-00259 are performed and successful installation confirmed. Software installation and checkout forms are required and must be approved for installations used to perform model runs. Approved users are registered in HISI for safety software.

5.4.1 Statement of Valid Software Application

The software identified previously was used consistent with intended use for CHPRC, as identified in CHPRC-00257, and is a valid use of this software for this application. The software was used within its limitations, as identified in CHPRC-00257.

™ Groundwater Vistas is a trademark of Environmental Simulations Incorporated, Reinholds, Pennsylvania.

® ArcGIS is a registered trademark of the Environmental Systems Research Institute, Inc., Redlands, California.

® MKS Integrity is a registered trademark of MKS, Inc., Needham, Massachusetts.

6 Calculation Steps and Output

This chapter describes the calculations that were performed. Modeling was performed under a general quality assurance project plan developed following U.S. Environmental Protection Agency guidance in EPA/240/R-02/007, *Guidance for Quality Assurance Project Plans for Modeling*, EPA QA/G-5M that implements U.S. Department of Energy requirements in DOE O 414.1D, *Quality Assurance*, and EM-QA-001, *Implementation of Revision 1 to the Corporate Quality Assurance Program, EM-QA-001, and Department of Energy Order 414.1D, Quality Assurance*. The calculations that were performed to provide general paths of groundwater flow and likely migration of releases from facilities throughout the entirety of the 200 West Area are described in ECF-200W-17-0070. The calculations that comprise more detailed simulations conducted for WMA S-SX are documented below.

6.1 Groundwater Flow Modeling

The following steps were used to develop the necessary input files, perform the calculations, and post-process the outputs to produce the figures presented in Chapter 7 and Appendices A and B of this ECF:

1. An input file for the MODFLOW Multi-Node Well Package for each sub-scenario was constructed to reflect the spatial and temporal configuration of the well operations. Groundwater extraction rates used to generate this input file through December 2014 are reported in the Environmental Model Management Archive (EMMA) and in the documentation accompanying the EMMA data archive, EMDT-ST-004, *Historical Pumping Rates 200 West Area, Electronic Modeling Data Transmittal – Boundary Condition (Historical Pumping Rates)*-0001. Pumping rates from CYs 2015 and 2016 were acquired from the 200 West Supervisory Control and Data Acquisition system and calculated on an average monthly basis. Assumed future pumping rates for each individual sub-scenario, developed in collaboration with CHPRC, are listed in Table A-4 in Appendix A of ECF-200W-17-0070.

2. The CPGWM flow model was executed to obtain simulated hydraulic head distributions, as well as the accessory outputs needed for particle-tracking (ModPath3DU) and dilution/transport (MT3DMS) calculations.

6.2 Particle Tracking

The following steps were used to perform the calculations and post-process the outputs to produce the particle-tracking figures presented in this ECF:

1. For the hypothetical waste site focused release scenarios, input files for the particle-tracking analyses were constructed, including assigning particle starting locations with 20 particles located along the perimeter of all 27 SSTs located in WMA S-SX (release locations shown on Figure 6-1). Particles were released at the water table (model layer 2) to reflect a hypothetical water table impact. The initial release time for scenarios 1 and 2 corresponds to October 1, 2017, representing a "current" release. Particles were then released from the same location every year until October 1, 2036 and run until October 1, 2037, when the P&T system operation ends. For scenario 3, since there is much less variability in the flow field following cessation of the P&T system operation, particles were initially released on October 1, 2037 and were then released every 5 years thereafter until October 1, 2132 and tracked until October 1, 2137.

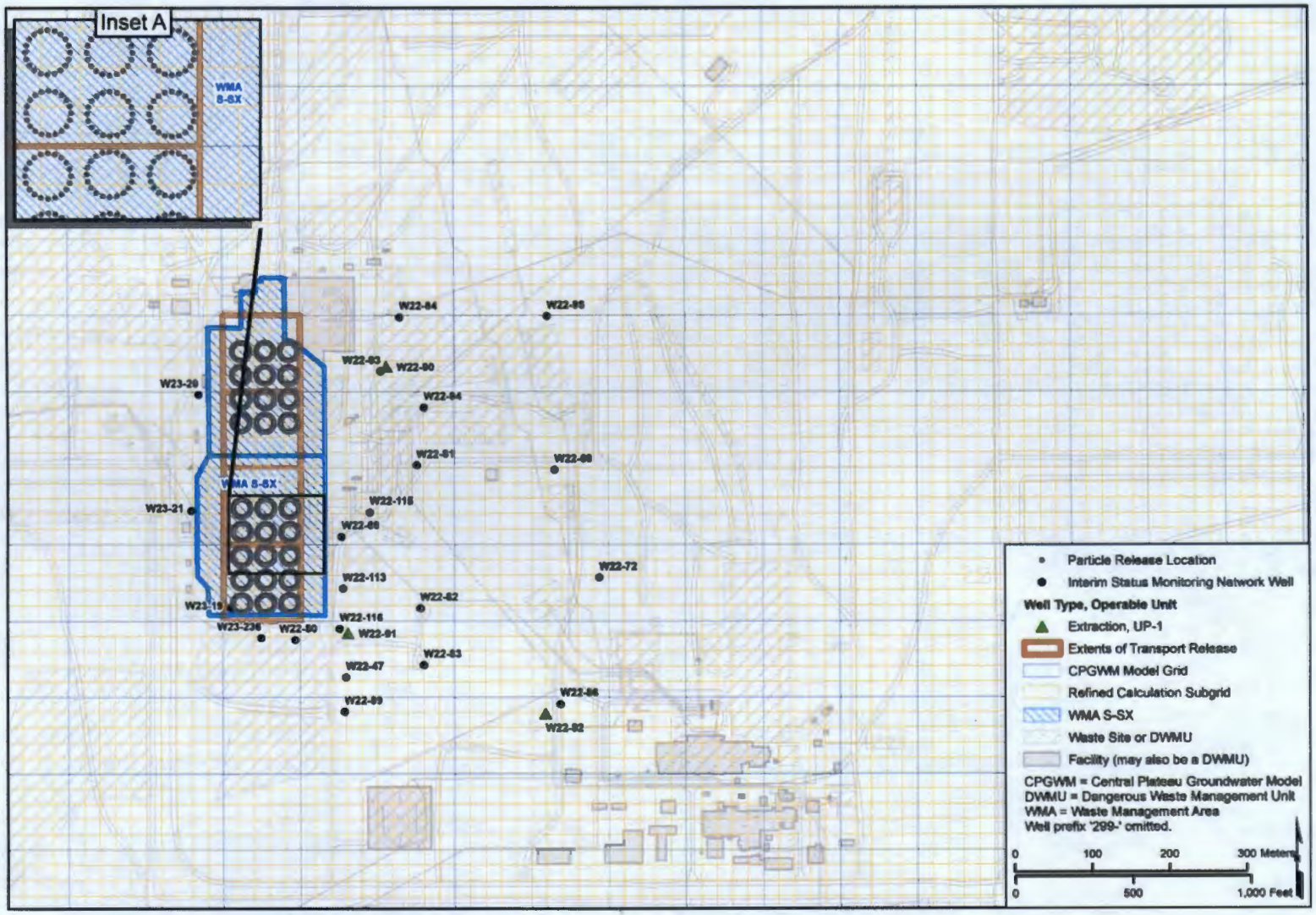

Figure 6-1. Locations of CPGWM and Refined Subgrid Cells in Relation to WMA S-SX

2. The particle-tracking program ModPath3DU was executed to track the particles, the results were post-processed, and particle tracks (pathlines) were generated and superimposed upon figures that included the extraction, injection, and monitoring well locations to determine if monitoring locations lie in the migration pathway of hypothetical releases from the facility.

   To simulate dispersion with particle tracking, the random-walk particle-tracking option implemented within ModPath3DU was used. As described in the software documentation (CHPRC-00261), for consistency this random-walk module reads and uses the same dispersion inputs as the Hanford Site version of the transport simulator MT3DMS.

3. For the focused release tracking scenarios, the objective is to identify areas of the aquifer where a hypothetical release that impacts the water table beneath the SSTs within WMA S-SX would be most likely to migrate and be detectable. To do this, the "relative detectability" was calculated. The relative detectability is a weighted sum of the number of particles that cross a model grid cell over all the sub-scenarios within each scenario. By using the weights of the sub-scenarios shown in Table 3-1, this calculation considers all sub-scenarios, giving the highest weight or influence to the more probable injection well operating conditions.

   To calculate relative detectability, first a refined calculation subgrid, which encompasses the 200 West Facilities was defined by applying 20 by 20 m (66 by 66 ft) cells, resulting in 25 calculation cells within each CPGWM simulation cell (Figure 6-1). This step allowed a map of relative detectability to be produced that illustrates the results of these calculations on a finer spatial resolution than the discretization of the CPGWM simulation grid. The relative detectability was calculated as follows:

   a. 20 particles are released annually around the perimeter of all 27 tanks located in the 241-S and 241-SX Tank Farms according to list item (1) above, resulting in a total of 10800 particles.

   b. For each sub-scenario, the number of released particles that traversed each cell of the calculation subgrid was calculated and maps of the count of particles that traversed each cell of the refined calculation subgrid were produced. The results shown in these "particle count maps" for each sub-scenario were then combined into a relative detectability map. The particle counts for all the sub-scenarios within each scenario were combined using a method that gives more weight to the more likely sub-scenarios.

   c. The relative detectability was determined for each cell of the calculation subgrid for each sub-scenario by computing a weighted sum of the combined counts. This procedure produces a value between zero (0) and one (1) for each calculation subgrid cell, as follows:

$$RD = \frac{1}{MNP}\sum_{1}^{n} P_i N_i$$

   where:

   RD = relative detectability (ranging from zero to one)

   MNP = maximum number of particles that traversed any subgrid cell in all sub-scenarios within a scenario

   P_i = ascribed weight or probability of sub-scenario *i* (as listed in Table 3-1)

   N_i = number of particles that traversed the calculation subgrid cell during sub-scenario *i*

n = total number of sub-scenarios within the simulated scenario (i.e., 18, the total of sub-scenarios A through R as presented in Table 3-1).

These calculations were made using the capabilities of the ArcGIS support software.

4. Post-processing scripts were then executed to produce the maps of relative detectability. In the maps of relative detectability presented in Chapter 7 and the particle count maps included in Appendix A of this ECF, the relative color scale of the concentration plume represents the relative concentration in groundwater (for either the treated water injection unit source or the hypothetical water table release unit source).

6.3 Transport Modeling

To evaluate the efficacy of the interim status WMA S-SX groundwater monitoring network at detecting hypothetical releases from the WMA S-SX, two distinct yet complementary transport simulations were performed:

- Simulation of treated water injection using the unit source approach to represent the water injected at injection wells.
- Simulation of a hypothetical release that impacts the water table below WMA S-SX using the unit-source approach to represent the water table impact and subsequent migration from WMA S-SX.

The following steps were used to develop the necessary input files, perform the calculations, and post-process the outputs to develop spatial maps and also time-series plots depicting relative release concentrations over time in the case of simulated water table releases and relative treated water dilution concentrations in the case of treated water injection:

1. For the evaluations of a hypothetical release to the groundwater table, the MT3DMS Sink/Source Mixing (SSM) Package was prepared to simulate constant concentration sources using constant unit concentrations at WMA S-SX. The unit concentrations were released at the water table (model layer 2) in four model grid cells representing WMA S-SX (Figure 6-1). The unit concentrations were assumed to be released at the start of FY 2017.

2. To simulate the injected treated water migration through FY 2037, the MT3DMS SSM Package was prepared to simulate constant-concentration sources representing the injection of a unit concentration at the following 200 West P&T system injection wells (Figure 3-3).

299-W6-13	299-W10-36	299-W15-229	299-W18-41
299-W6-14	299-W15-29	299-W18-36	299-W18-42
299-W6-16	299-W15-226	299-W18-37	299-W18-43
299-W7-14	299-W15-227	299-W18-38	299-W18-44
299-W10-35	299-W15-228	299-W18-39	

   The unit concentration was released at each injection well corresponding with the month of its initial historical operation.

3. For all scenarios, the MT3DMS SSM Package was prepared to simulate transport following shutdown of the P&T system, during which time monitored natural attenuation is the operating remedy. For the hypothetical water table release evaluation, the unit concentrations representing water table impacts at WMA S-SX were maintained, whereas for the injected treated water evaluation, the unit concentrations representing injected water were not maintained (consistent with system shutdown).

4. Each transport model was executed to simulate the fate of the prescribed unit concentrations over time and produce the required MT3DMS output files.

5. Post-processing scripts were executed to produce the figures presented in Chapter 7 and Appendices A and B of this ECF. Time-series plots of concentrations at selected spatial locations were produced both for treated water injection as the unit source and for a simulated water table release from WMA S-SX as the unit source. In addition, spatial "snapshots" of concentrations at the water table throughout the aquifer at certain times were produced for the treated water injection as the unit source. These figures include the following:

    a. Time-series plots depicting injected treated water dilution breakthrough curves at existing monitoring wells 299-W22-47, 299-W22-69, 299-W22-72, 299-W22-80, 299-W22-81, 299-W22-82, 299-W22-83, 299-W22-84, 299-W22-85, 299-W22-86, 299-W22-89, 299-W22-93, 299-W22-94, 299-W22-95, 299-W22-113, 299-W22-115, 299-W22-116, 299-W23-19, 299-W23-20, 299-W23-21, and 299-W23-236.

    b. Time-series plots depicting release concentration breakthrough curves at existing monitoring wells 299-W22-47, 299-W22-69, 299-W22-72, 299-W22-80, 299-W22-81, 299-W22-82, 299-W22-83, 299-W22-84, 299-W22-85, 299-W22-86, 299-W22-89, 299-W22-93, 299-W22-94, 299-W22-95, 299-W22-113, 299-W22-115, 299-W22-116, 299-W23-19, 299-W23-20, 299-W23-21, and 299-W23-236.

    c. Injected treated water dilution plume maps depicting a spatial snapshot shown at the end of the operation of the 200 West P&T system in 2037 in model layer 2, which corresponds to the water table, of the unit concentrations of injected treated water. These are shown superimposed on the WMA S-SX release flow pathlines (produced as described in Section 6.2).

    d. Release unit plume maps depicting a spatial snapshot shown at the end of the operation of the 200 West P&T system in 2037 in model layer 2, which corresponds to the water table, of the unit concentrations of the release to the water table under the facility (release unit plume maps for scenario 3 depict conditions in 2137).

In the map-based (spatial) figures presented in Chapter 7 and Appendix B of this ECF, the relative color scale of the concentration plume represents the relative concentration in groundwater (versus either the treated water injection unit source or the hypothetical water table release unit source).

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7 Results

This chapter presents outputs from the calculations described previously for the scenarios listed in Table 3-1. The particle-tracking and transport calculations were used to produce output that aided in the evaluation of the monitoring well network and potential new well locations. The calculation methods differ in some key ways (described in Chapters 3 and 6), including the extent of the source area and the interpolation between cells, which may produce differing evaluation results. The calculations are complementary, and results from both calculation methods are used in evaluating the monitoring well network.

Groundwater elevations in the 200 West Area were simulated and mapped (i.e. interpolated) and the results were presented in Appendices B and C of ECF-200W-17-0070, respectively. The water-level evaluations were not repeated on a facility-specific scale. The particle-tracking and transport modeling results are based on simulated water levels, like those presented in Appendix B of ECF-200W-17-0070.

7.1 Scenario 1

The injected treated water dilution breakthrough curves, release concentration breakthrough curves, and particle-tracking results superimposed on injected treated water dilution plumes for scenario 1 are presented in the following sections.

7.1.1 Injected Treated Water Dilution Breakthrough Curves

Figures 7-1 through 7-21 depict the simulated breakthroughs at wells 299-W22-47, 299-W22-69, 299-W22-72, 299-W22-80, 299-W22-81, 299-W22-82, 299-W22-83, 299-W22-84, 299-W22-85, 299-W22-86, 299-W22-89, 299-W22-93, 299-W22-94, 299-W22-95, 299-W22-113, 299-W22-115, 299-W22-116, 299-W23-19, 299-W23-20, 299-W23-21, and 299-W23-236, respectively, of a unit concentration representing treated water injected at injection wells. The injection time corresponds to the CY 2012 startup of the 200 West P&T system. The bold black line on the figures represents sub-scenario A, which reflects the most likely operating conditions.

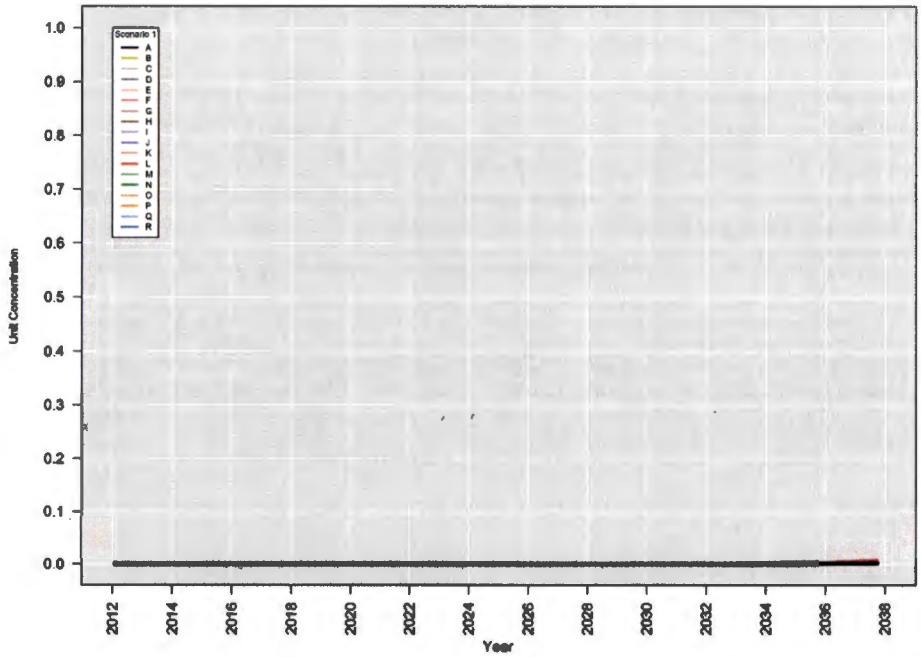

Figure 7-1. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-47

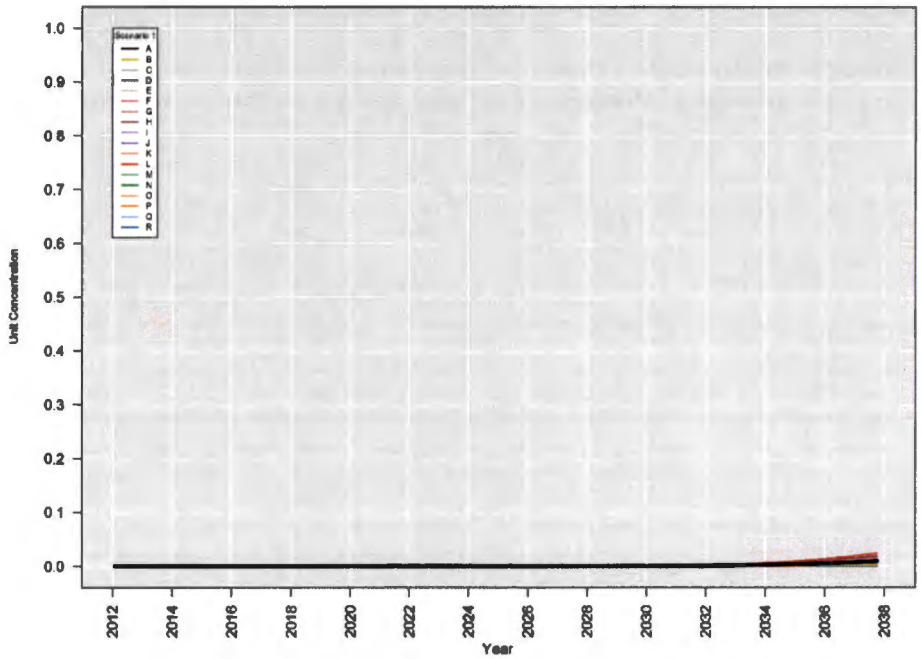

Figure 7-2. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-69

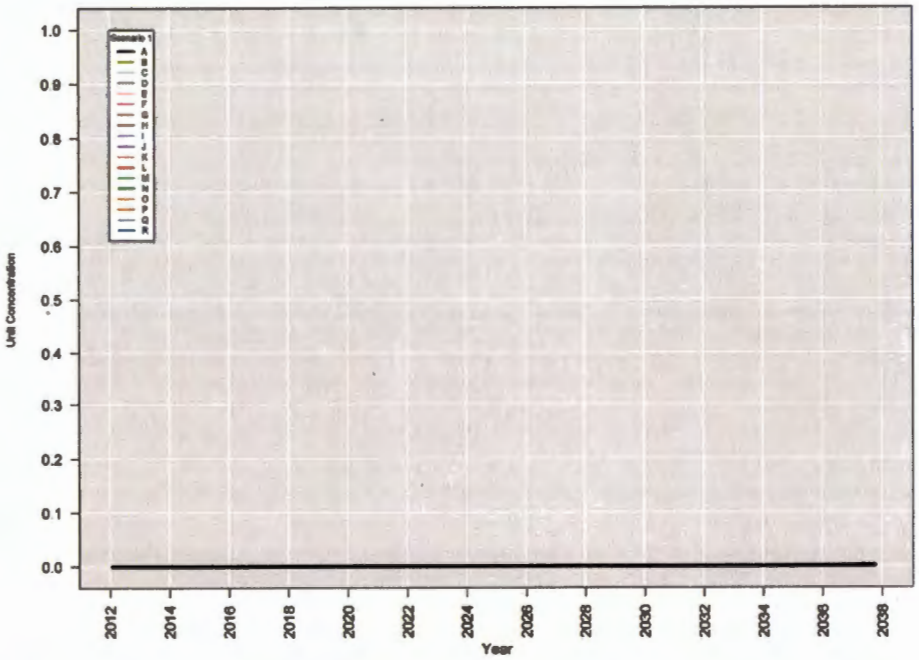

Figure 7-3. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-72

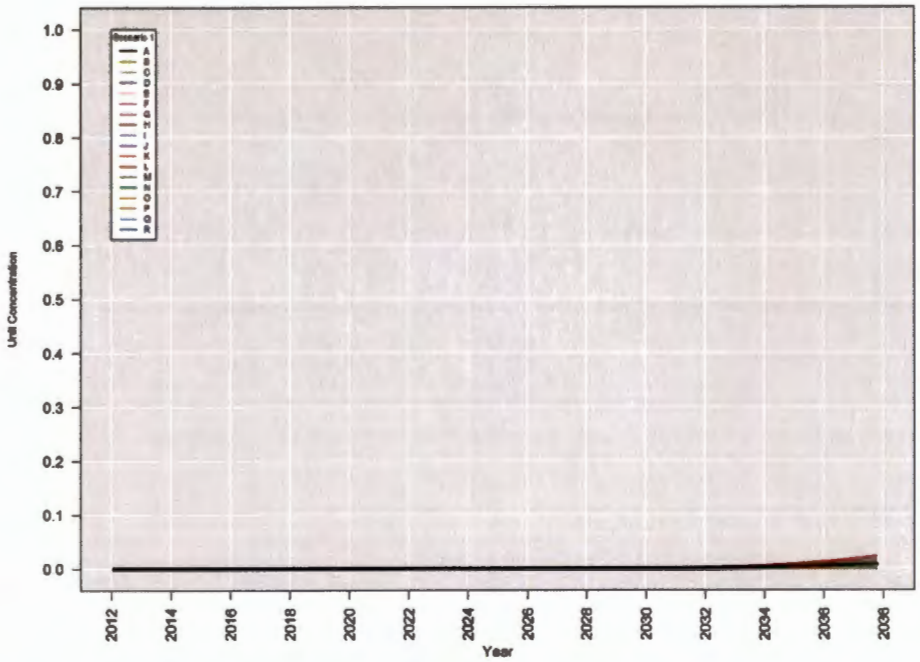

Figure 7-4. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-80

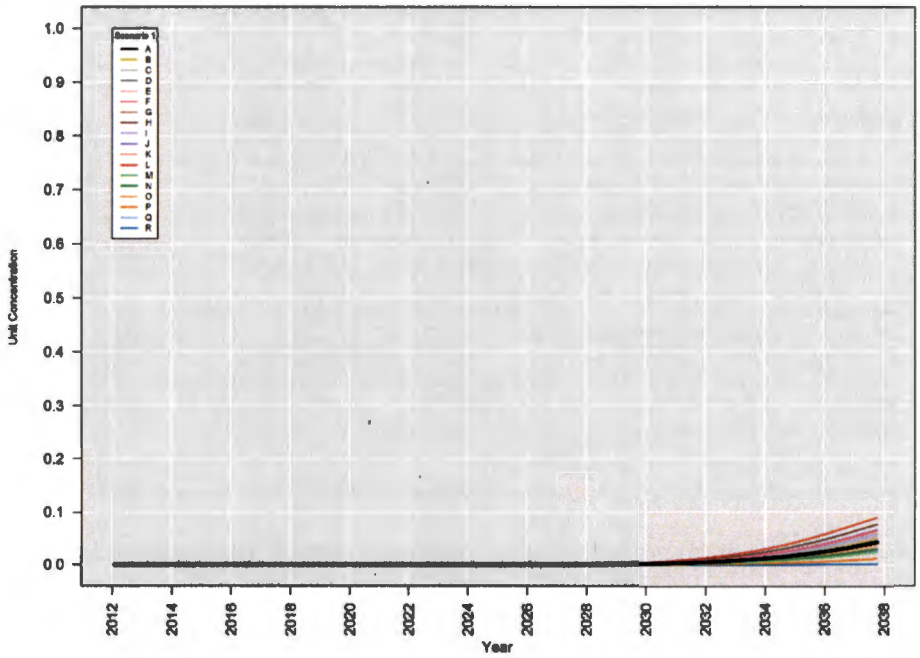

Figure 7-5. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-81

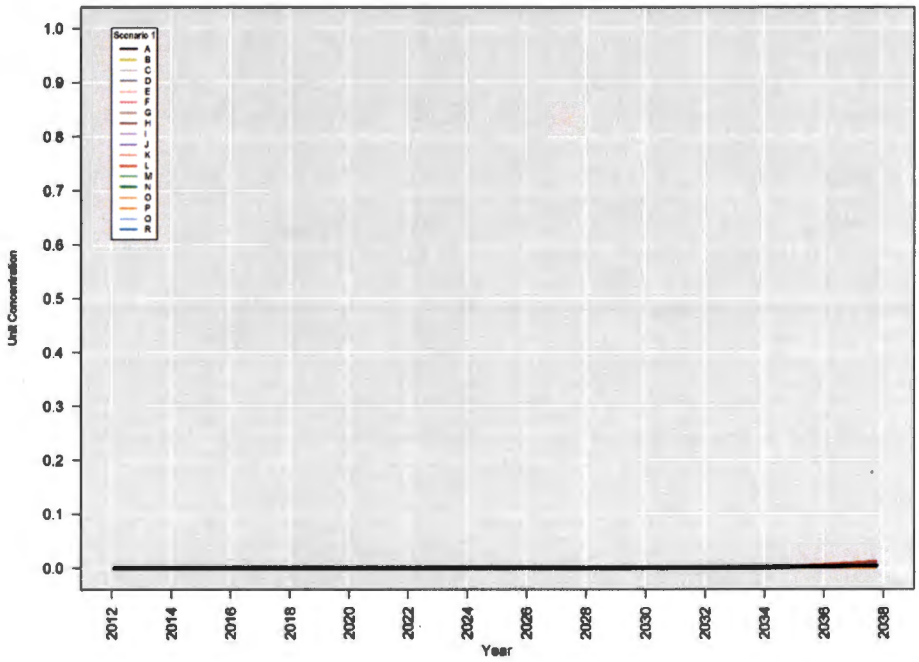

Figure 7-6. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-82

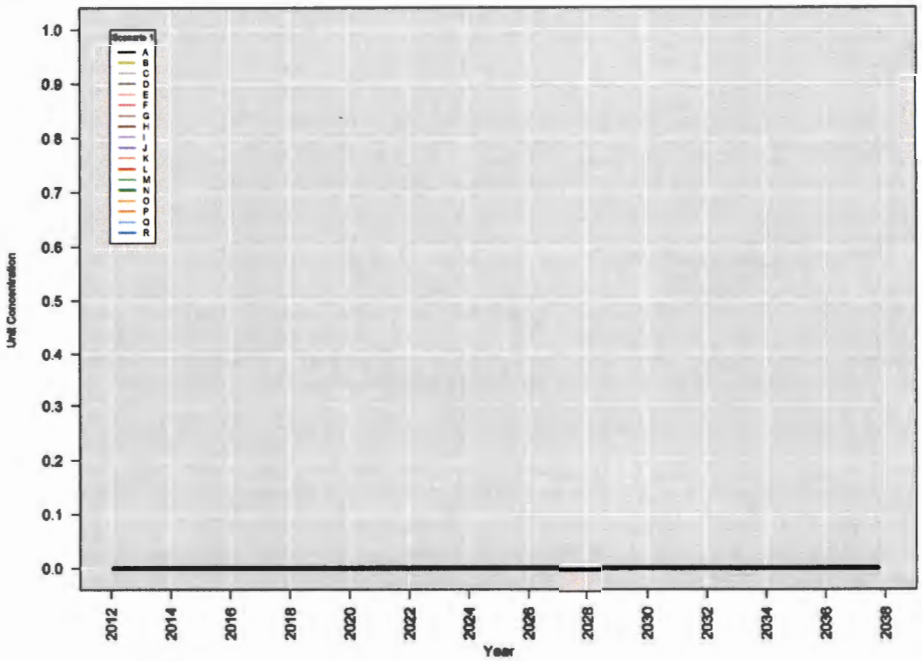

Figure 7-7. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-83

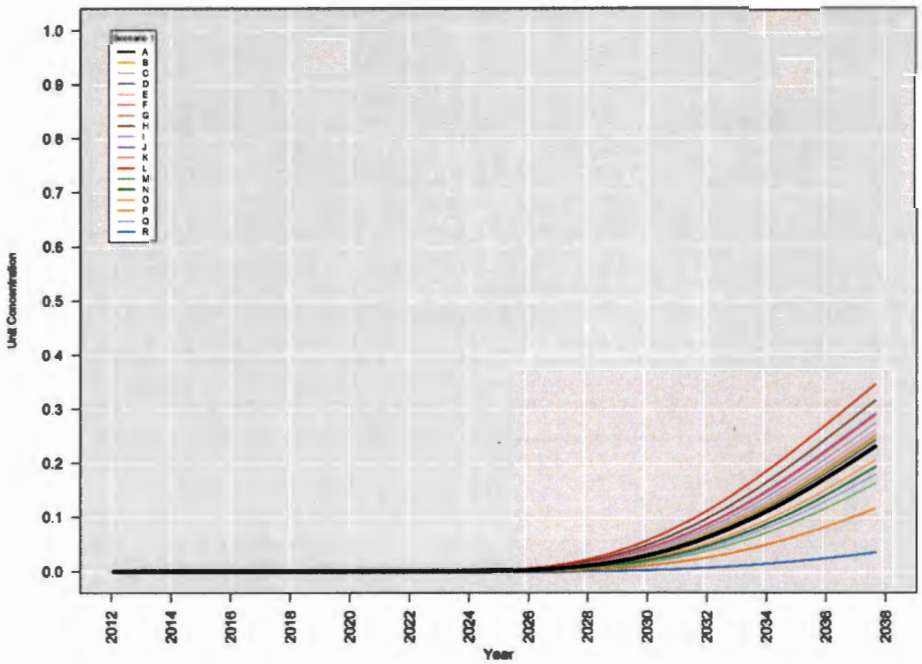

Figure 7-8. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-84

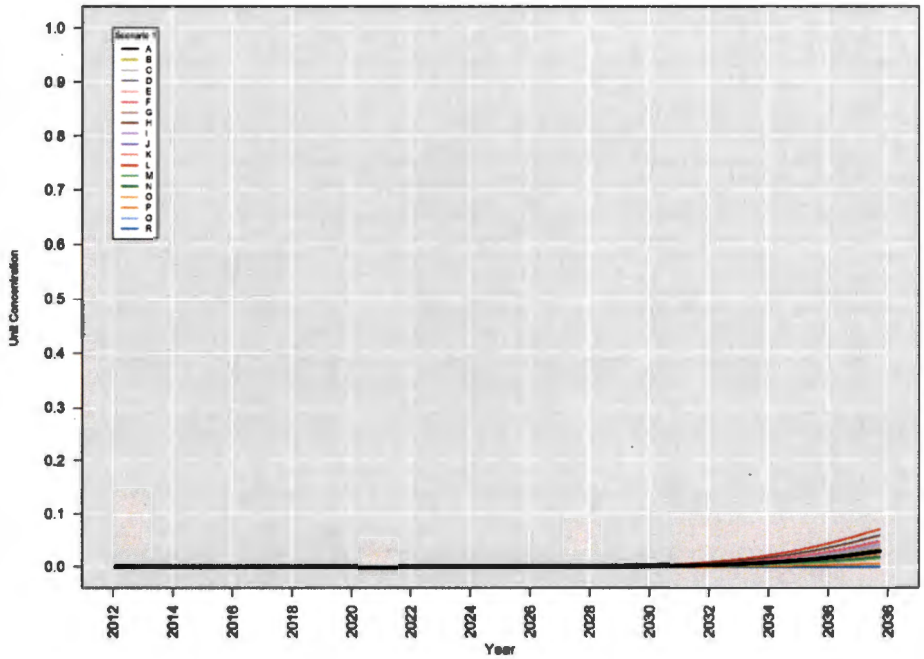

Figure 7-9. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-85

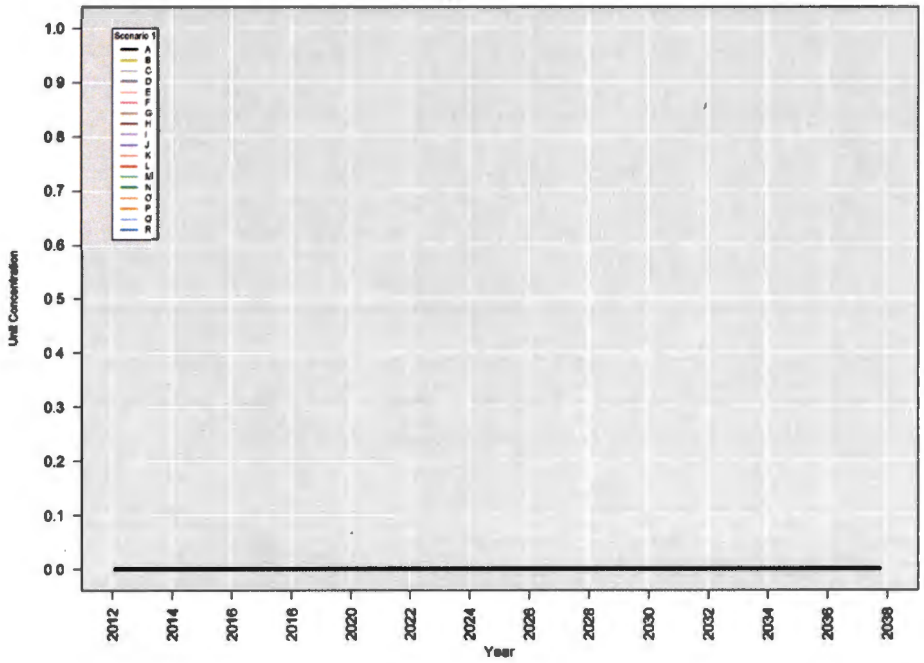

Figure 7-10. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-86

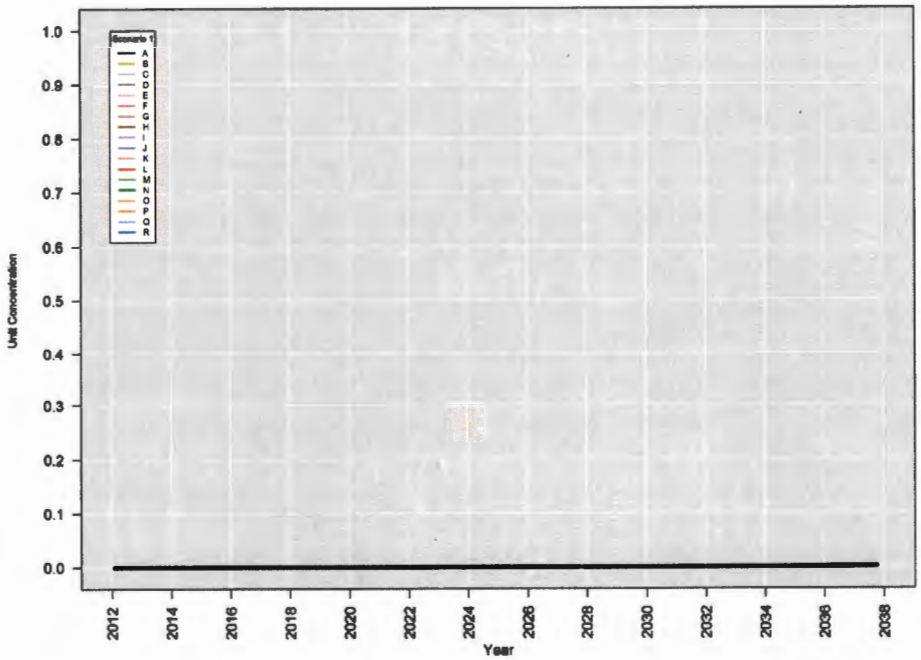

Figure 7-11. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-89

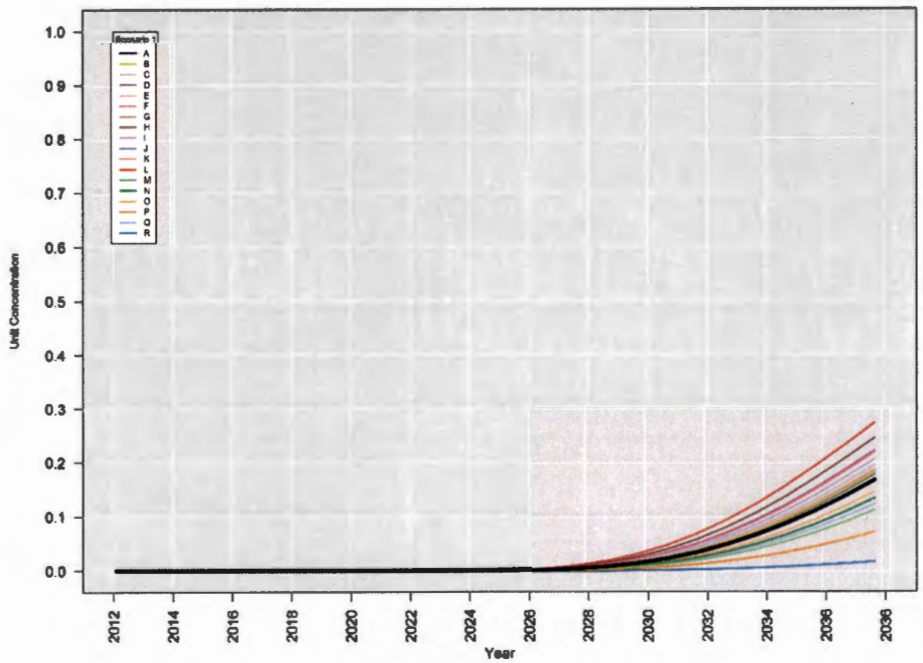

Figure 7-12. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-93

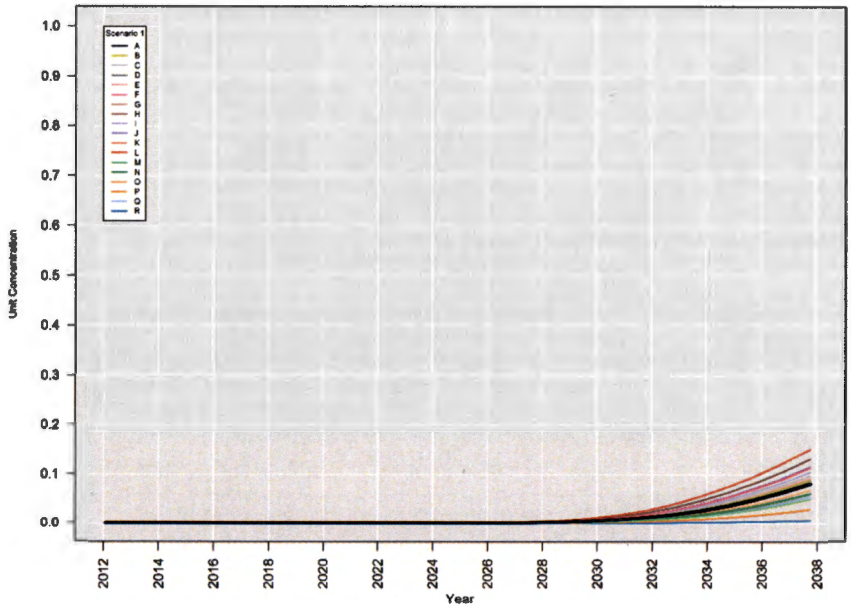

Figure 7-13. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-94

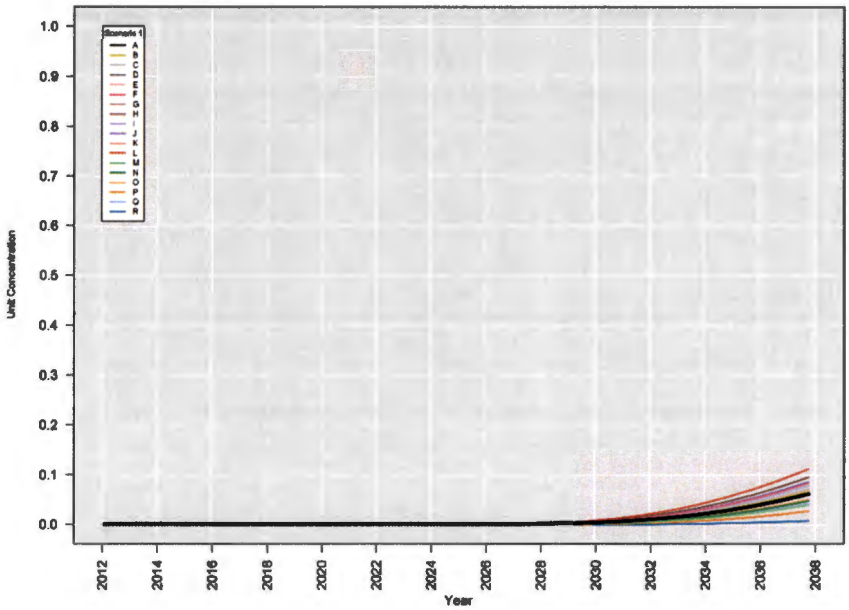

Figure 7-14. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-95

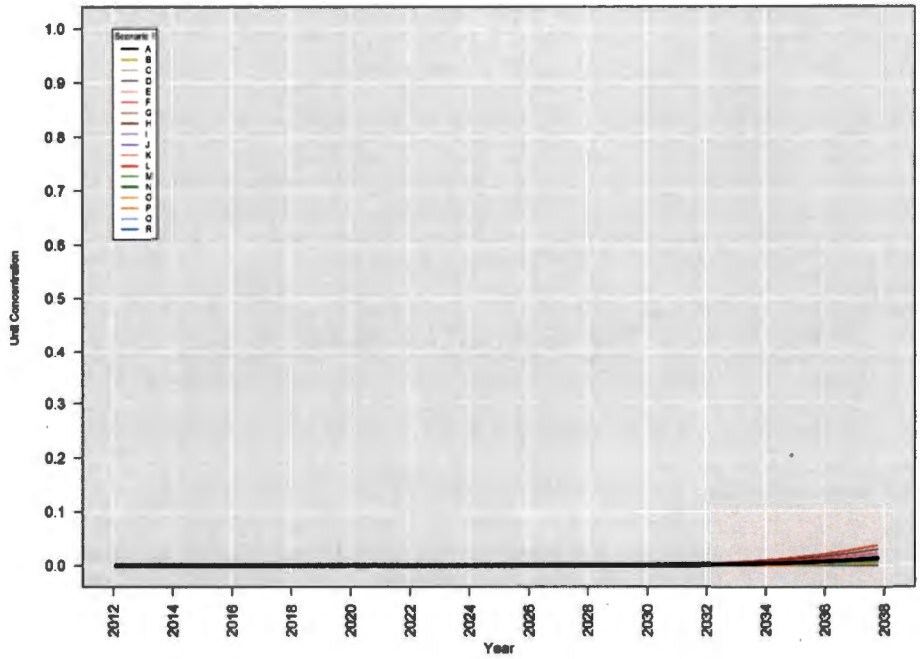

Figure 7-15. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-113

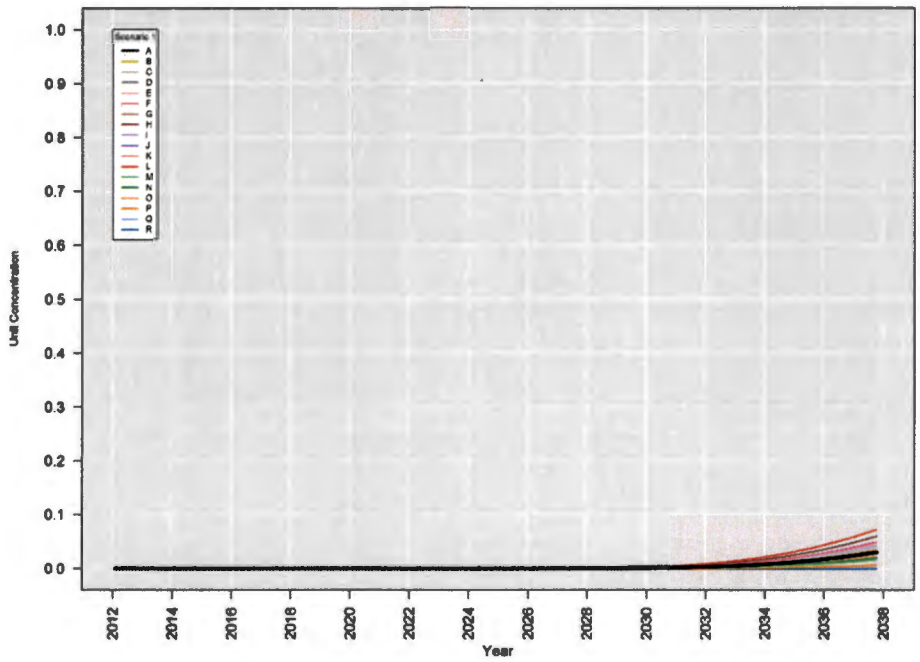

Figure 7-16. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-115

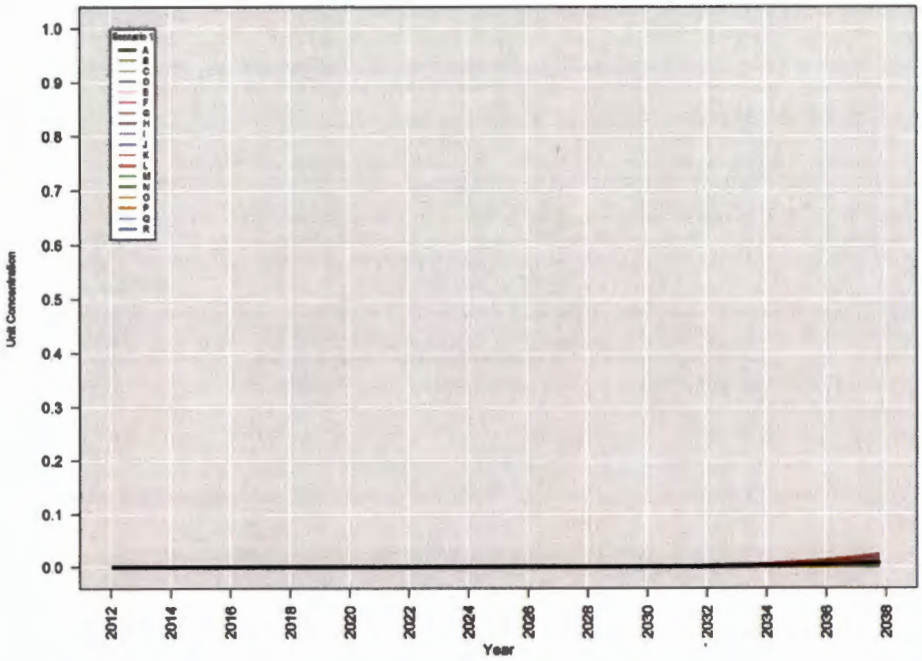

Figure 7-17. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-116

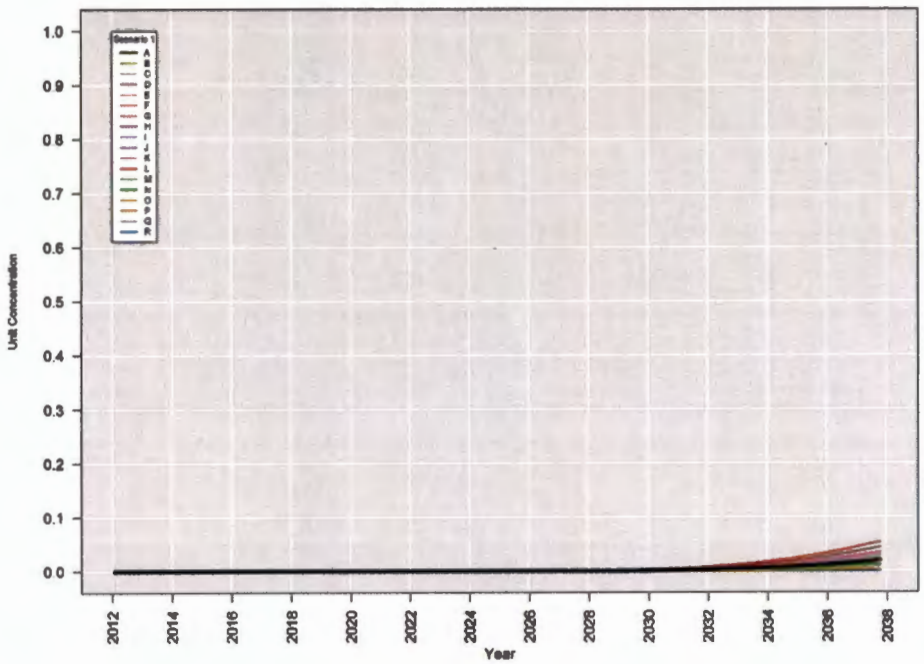

Figure 7-18. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W23-19

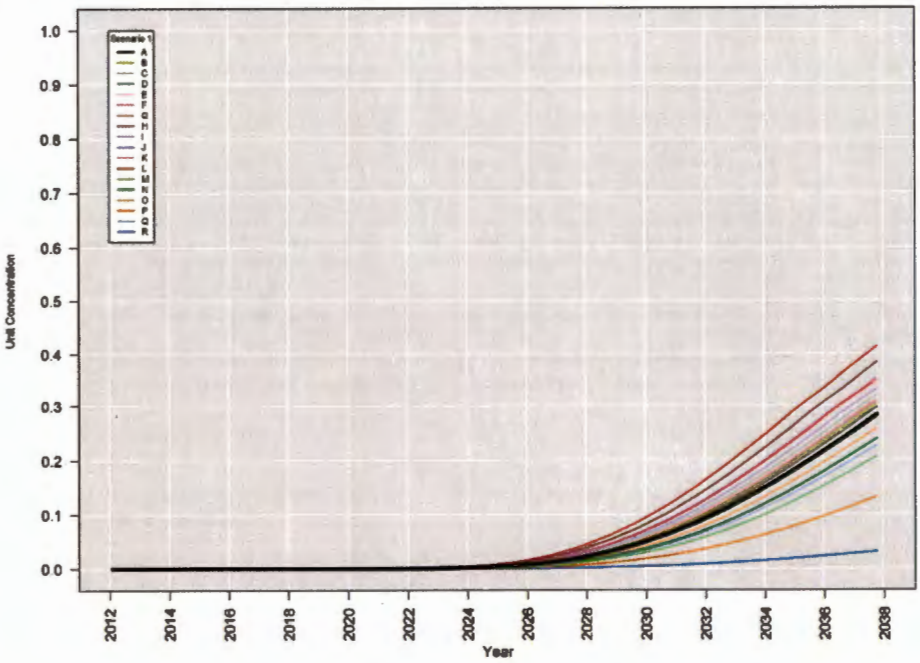

Figure 7-19. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W23-20

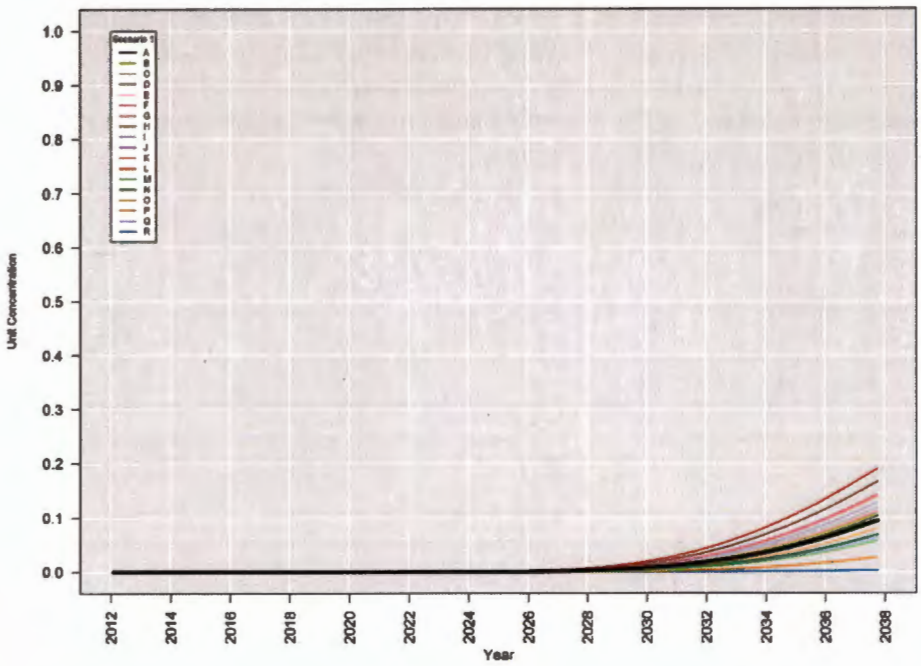

Figure 7-20. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W23-21

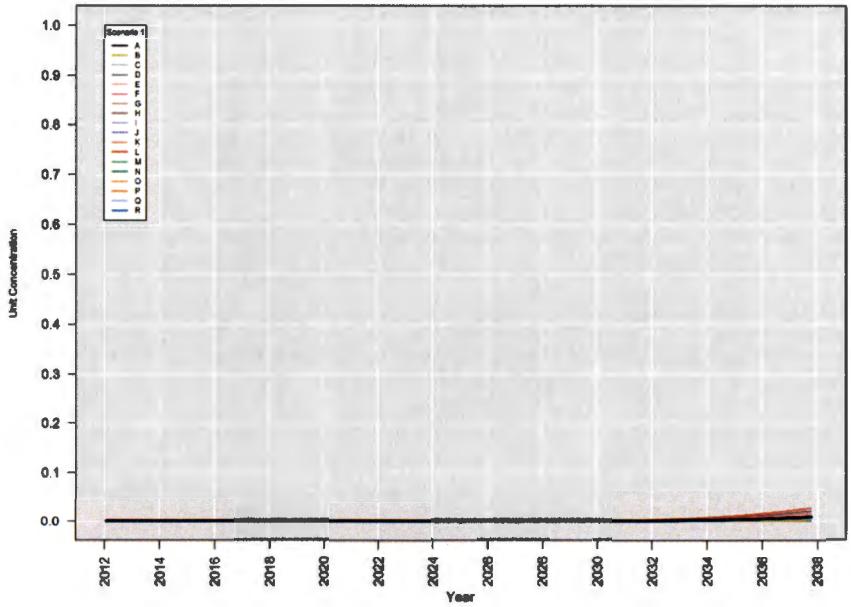

Figure 7-21. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W23-236

7.1.2 Release Concentration Breakthrough Curves

Figures 7-22 through 7-42 depict the simulated breakthrough of a unit-source water table release from WMA S-SX, at monitoring wells 299-W22-47, 299-W22-69, 299-W22-72, 299-W22-80, 299-W22-81, 299-W22-82, 299-W22-83, 299-W22-84, 299-W22-85, 299-W22-86, 299-W22-89, 299-W22-93, 299-W22-94, 299-W22-95, 299-W22-113, 299-W22-115, 299-W22-116, 299-W23-19, 299-W23-20, 299-W23-21, and 299-W23-236, respectively. The release time (represented on the figures as arrival time year 0) corresponds to October 1, 2017. The bold black line on the figures represents sub-scenario A, which reflects the most likely operating conditions.

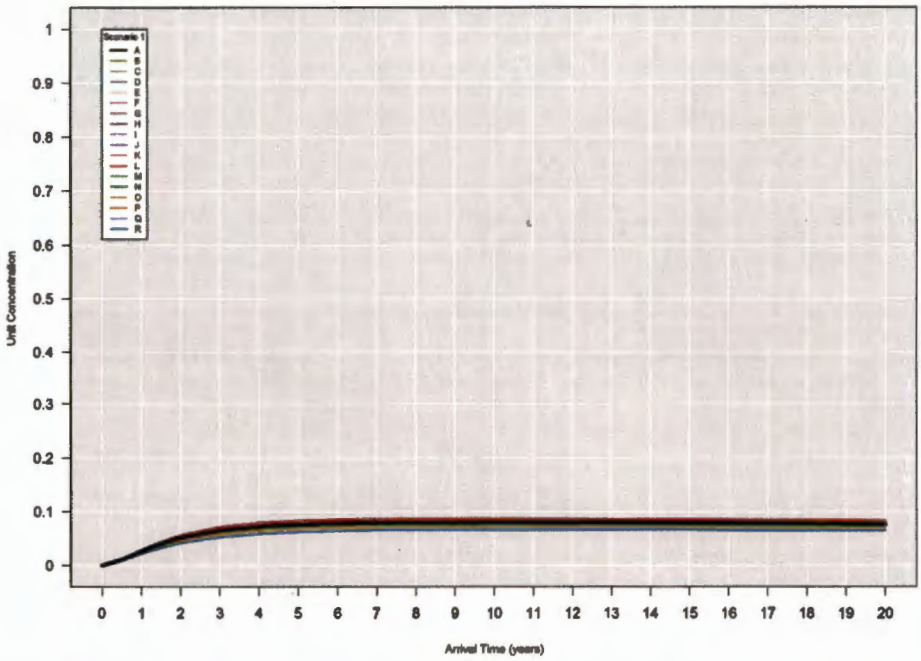

Figure 7-22. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-47

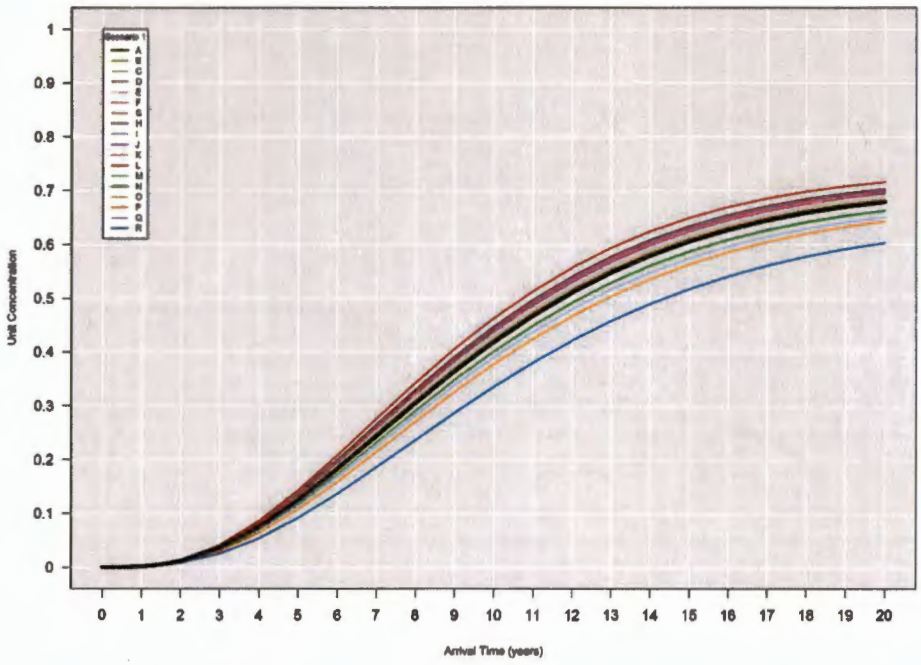

Figure 7-23. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-69

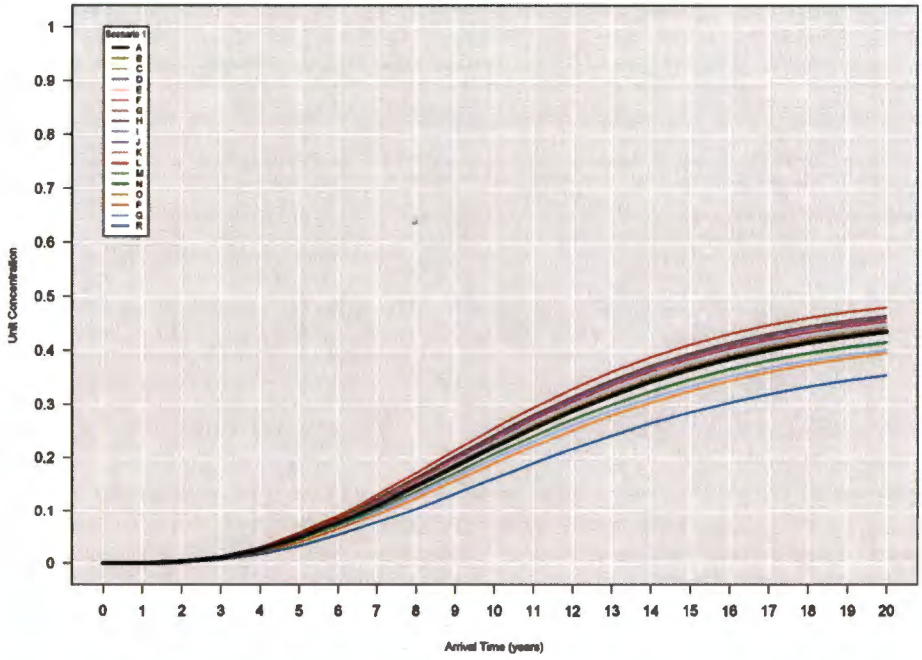

Figure 7-24. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-72

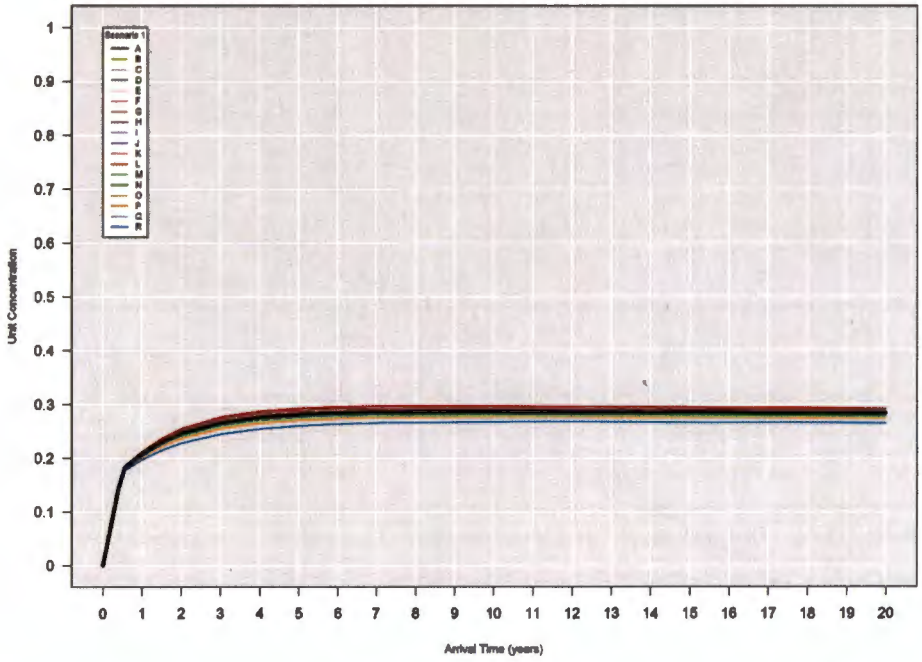

Figure 7-25. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-80

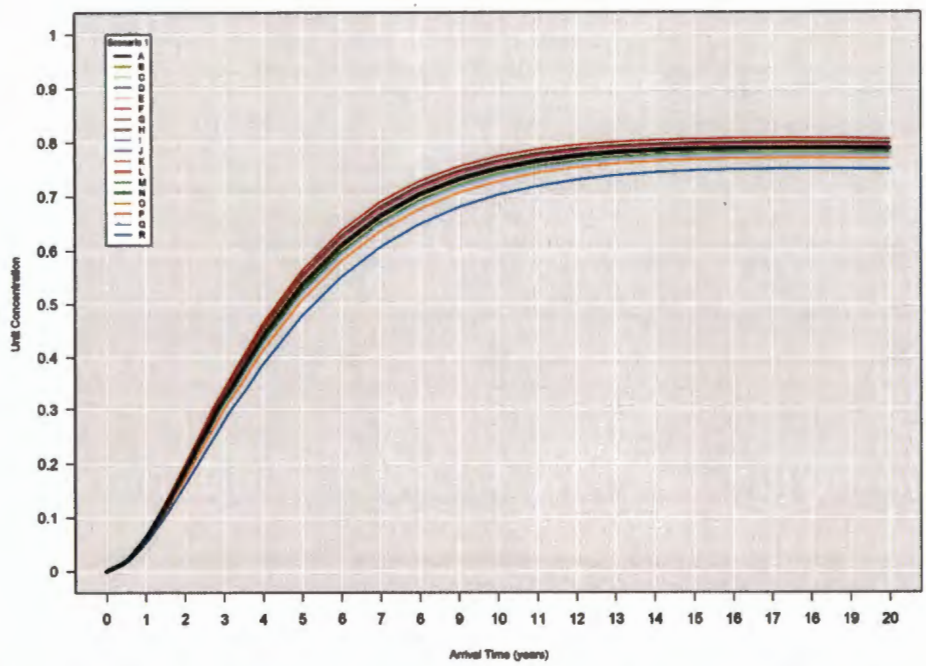

Figure 7-26. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-81

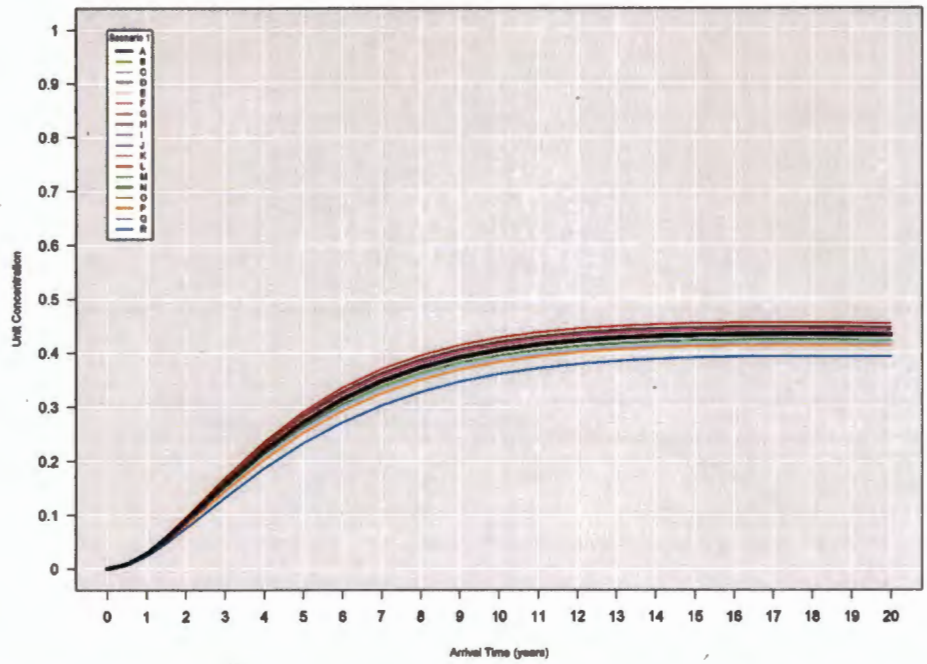

Figure 7-27. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-82

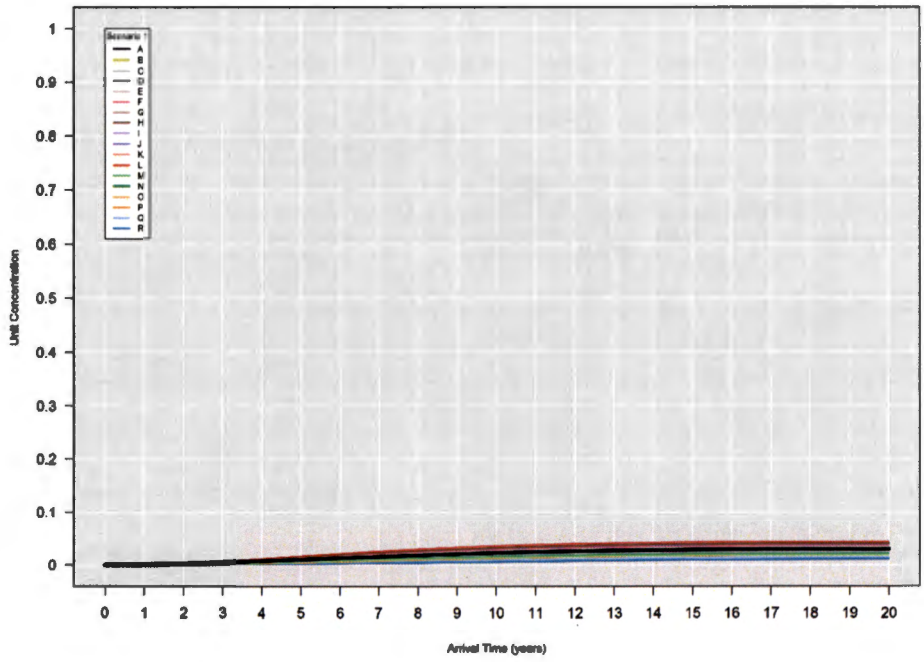

Figure 7-28. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-83

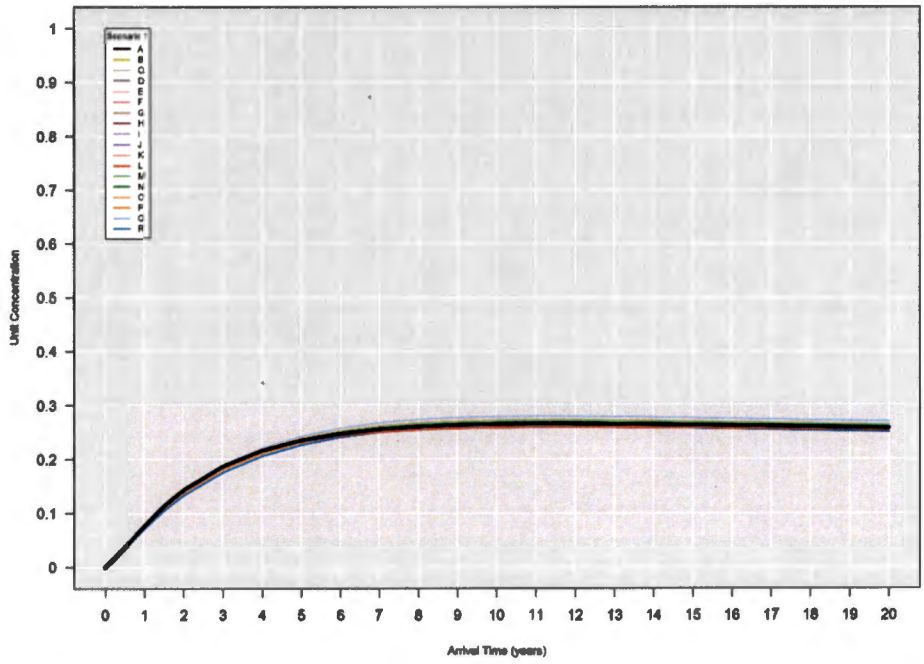

Figure 7-29. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-84

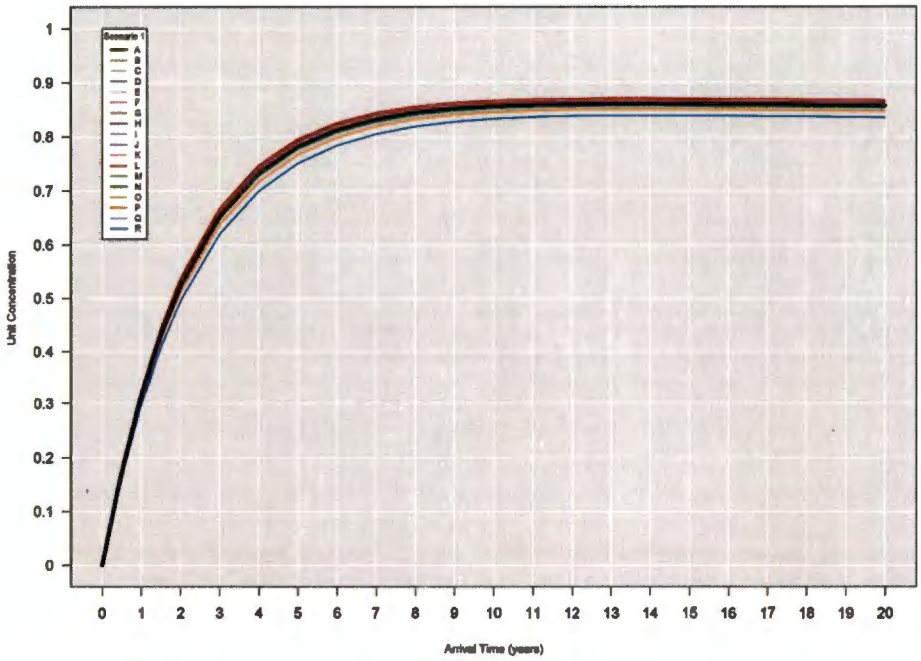

Figure 7-30. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-85

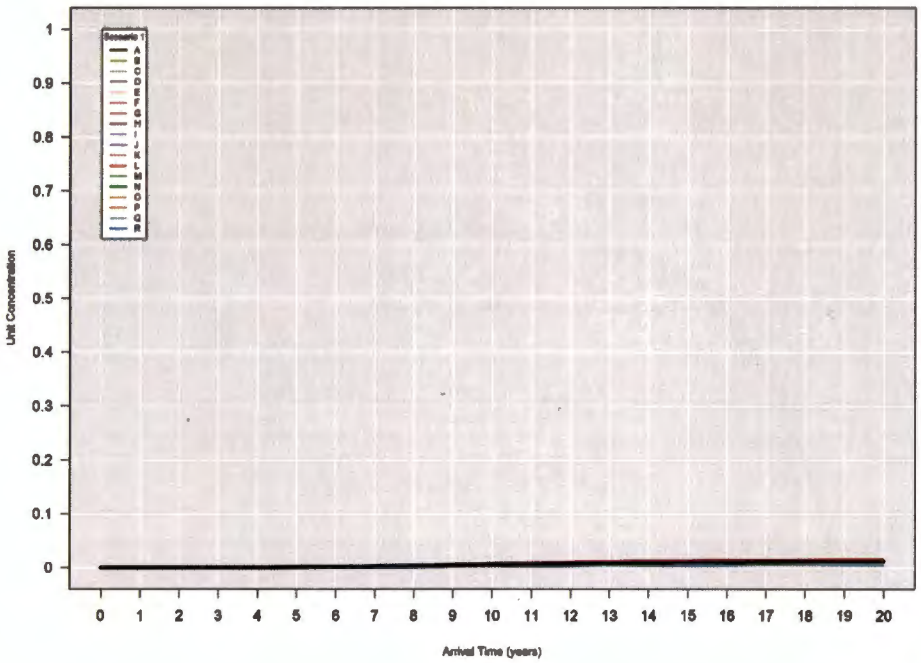

Figure 7-31. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-86

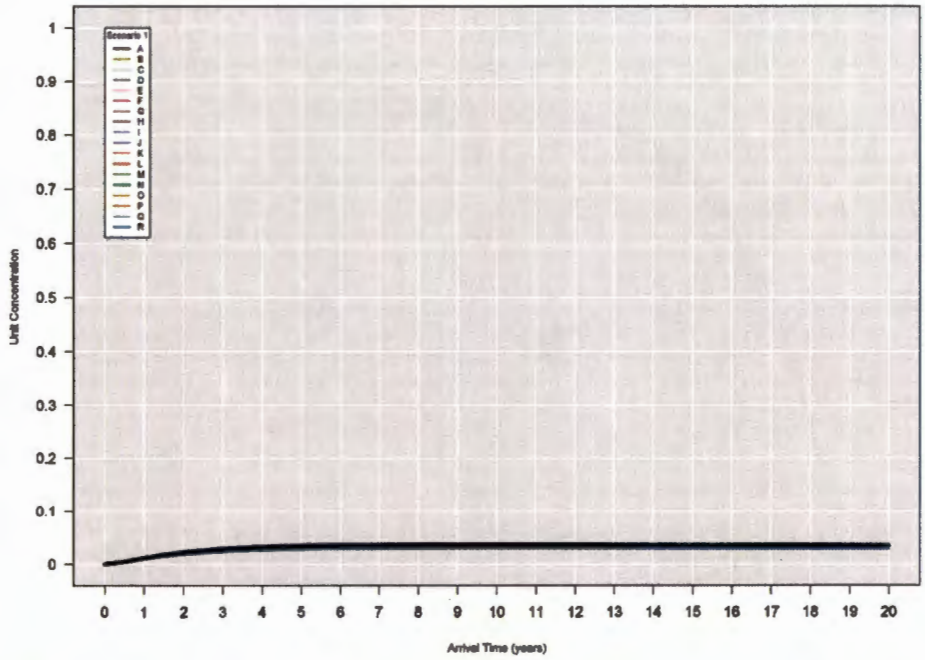

Figure 7-32. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-89

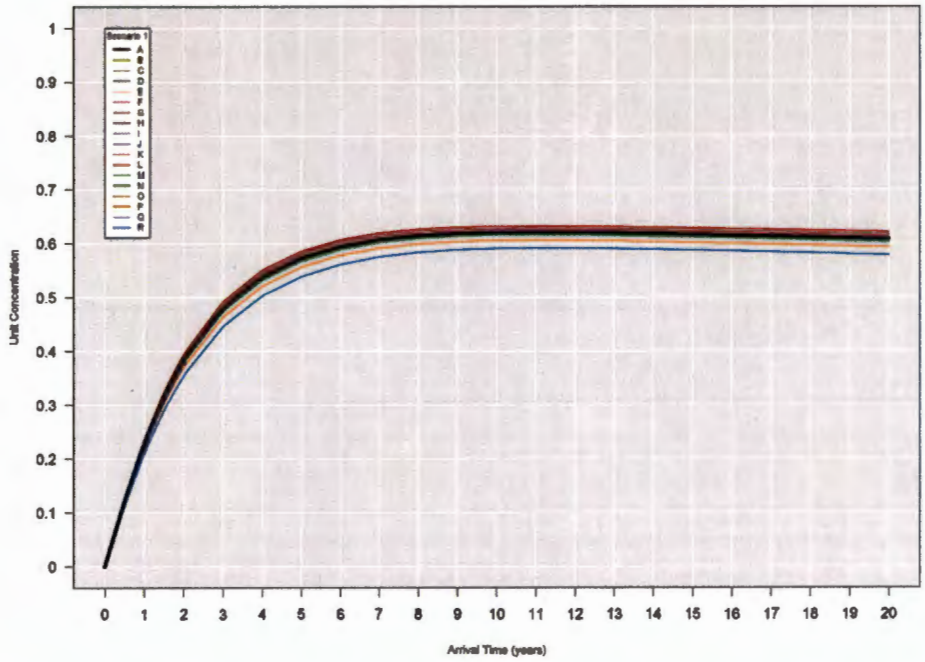

Figure 7-33. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-93

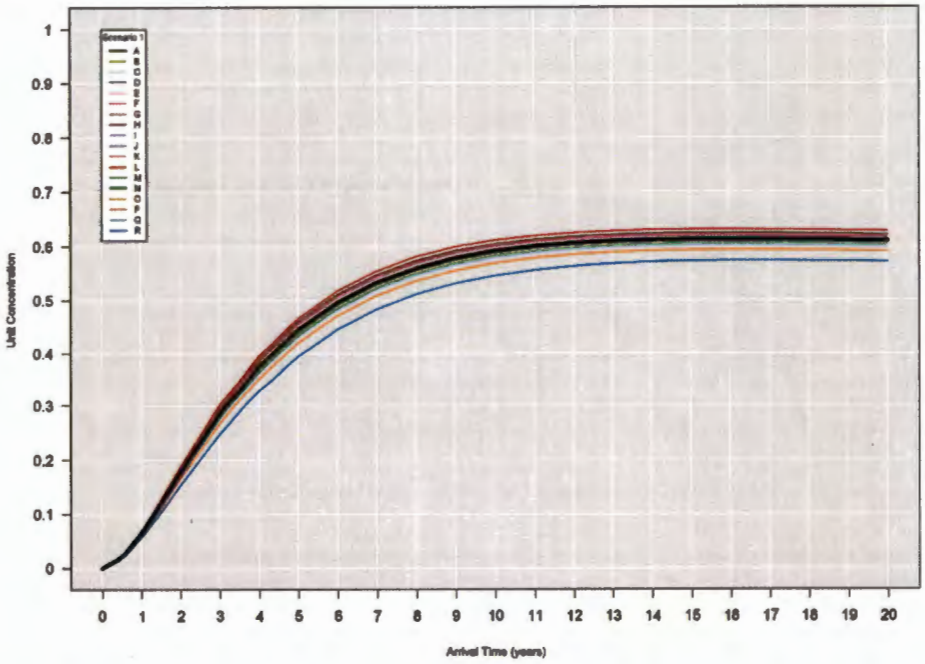

Figure 7-34. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-94

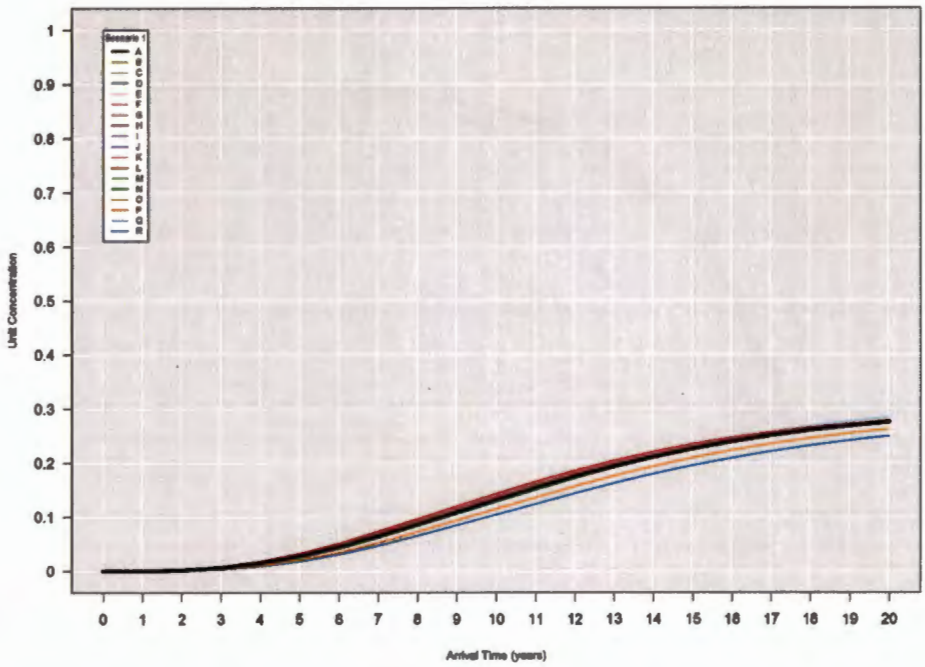

Figure 7-35. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-95

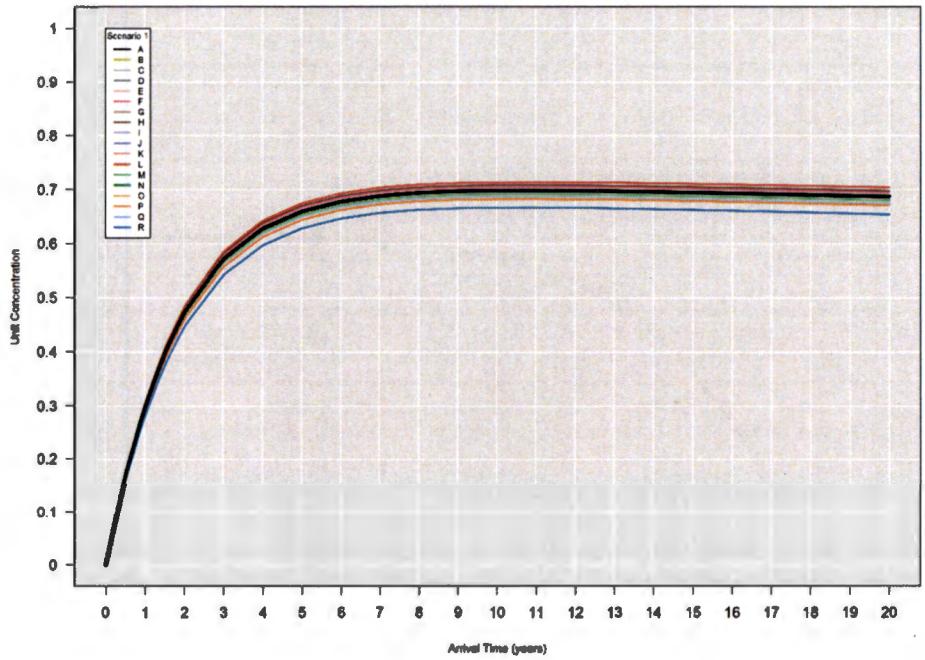

Figure 7-36. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-113

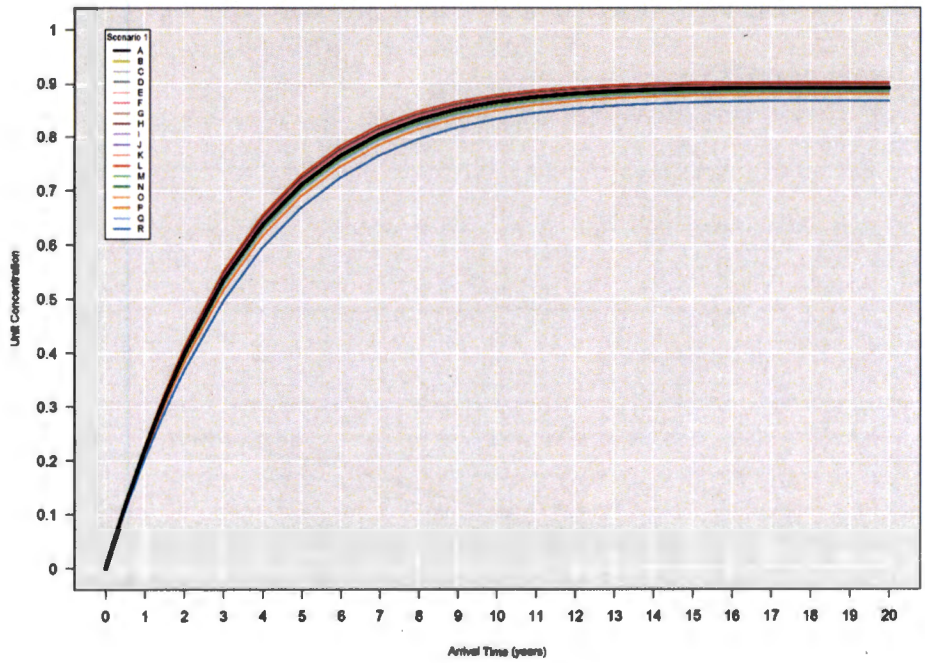

Figure 7-37. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-115

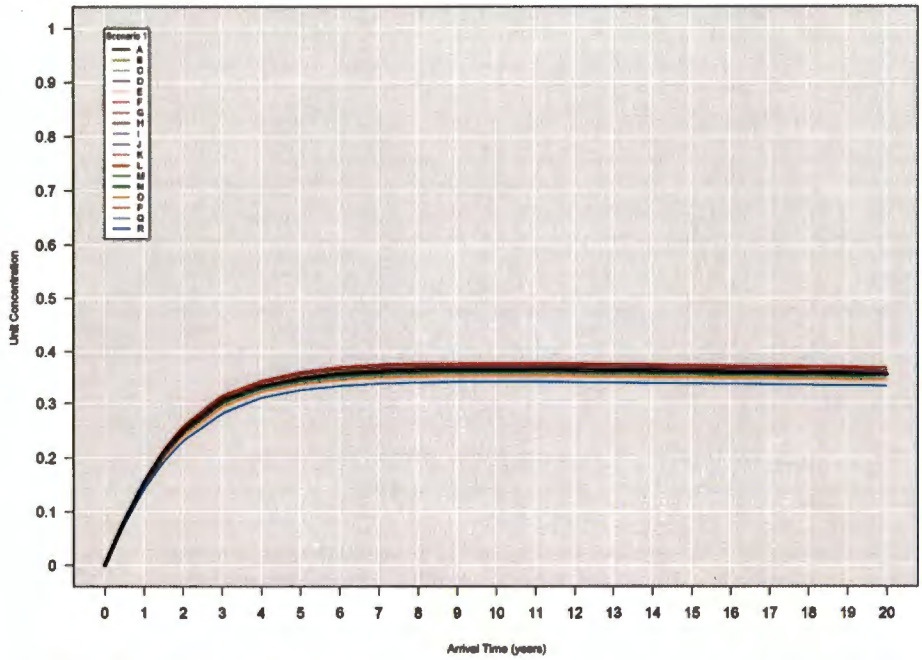

Figure 7-38. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-116

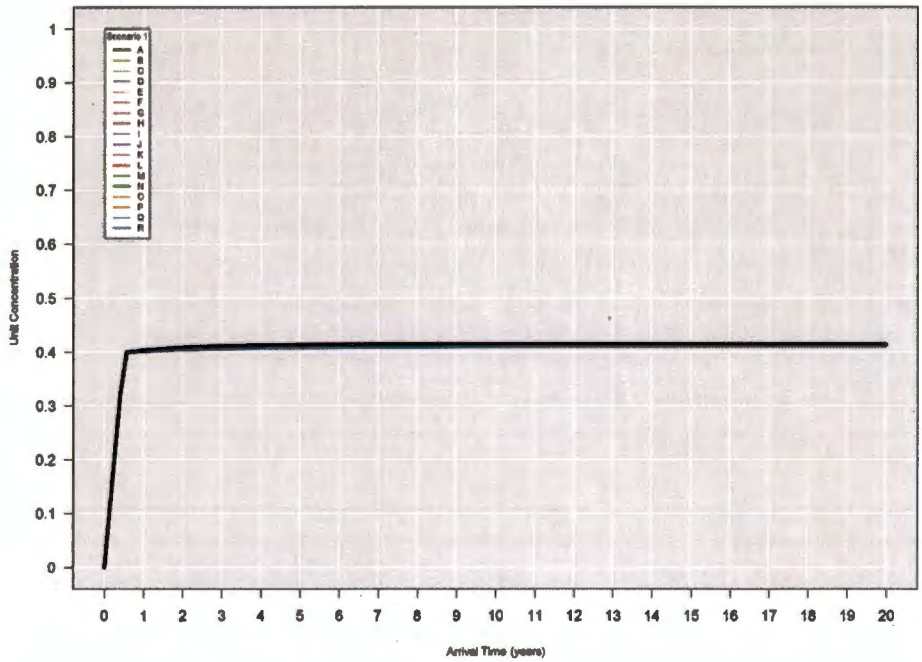

Figure 7-39. Release Concentration Breakthrough Curves at Monitoring Well 299-W23-19

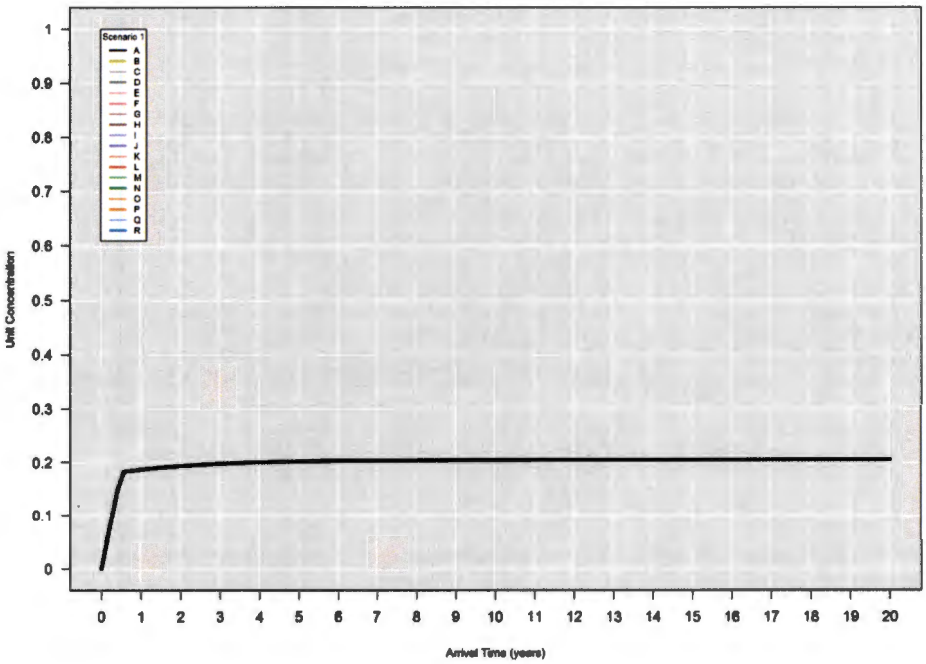

Figure 7-40. Release Concentration Breakthrough Curves at Monitoring Well 299-W23-20

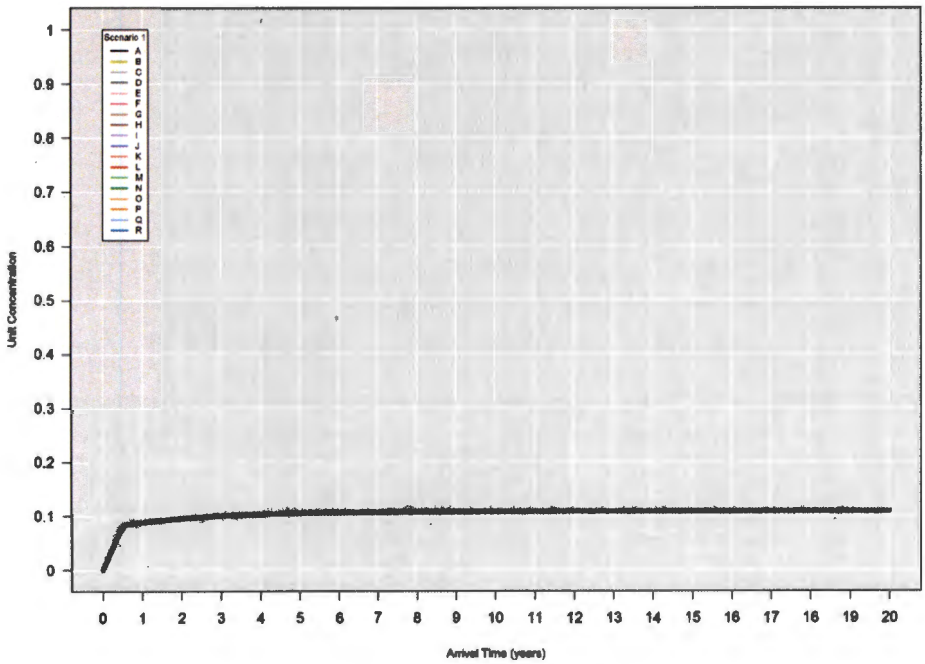

Figure 7-41. Release Concentration Breakthrough Curves at Monitoring Well 299-W23-21

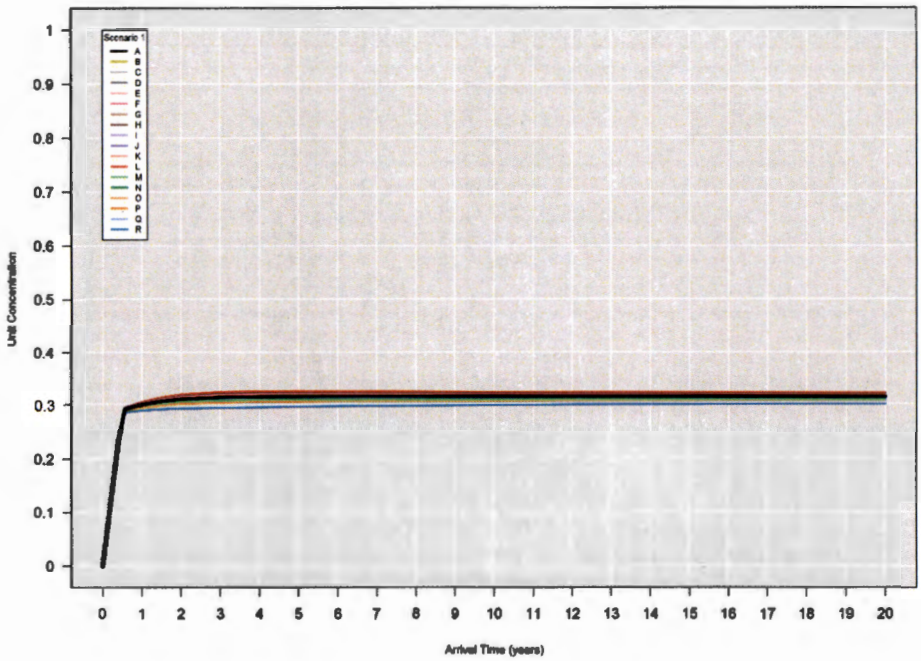

Figure 7-42. Release Concentration Breakthrough Curves at Monitoring Well 299-W23-236

7.1.3 Injected Treated Water Dilution Plumes and Release Particle Pathlines

Figures 7-43 through 7-60 depict simulated injected treated water dilution plumes, as well as the simulated pathlines, for a hypothetical water table release below WMA S-SX when considering advection and dispersion for scenario 1, sub-scenarios A through R, respectively (see Table 3-1 for scenario details). The figures represent the conditions at the end of the operation of the 200 West P&T system in 2037 and display model layer 2, which corresponds to the water table. The colored regions in the dilution plumes represent the relative fraction of injected water that is introduced at the injection wells. The dilution plume maps are interpolated and contoured in an additional post-processing step and do not show the raw output from MT3DMS.

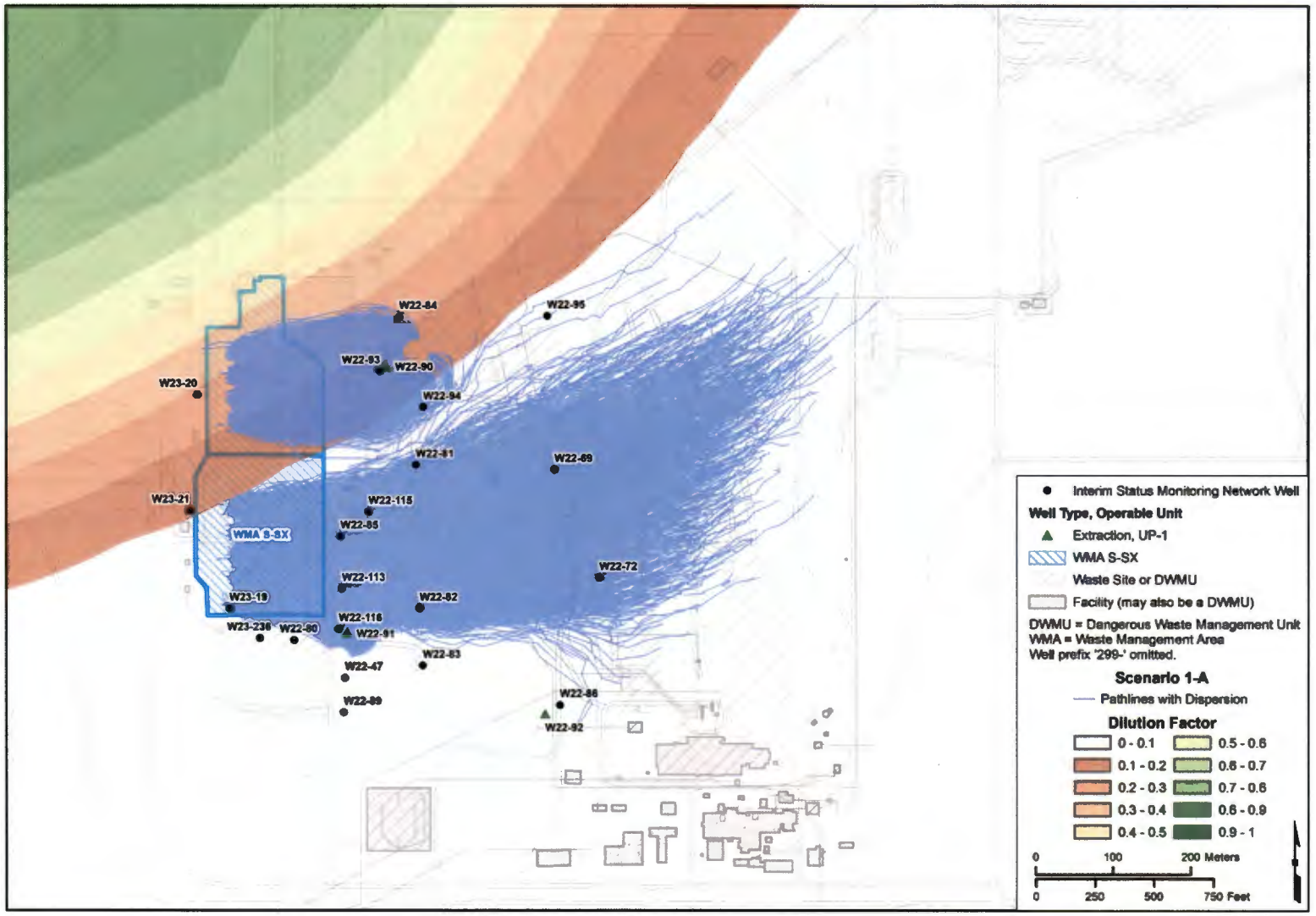

Figure 7-43. Scenario 1, Sub-scenario A Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

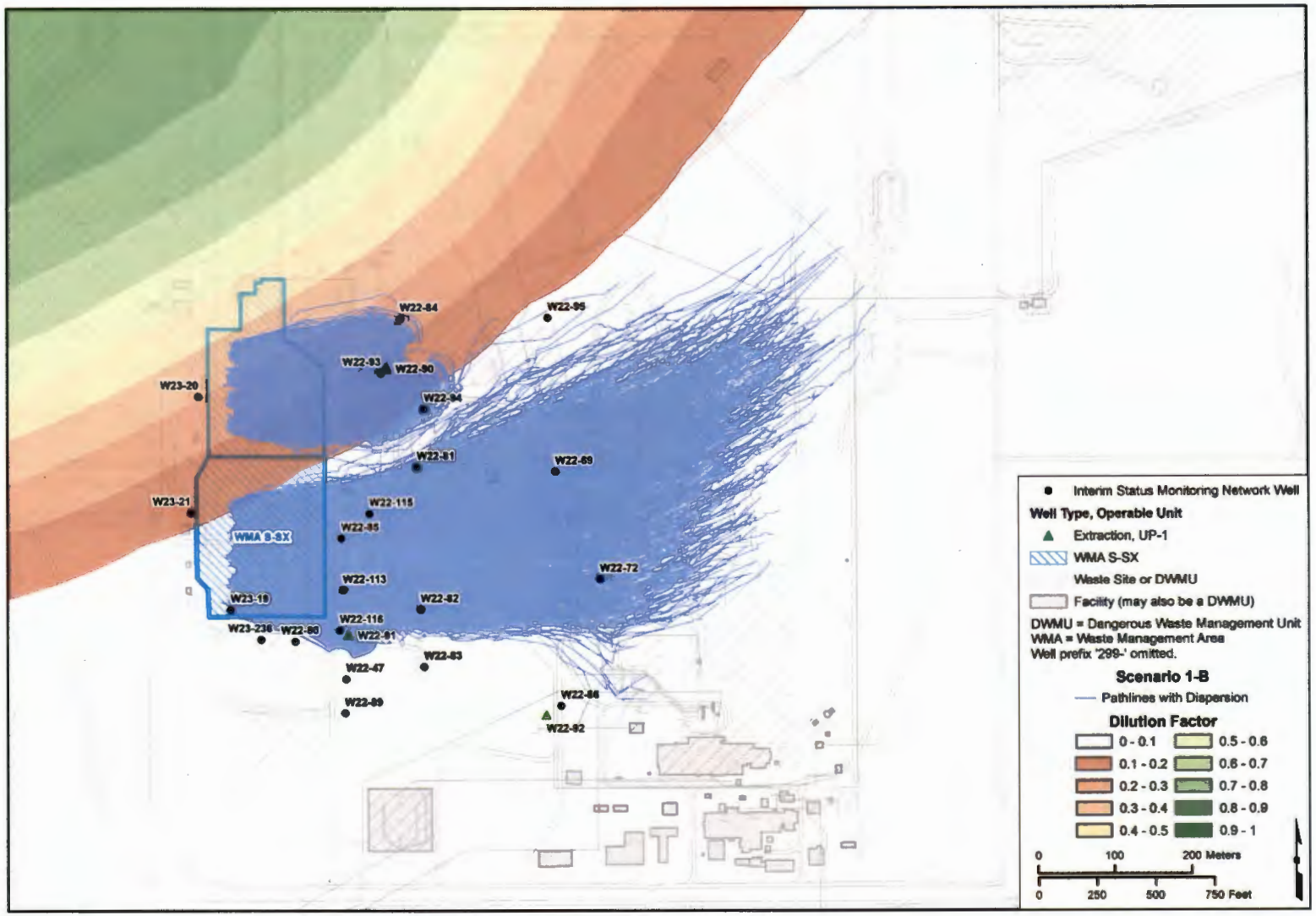

Figure 7-44. Scenario 1, Sub-scenario B Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

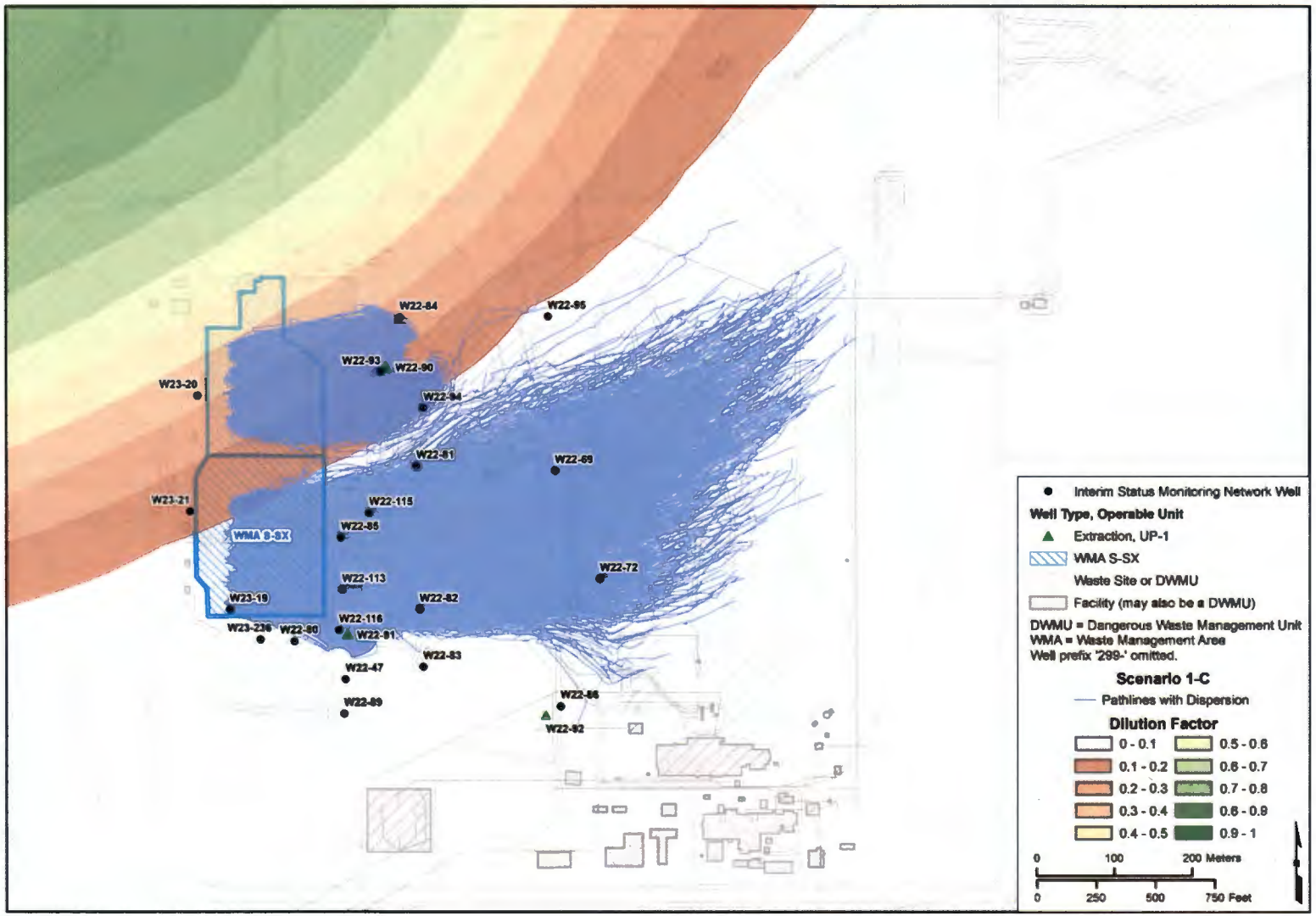

Figure 7-45. Scenario 1, Sub-scenario C Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

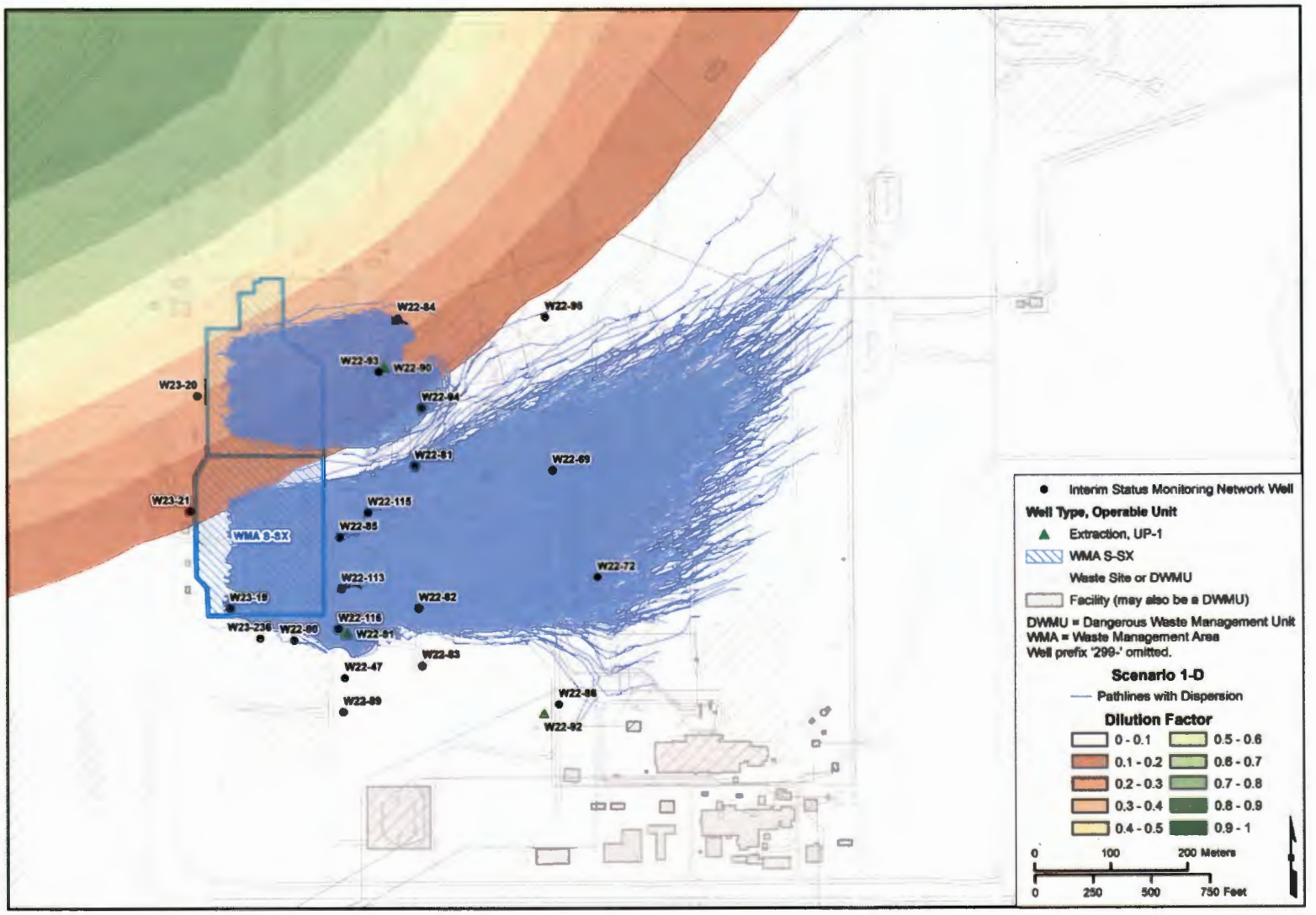

Figure 7-46. Scenario 1, Sub-scenario D Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

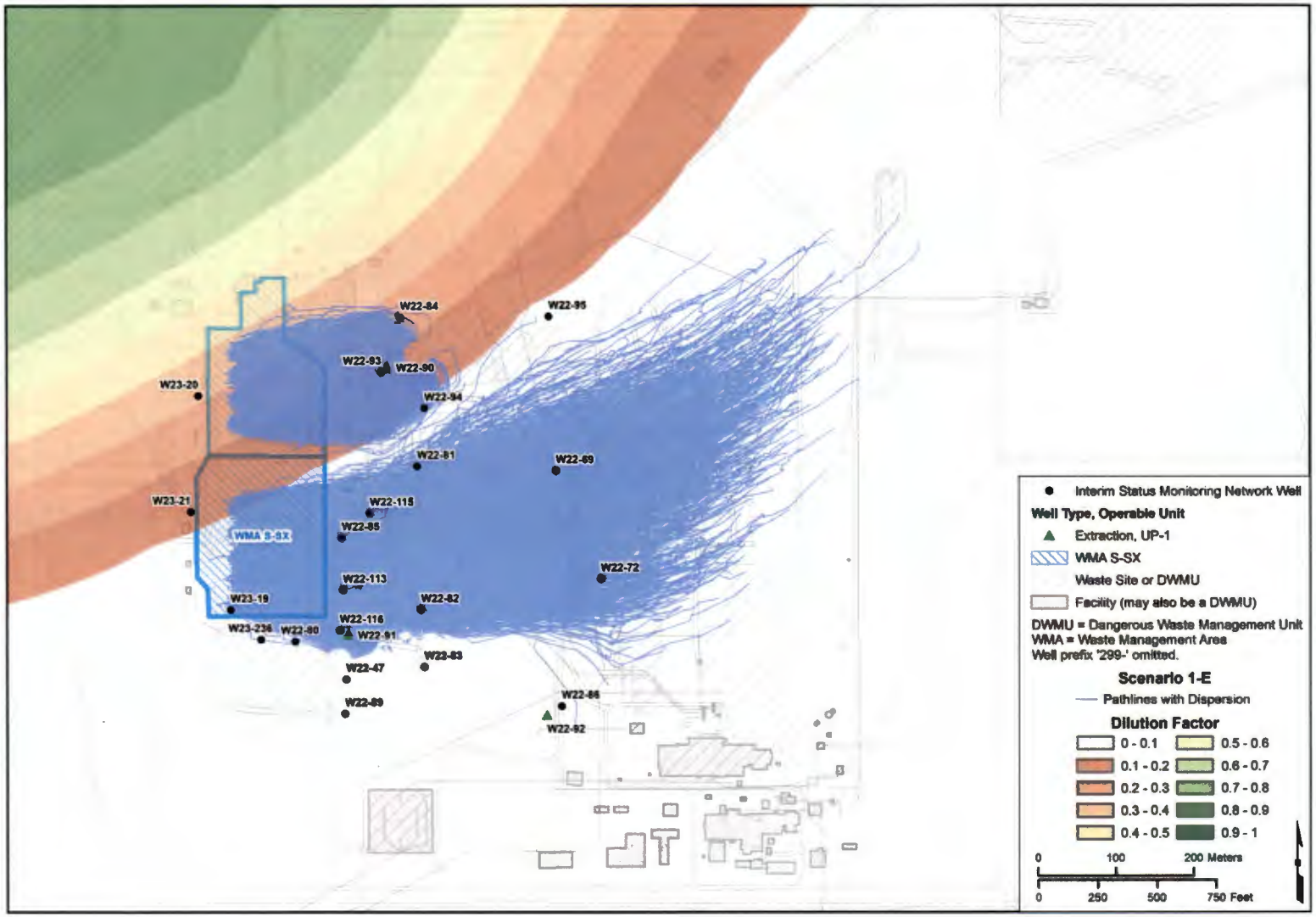

Figure 7-47. Scenario 1, Sub-scenario E Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

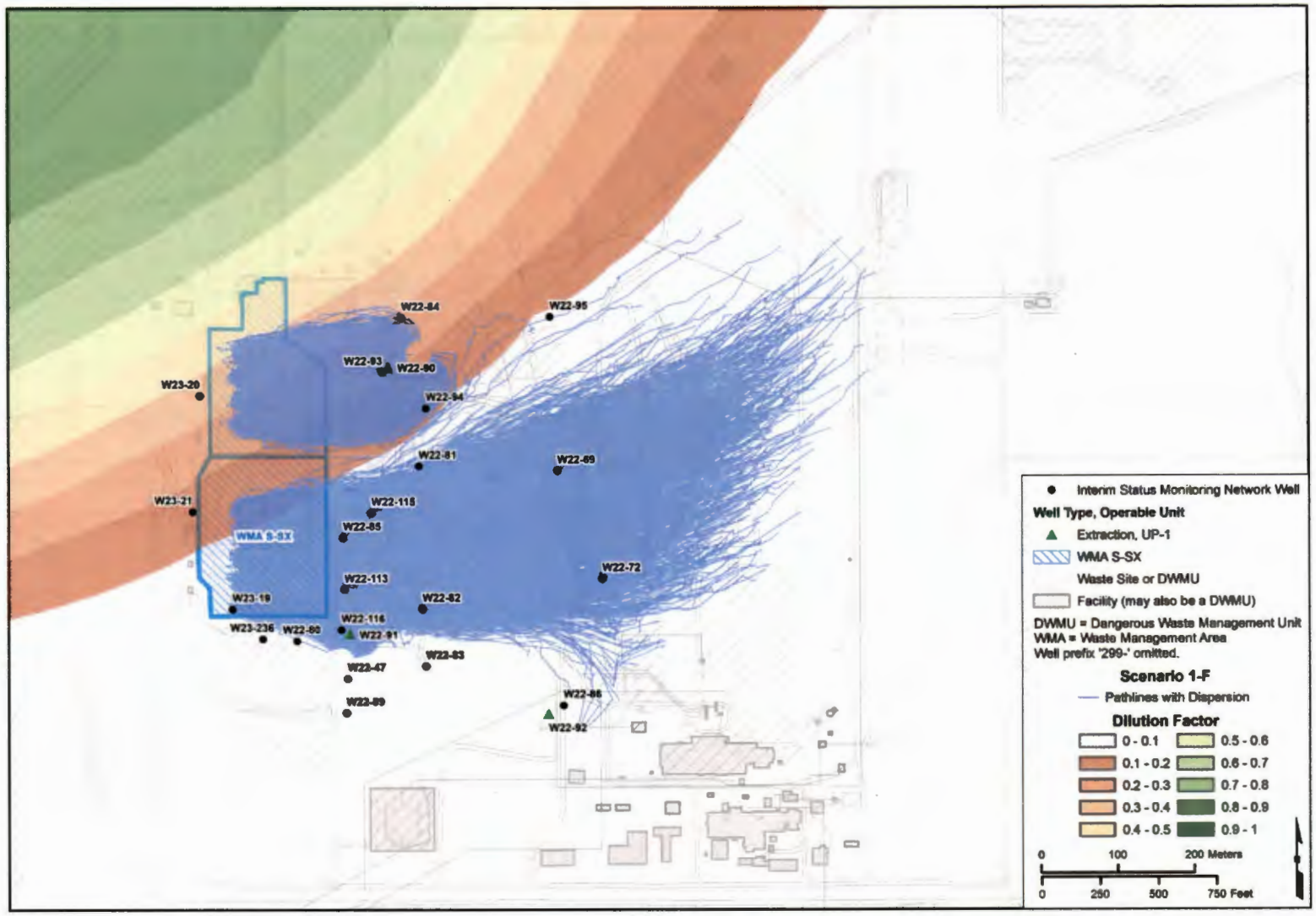

Figure 7-48. Scenario 1, Sub-scenario F Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

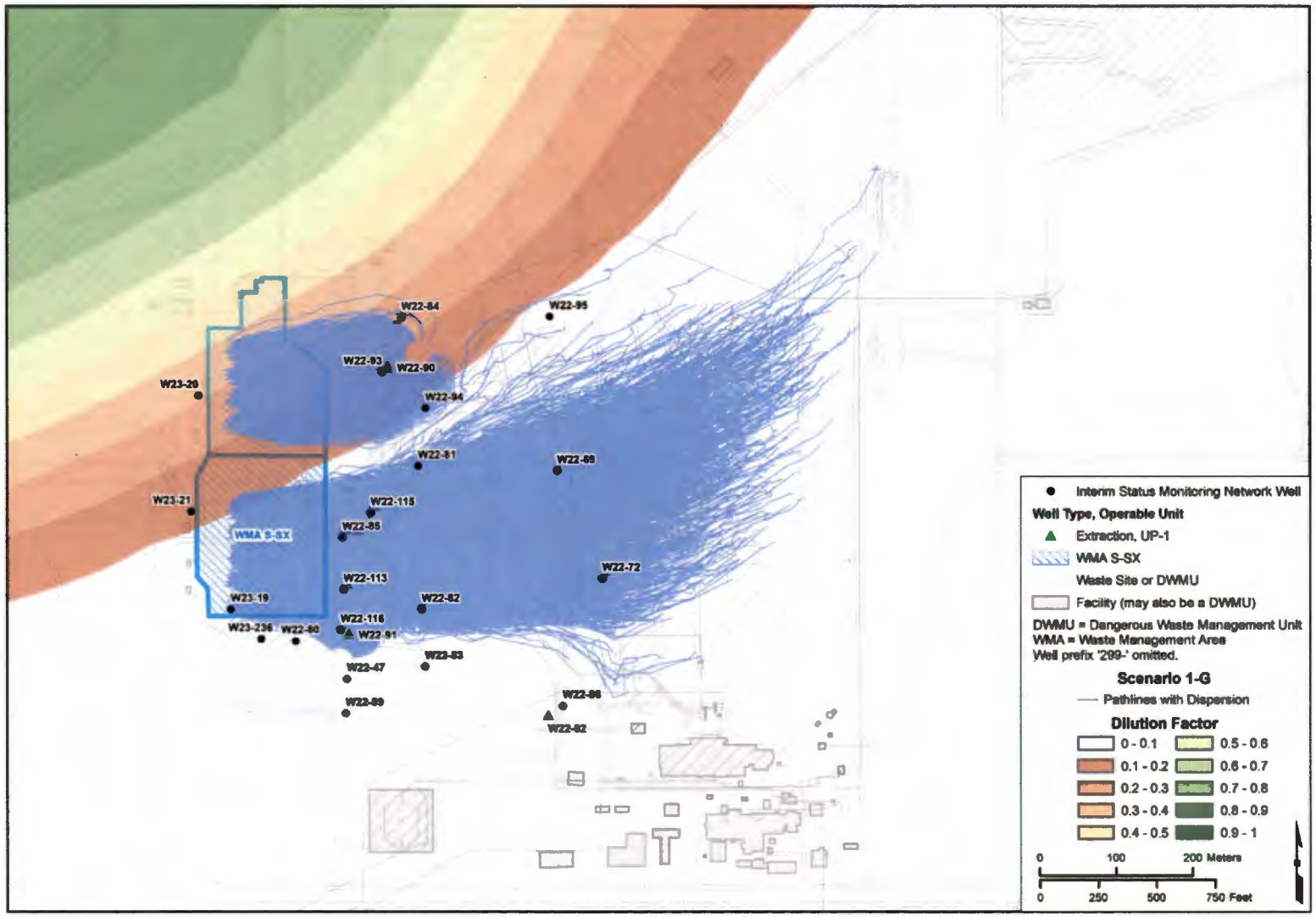

Figure 7-49. Scenario 1, Sub-scenario G Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

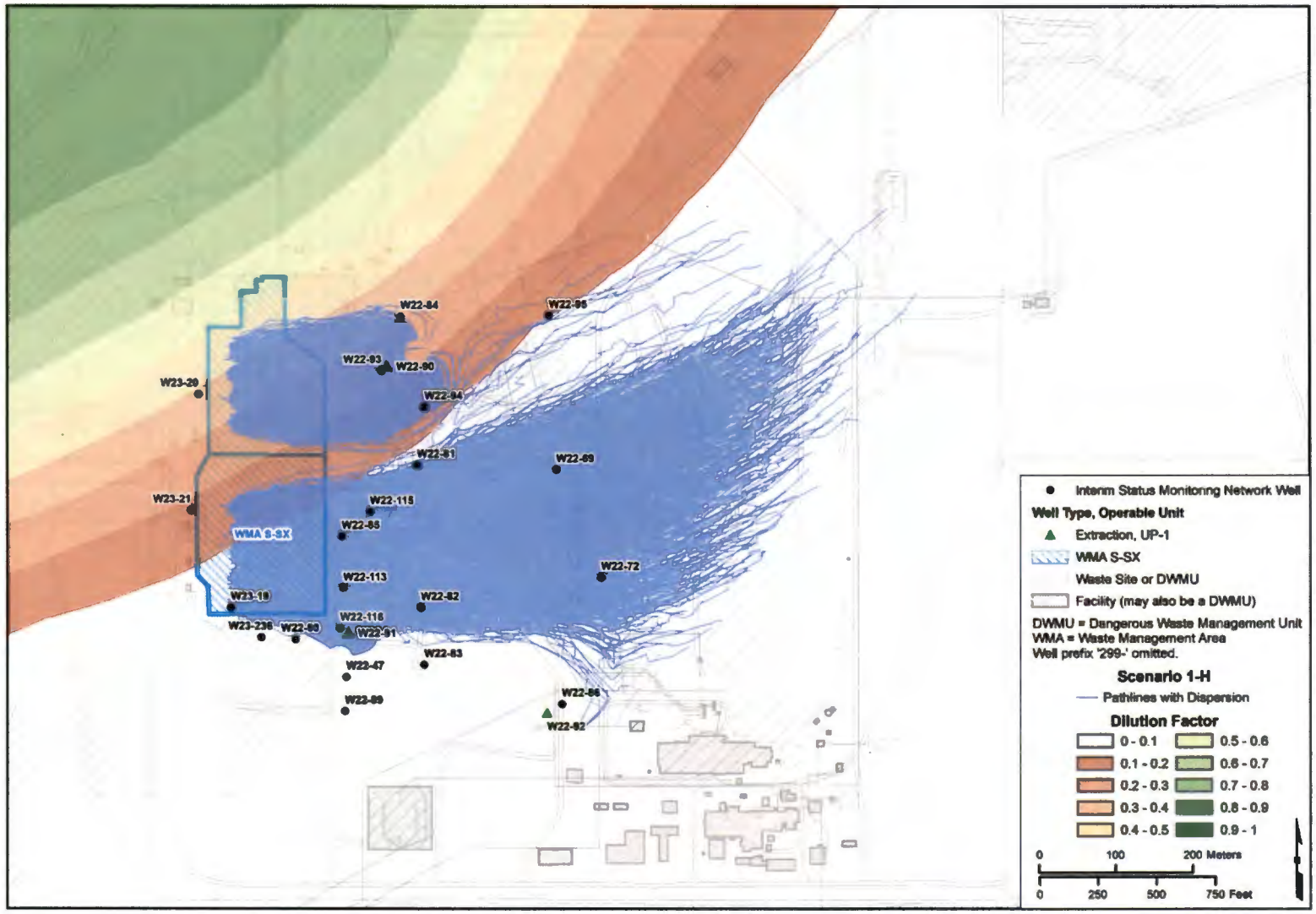

Figure 7-50. Scenario 1, Sub-scenario H Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

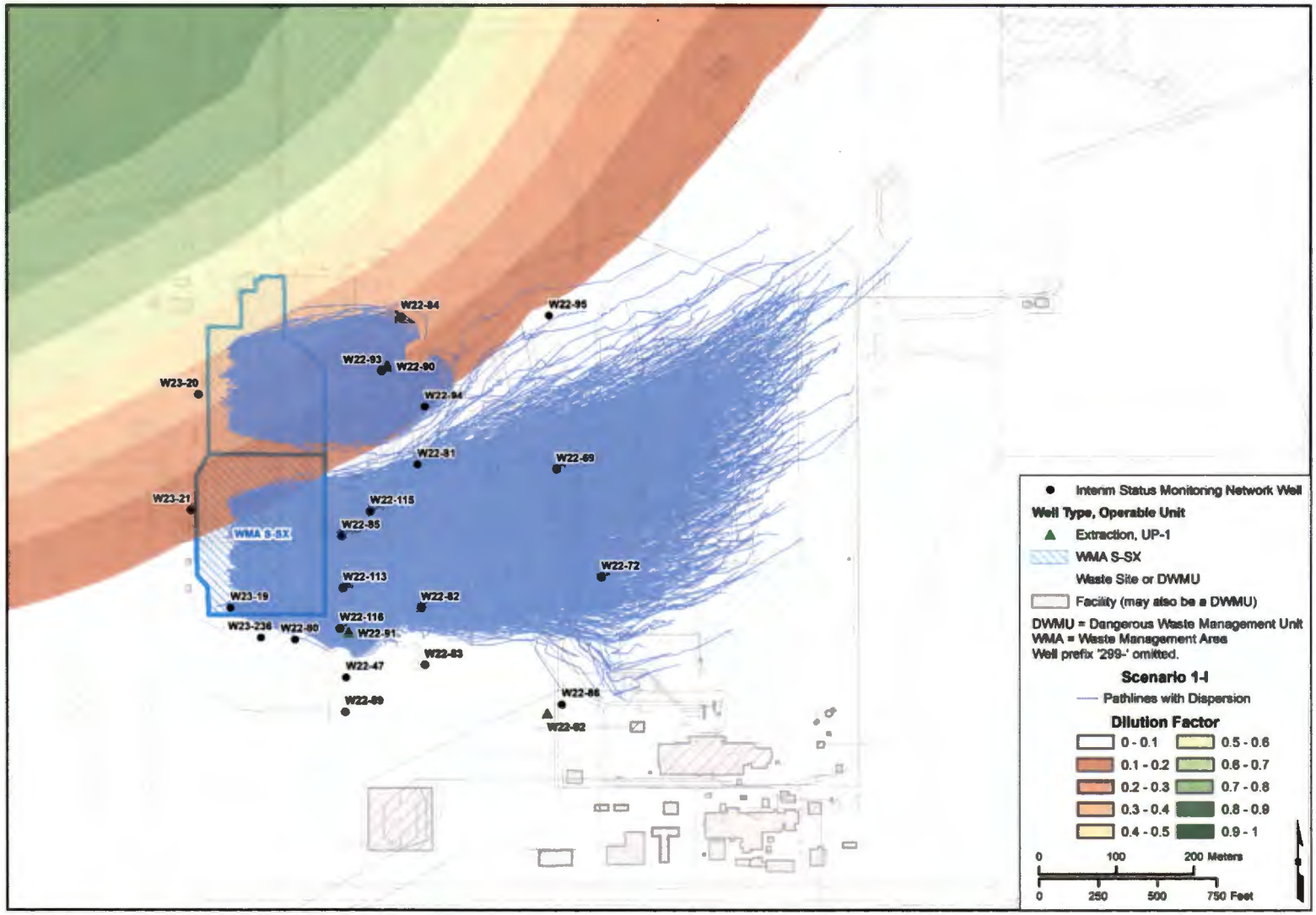

Figure 7-51. Scenario 1, Sub-scenario I Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

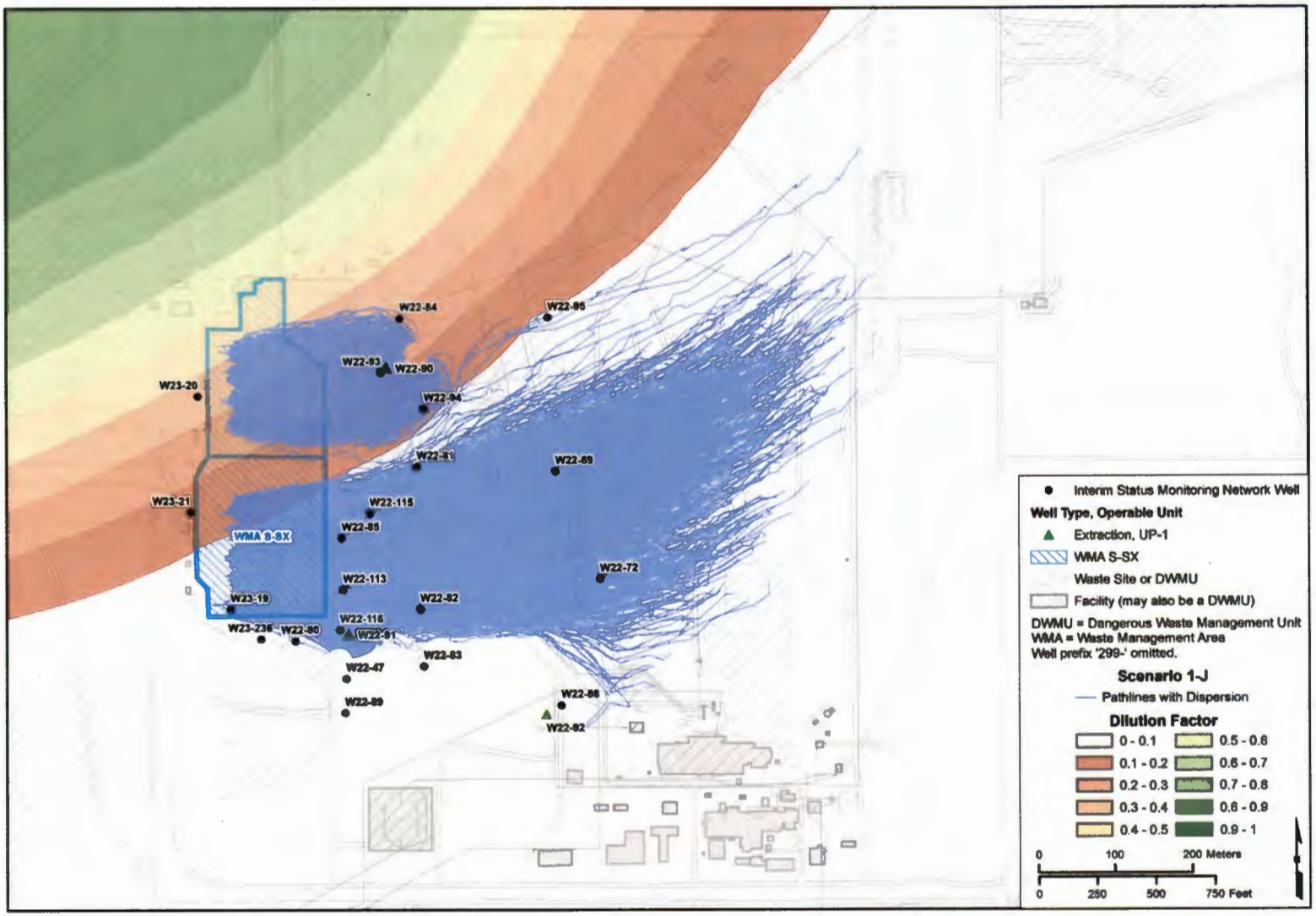

Figure 7-52. Scenario 1, Sub-scenario J Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

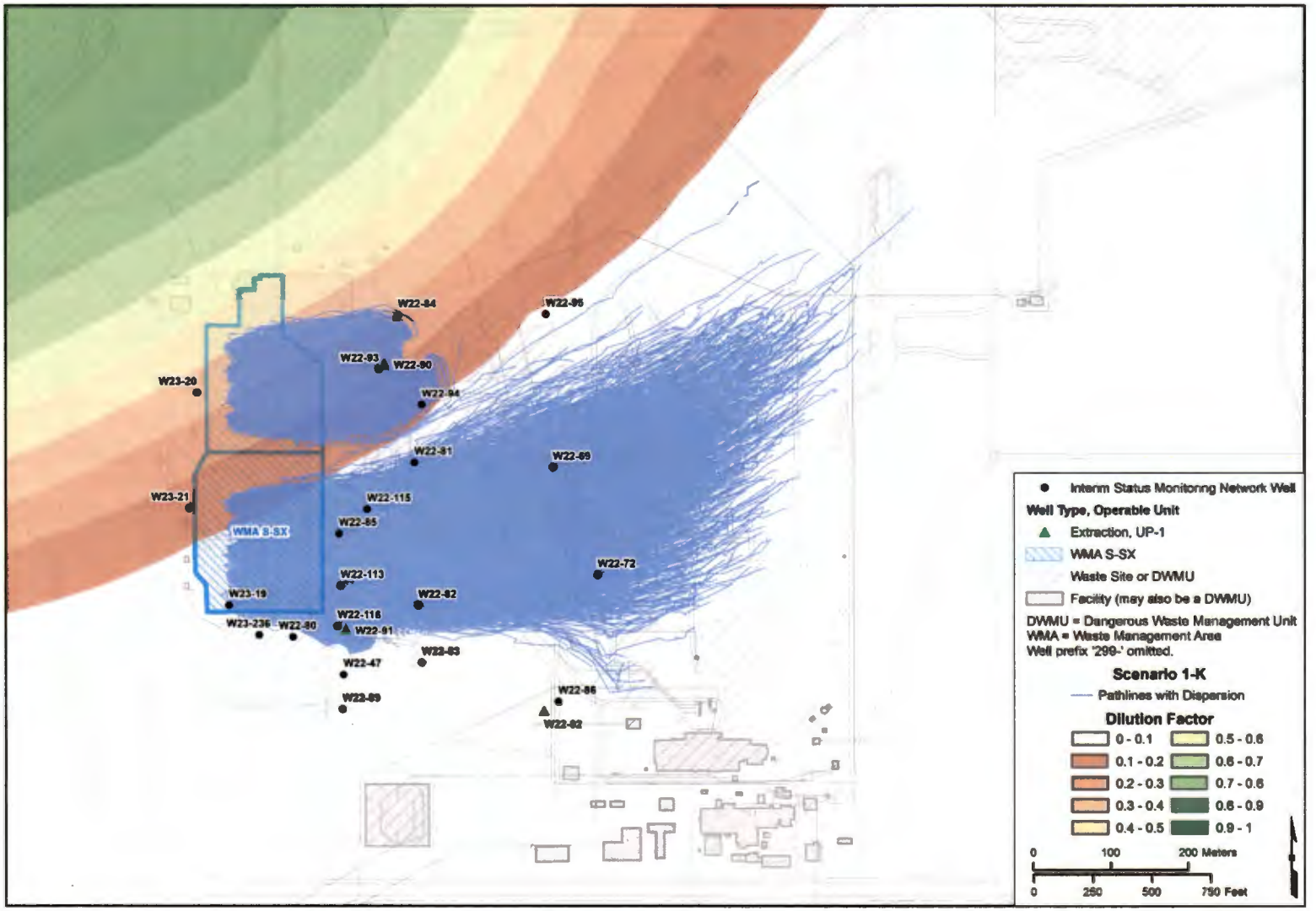

Figure 7-53. Scenario 1, Sub-scenario K Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

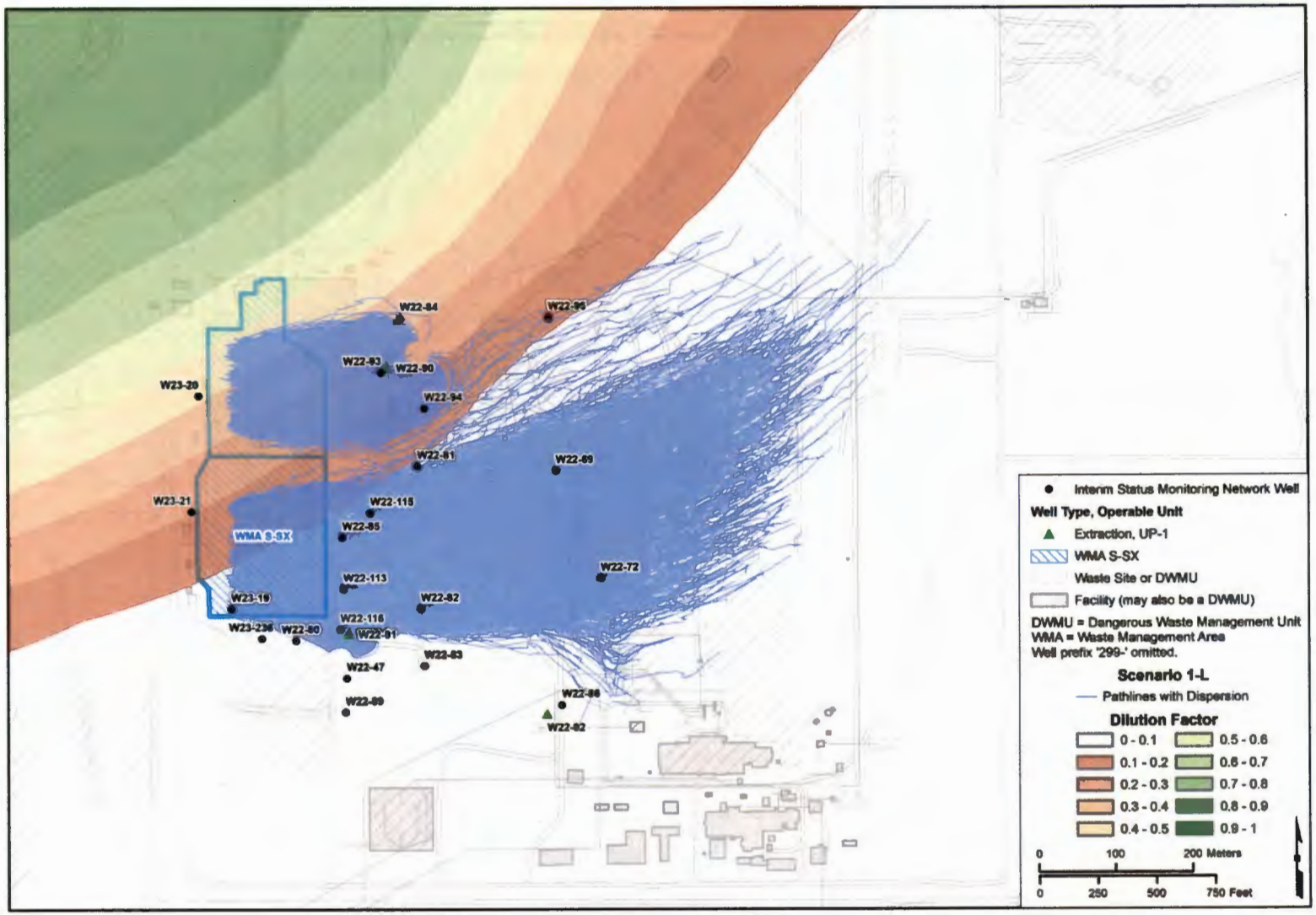

Figure 7-54. Scenario 1, Sub-scenario L Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

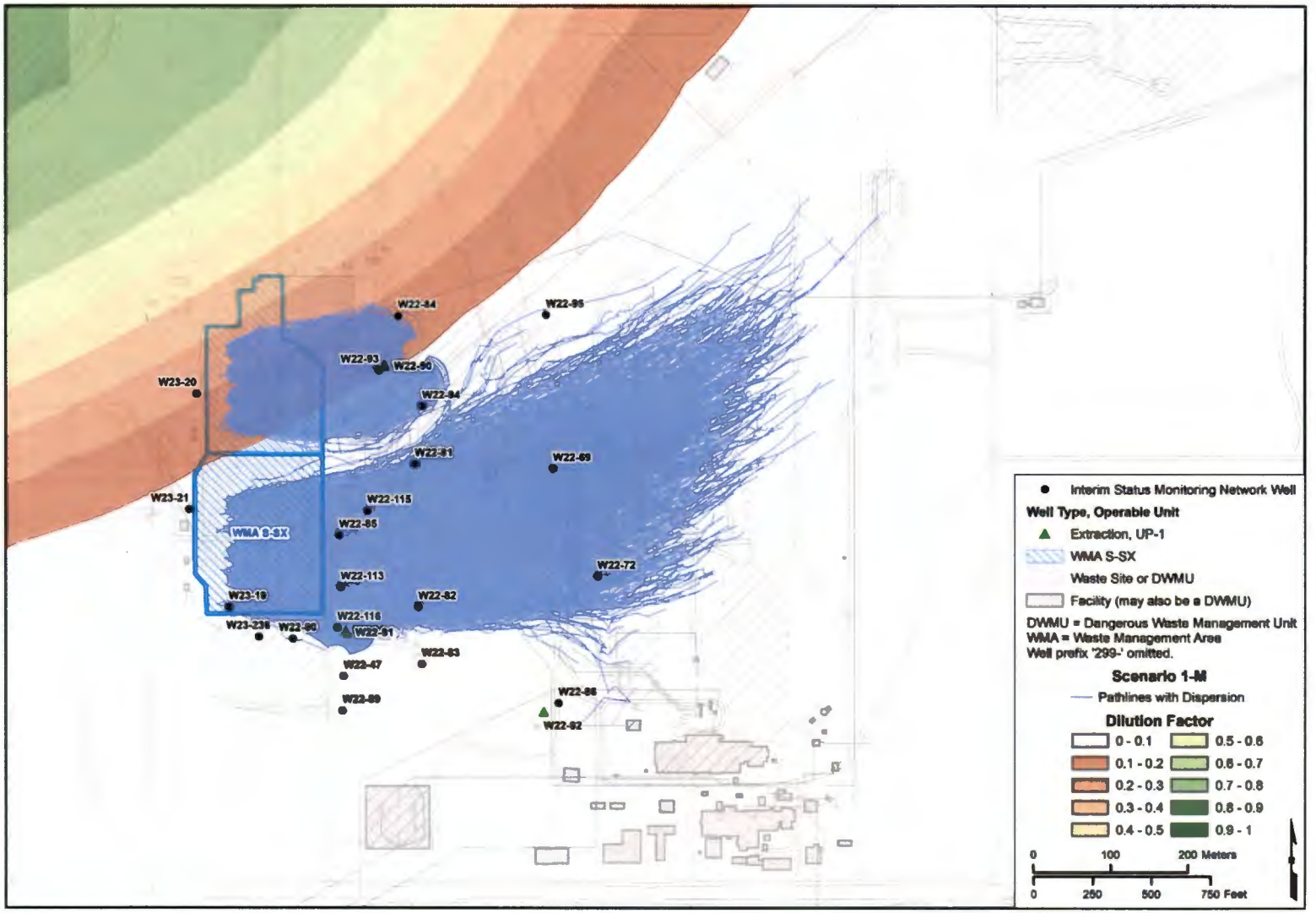

Figure 7-55. Scenario 1, Sub-scenario M Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

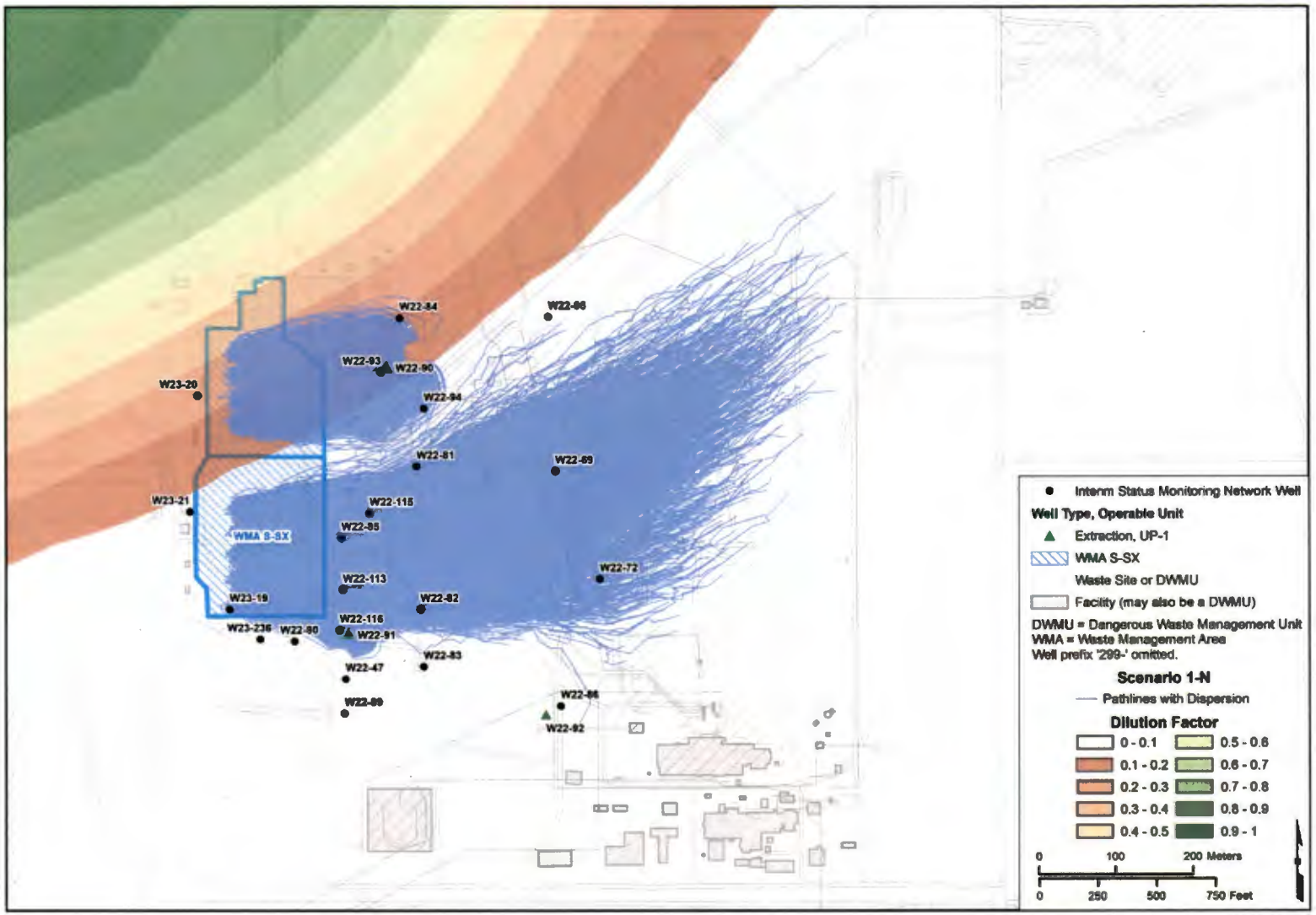

Figure 7-56. Scenario 1, Sub-scenario N Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

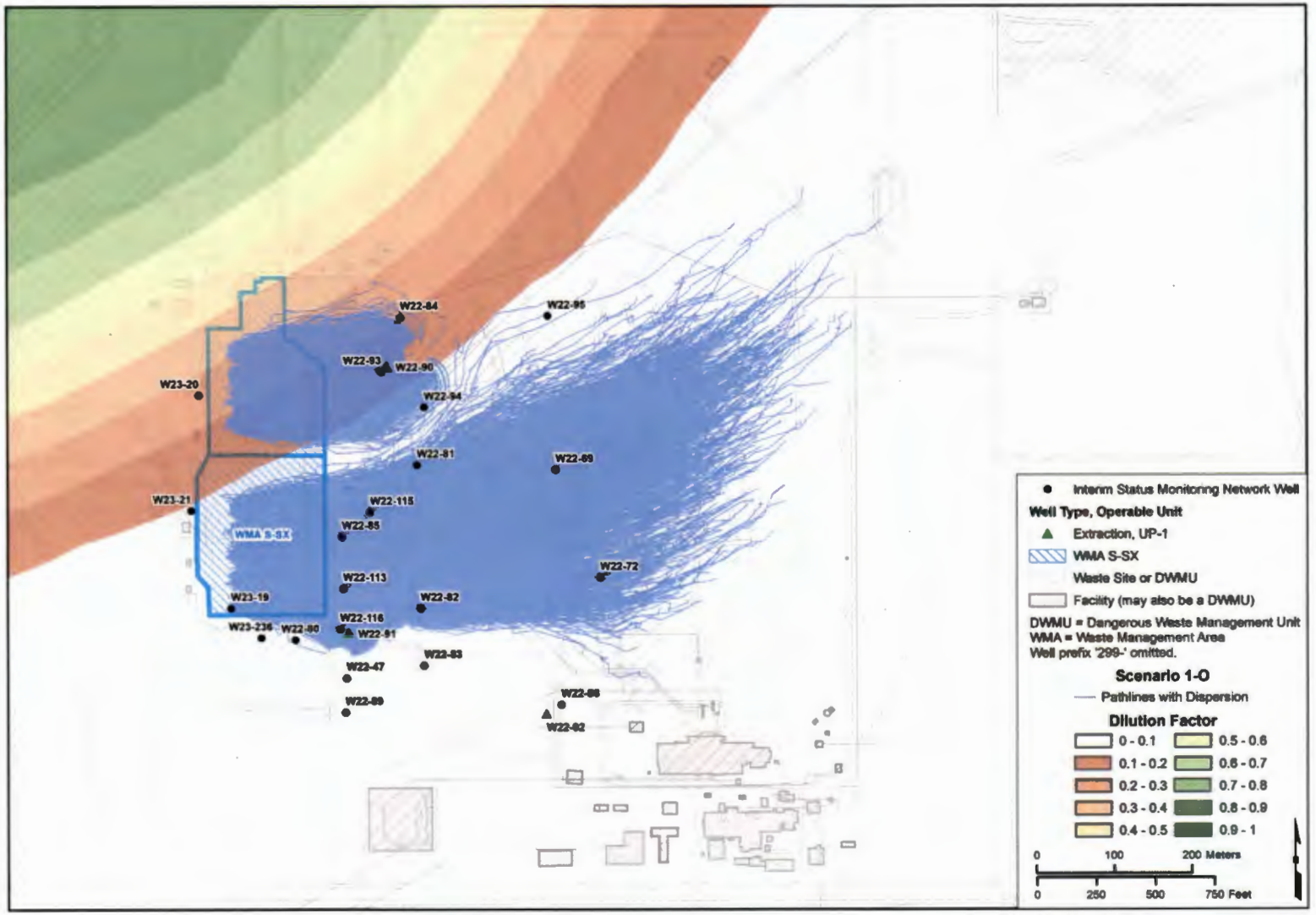

Figure 7-57. Scenario 1, Sub-scenario O Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

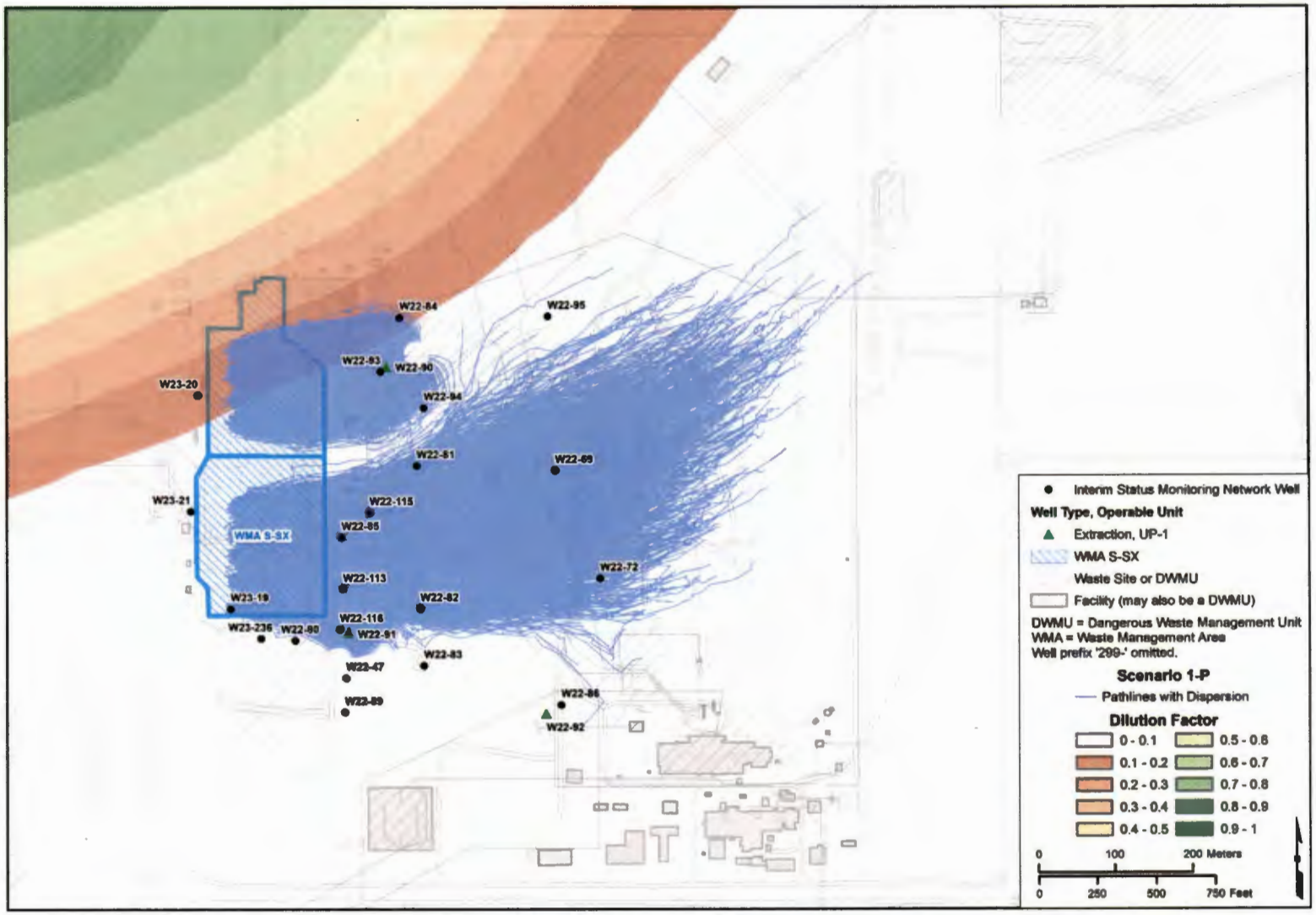

Figure 7-58. Scenario 1, Sub-scenario P Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

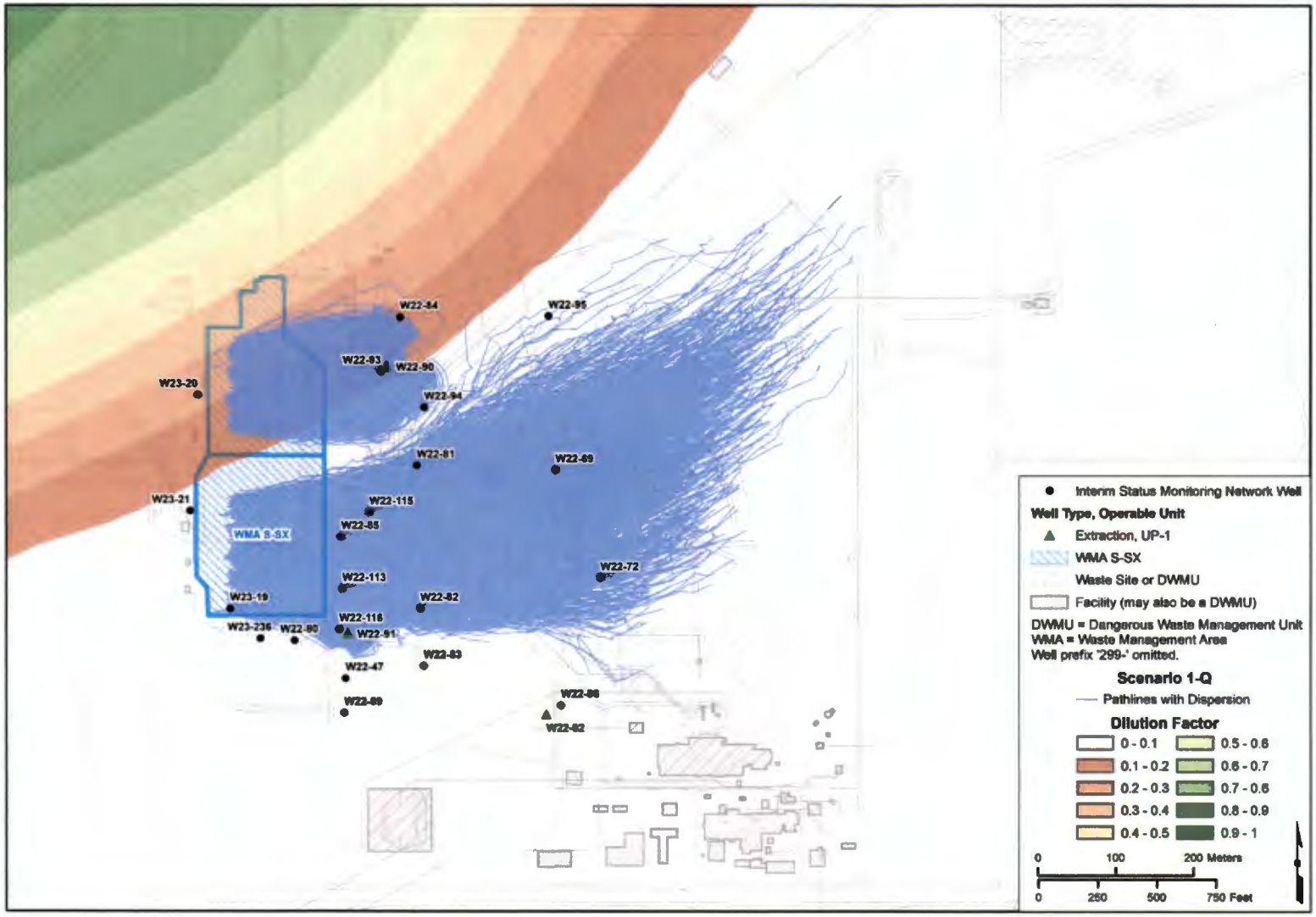

Figure 7-59. Scenario 1, Sub-scenario Q Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

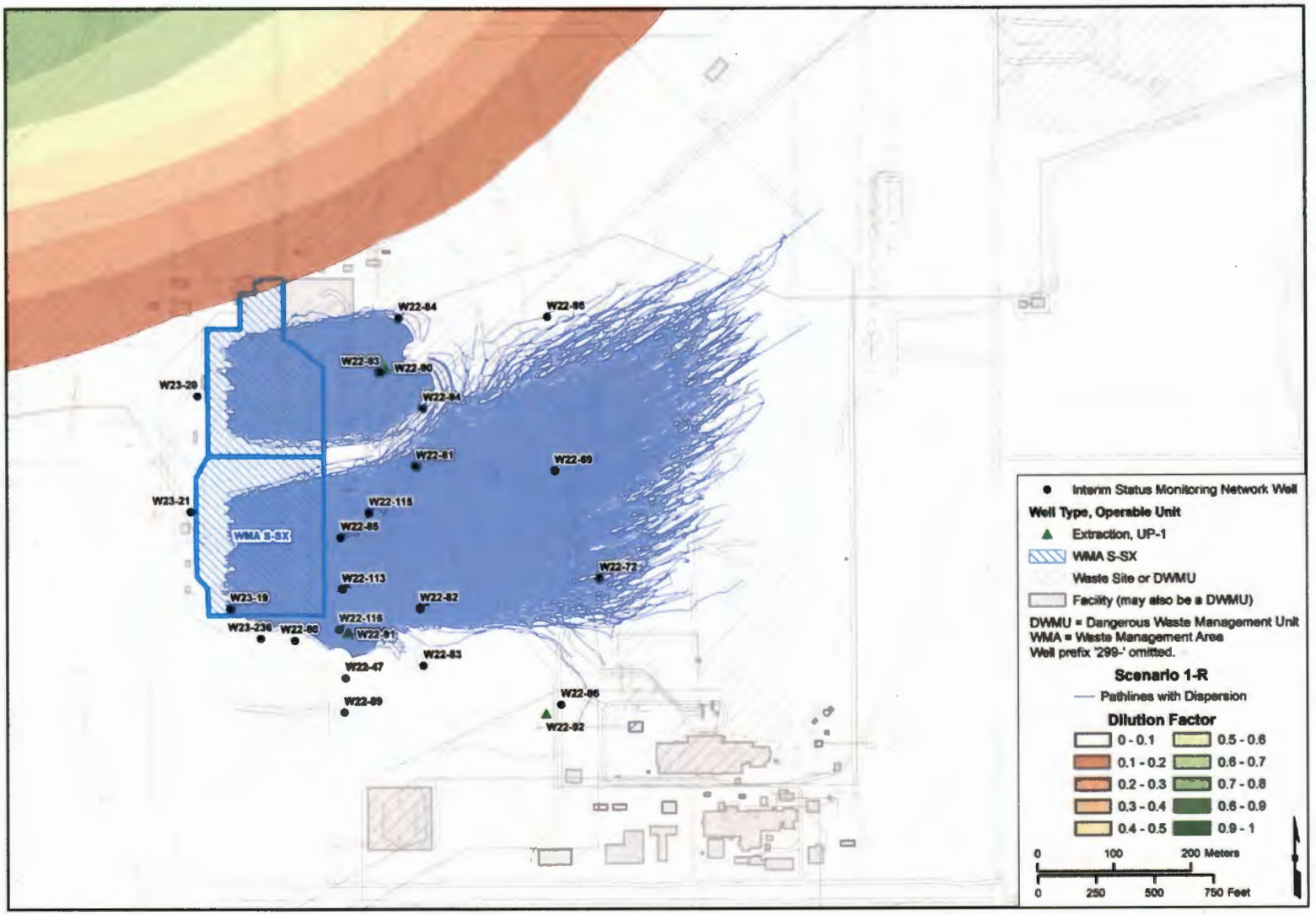

Figure 7-60. Scenario 1, Sub-scenario R Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

7.2 Scenario 2

The injected treated water dilution breakthrough curves, release concentration breakthrough curves, and particle-tracking results superimposed on injected treated water dilution plumes for scenario 2 are presented in the following sections.

7.2.1 Injected Treated Water Dilution Breakthrough Curves

Figures 7-61 through 7-81 depict the simulated breakthrough at wells 299-W22-47, 299-W22-69, 299-W22-72, 299-W22-80, 299-W22-81, 299-W22-82, 299-W22-83, 299-W22-84, 299-W22-85, 299-W22-86, 299-W22-89, 299-W22-93, 299-W22-94, 299-W22-95, 299-W22-113, 299-W22-115, 299-W22-116, 299-W23-19, 299-W23-20, 299-W23-21, and 299-W23-236, respectively, of a unit concentration representing treated water injected at the injection wells. The injection time corresponds to the CY 2012 startup of the 200 West P&T system. The bold black line on the figures represents sub-scenario A, which reflects the most likely operating conditions.

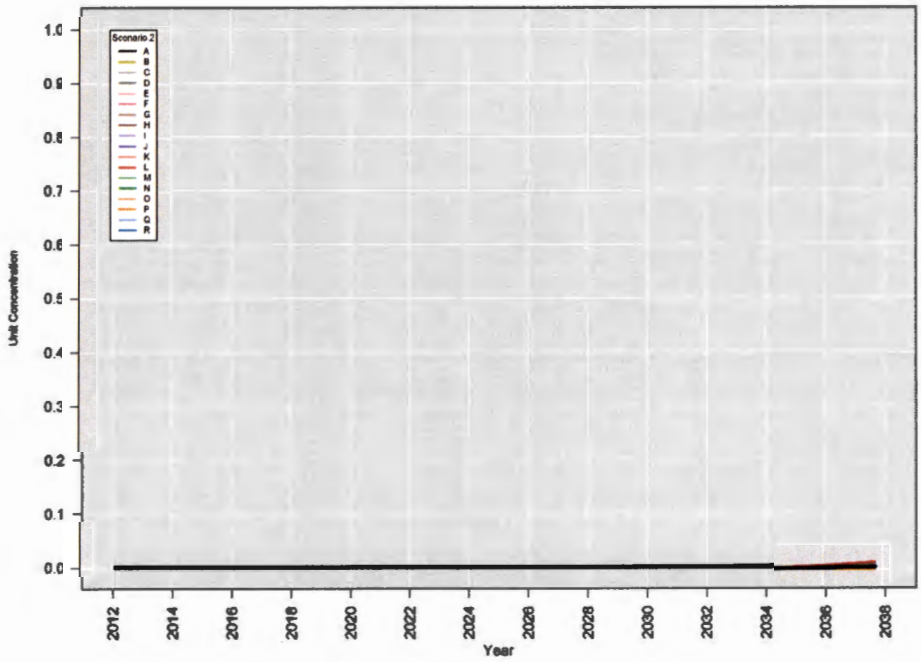

Figure 7-61. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-47

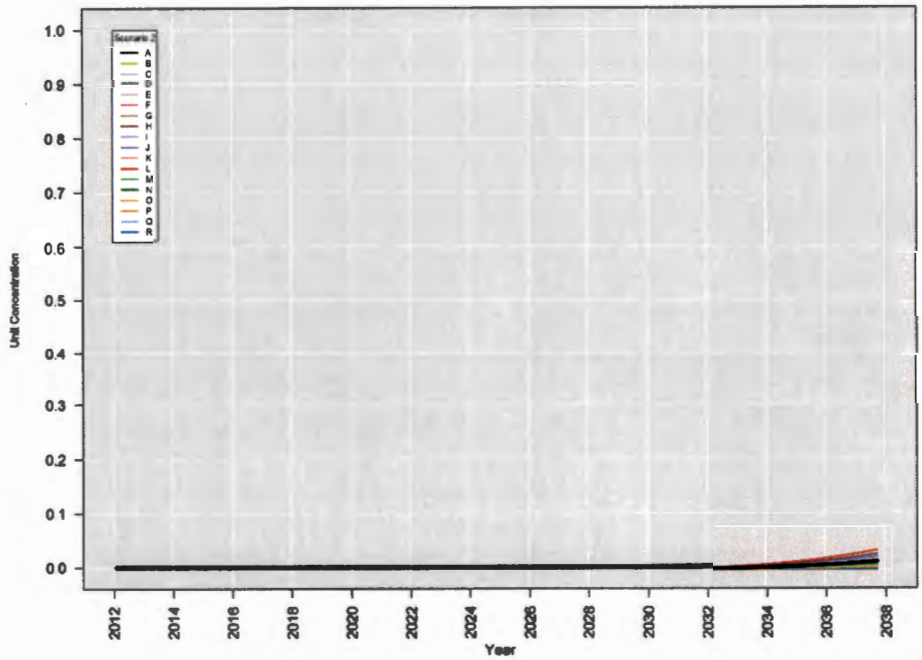

Figure 7-62. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-69

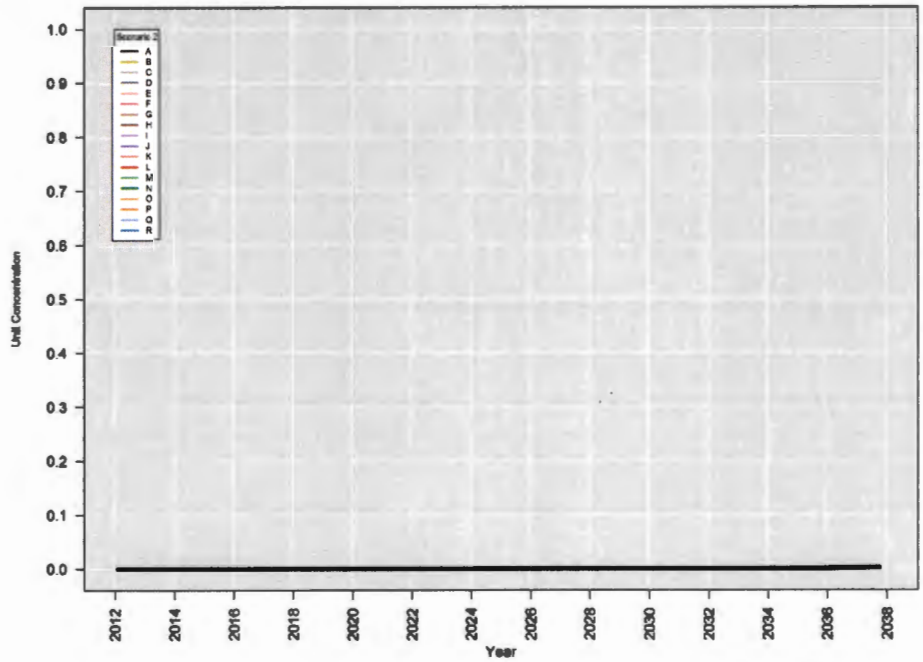

Figure 7-63. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-72

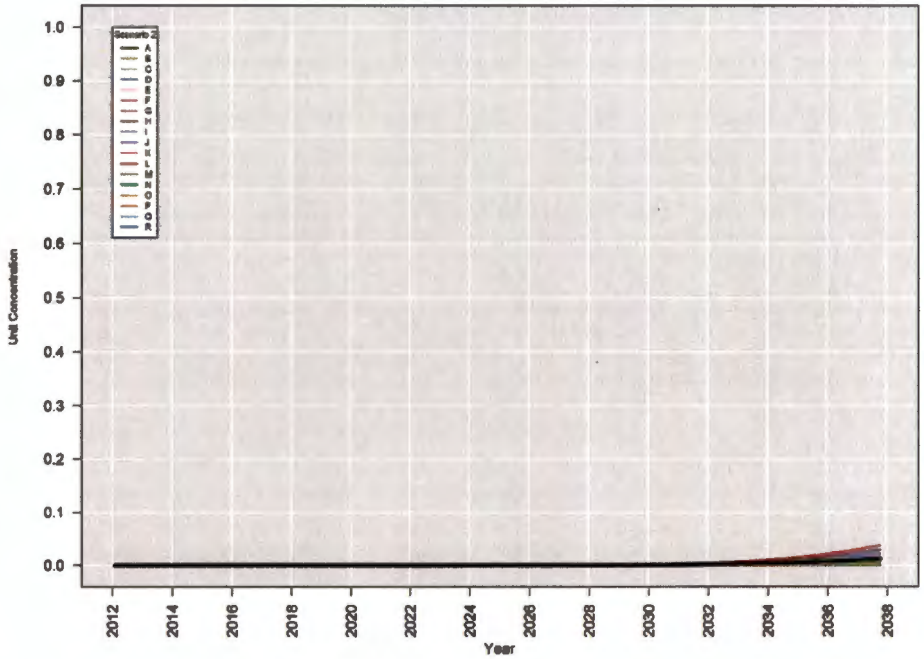

Figure 7-64. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-80

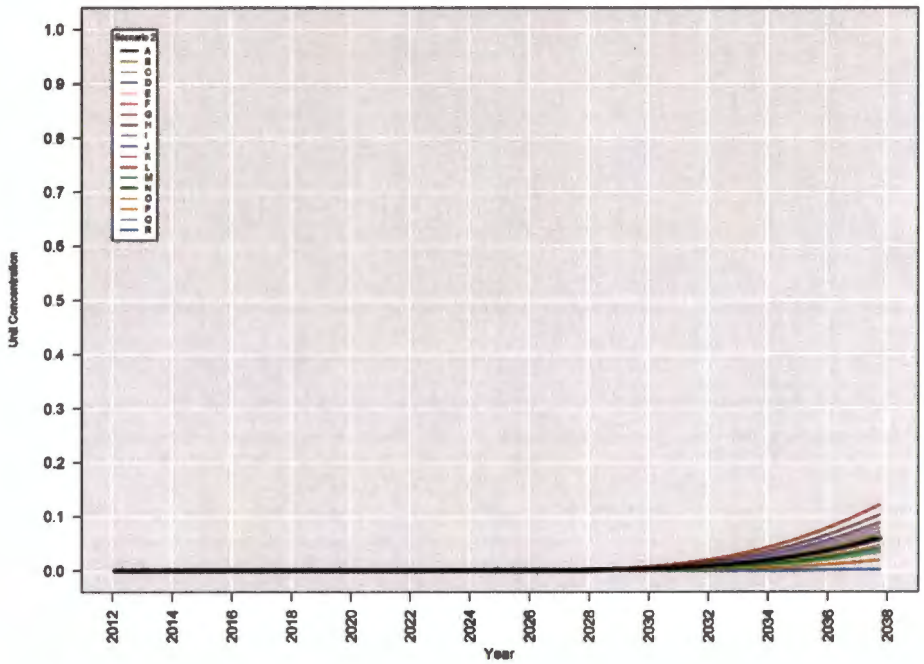

Figure 7-65. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-81

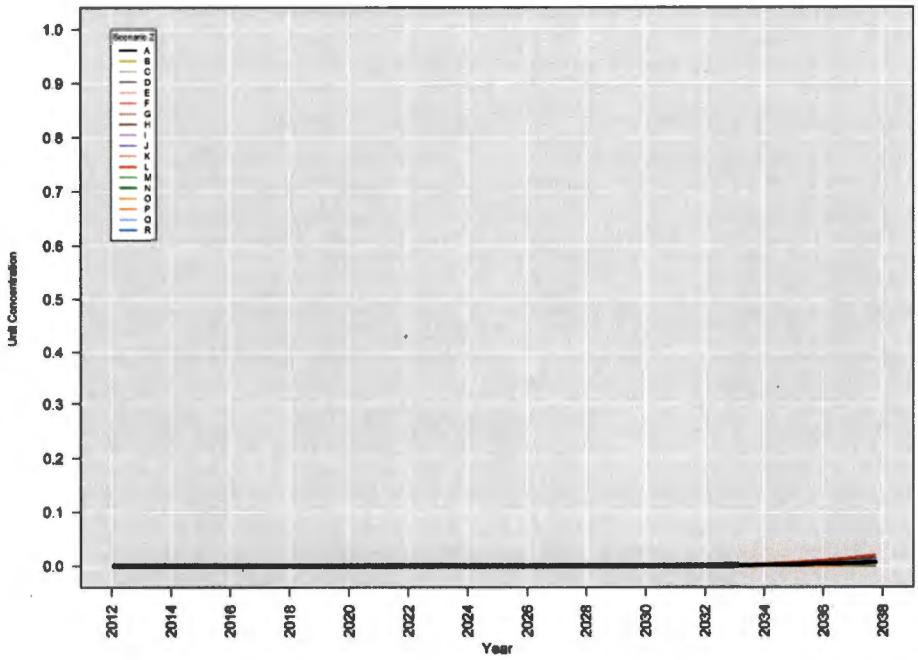

Figure 7-66. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-82

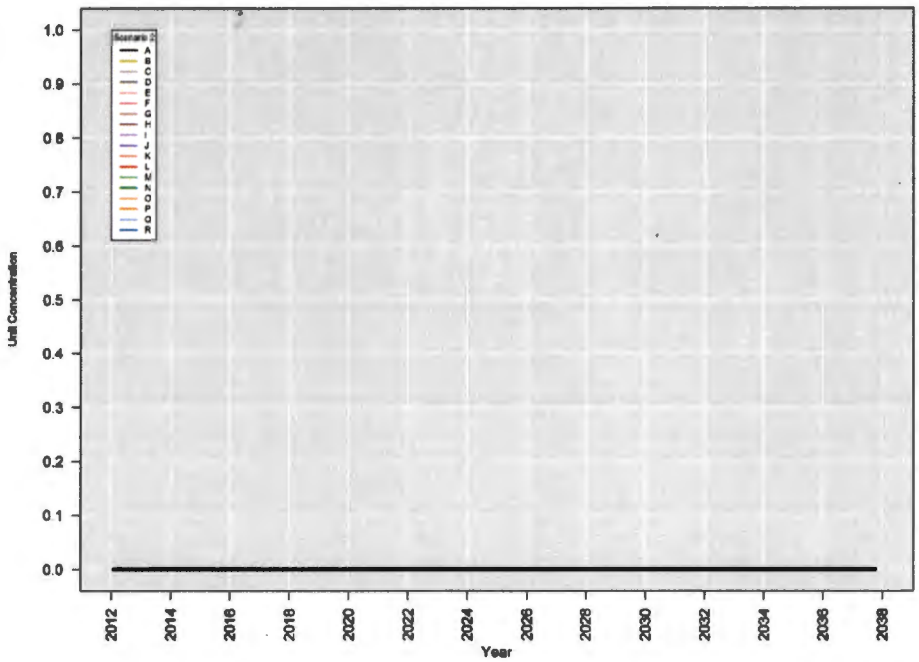

Figure 7-67. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-83

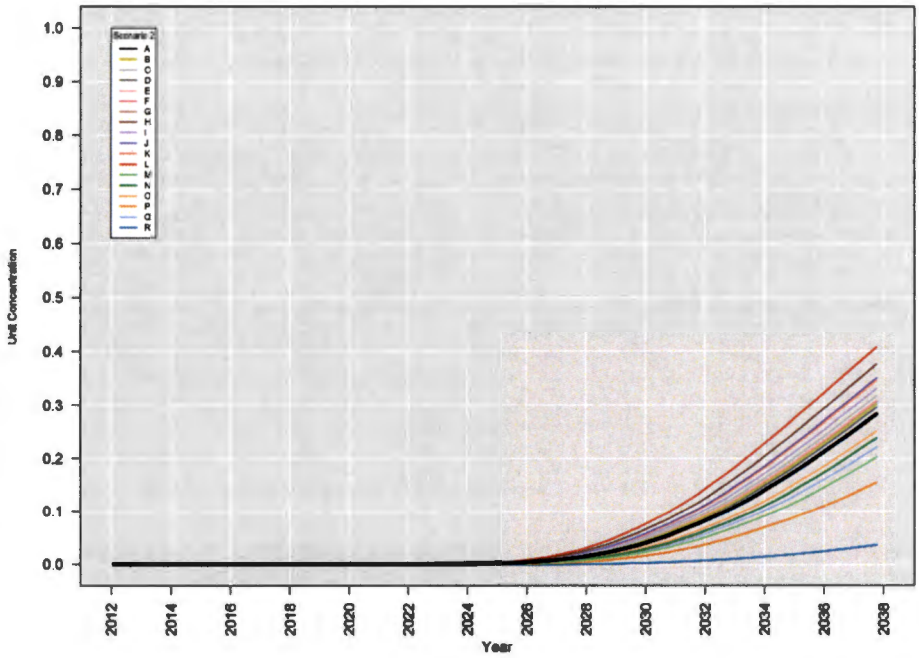

Figure 7-68. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-84

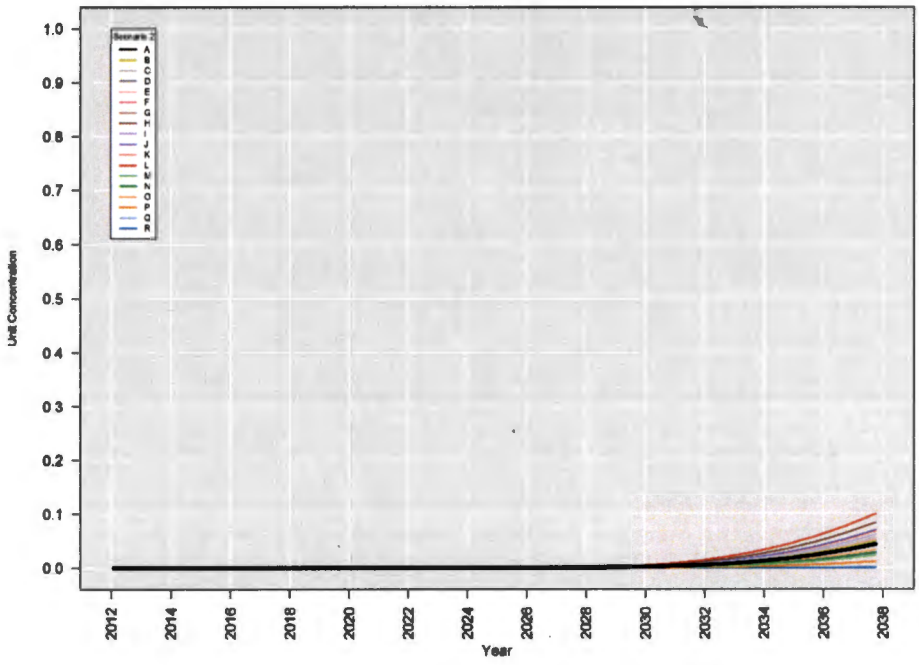

Figure 7-69. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-85

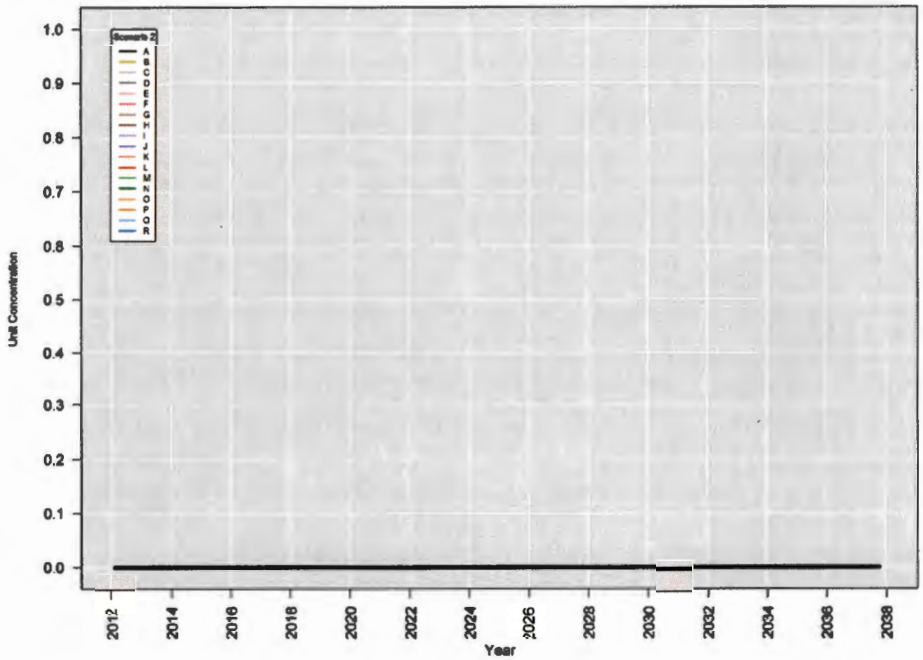

Figure 7-70. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-86

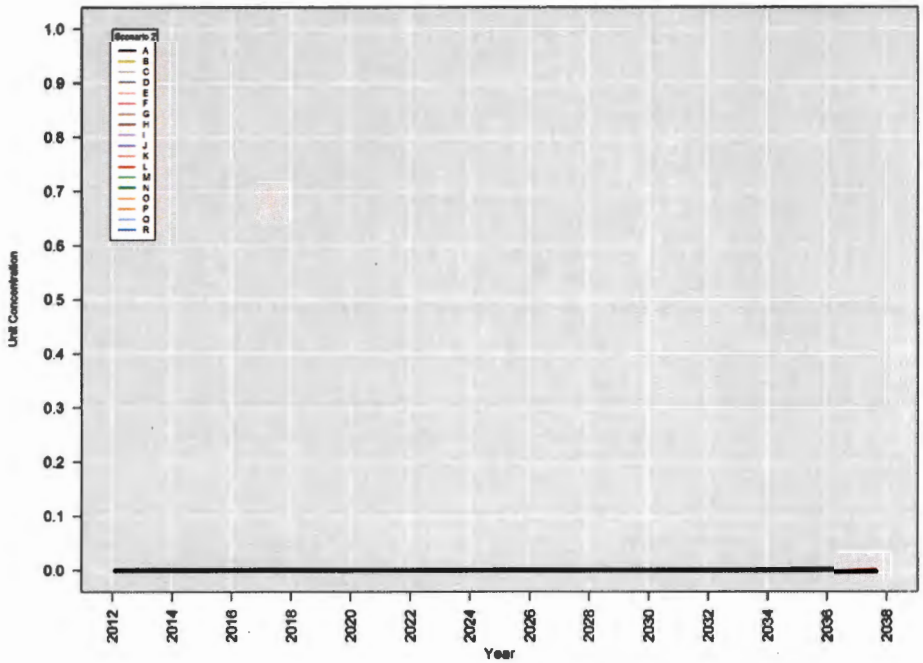

Figure 7-71. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-89

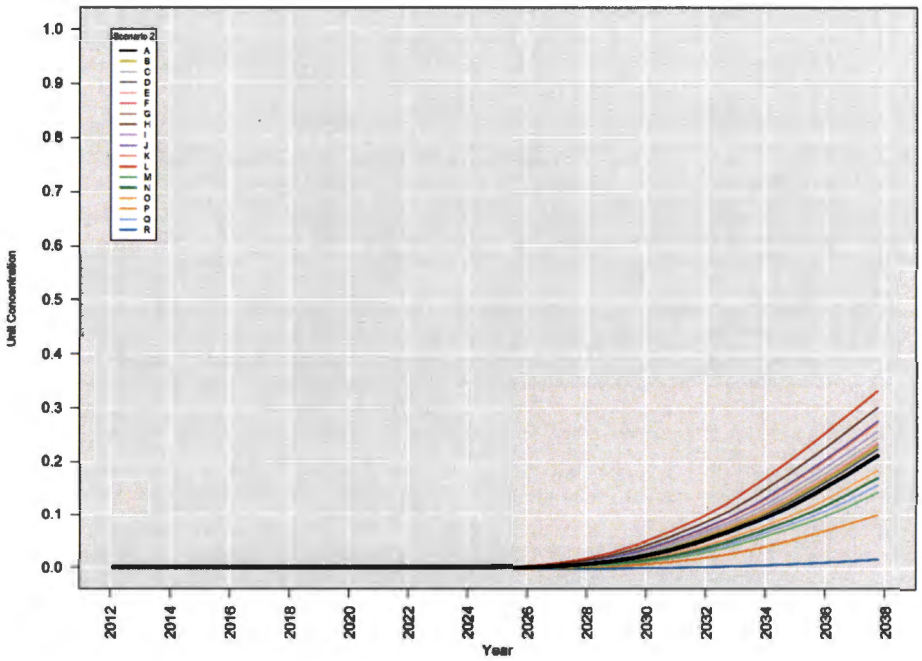

Figure 7-72. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-93

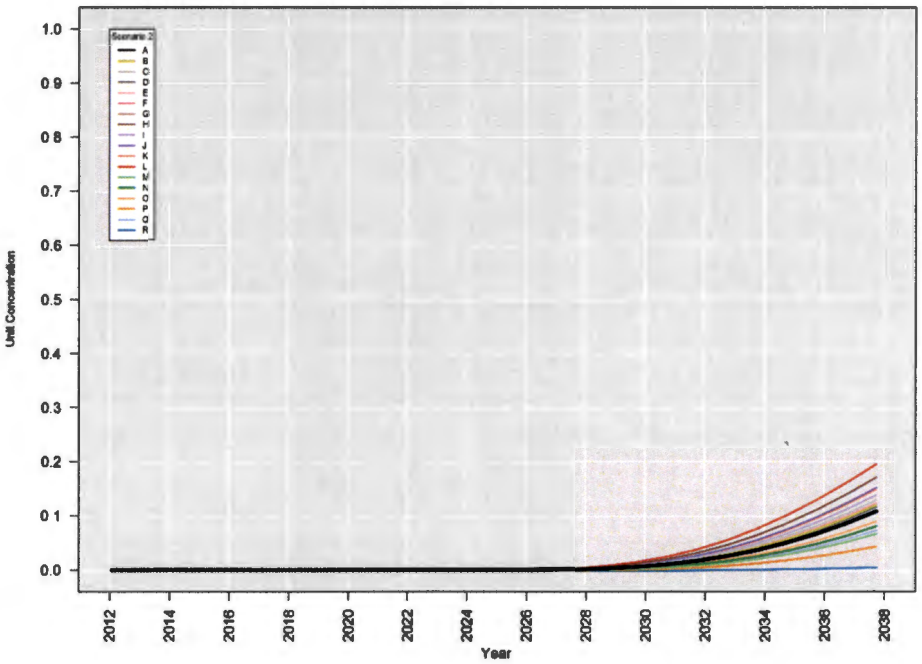

Figure 7-73. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-94

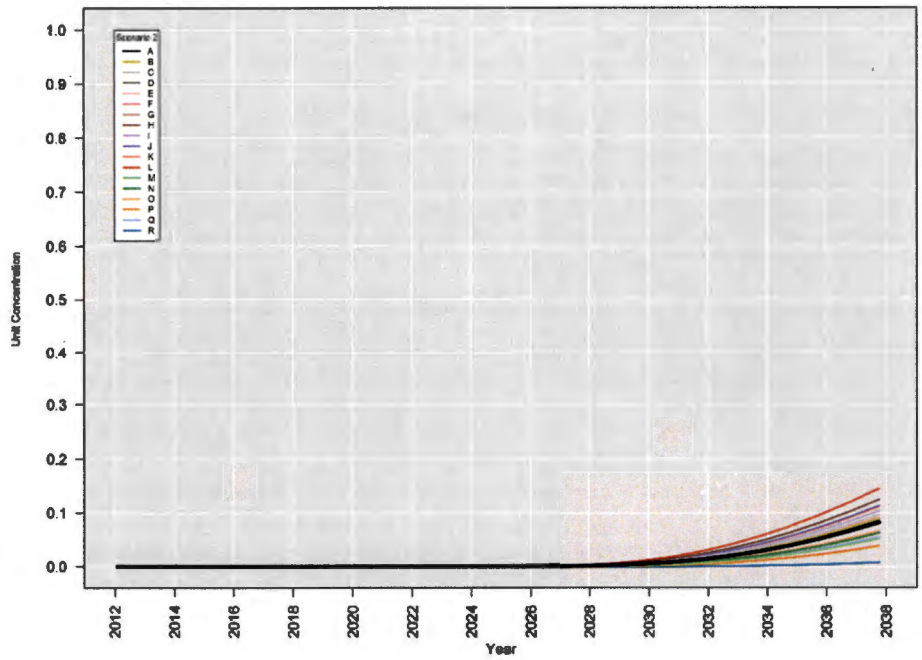

Figure 7-74. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-95

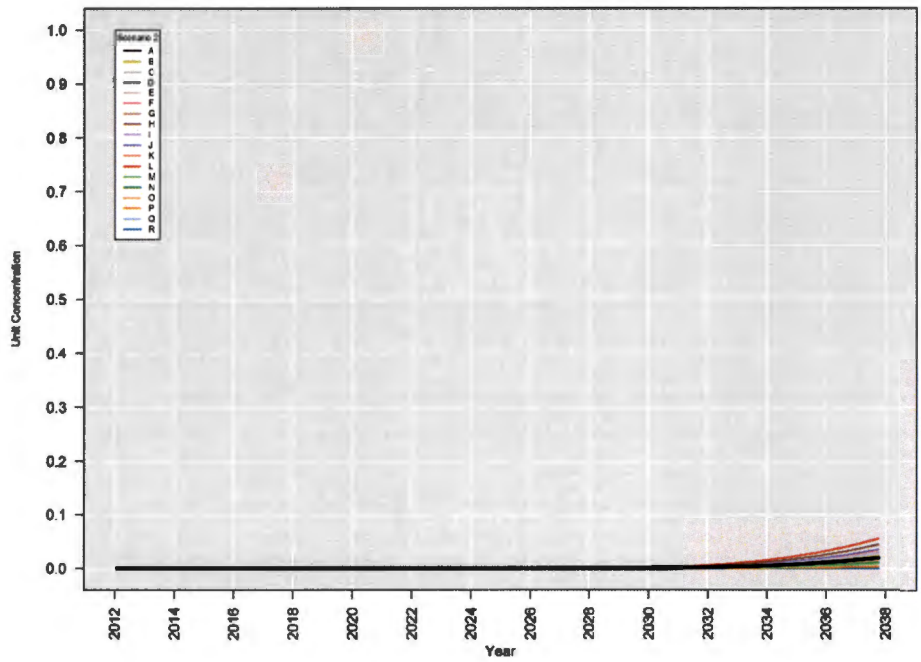

Figure 7-75. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-113

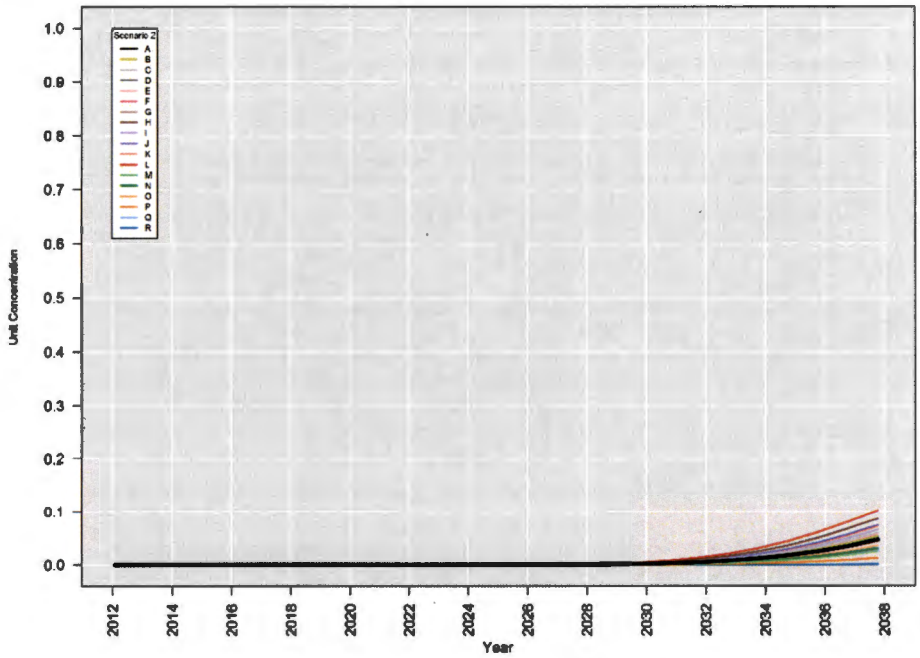

Figure 7-76. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-115

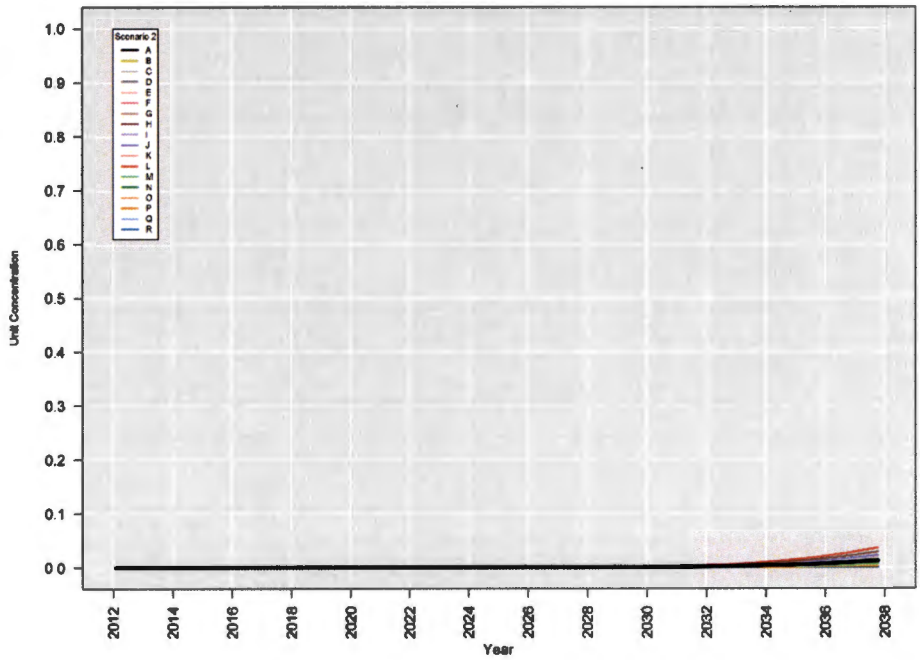

Figure 7-77. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W22-116

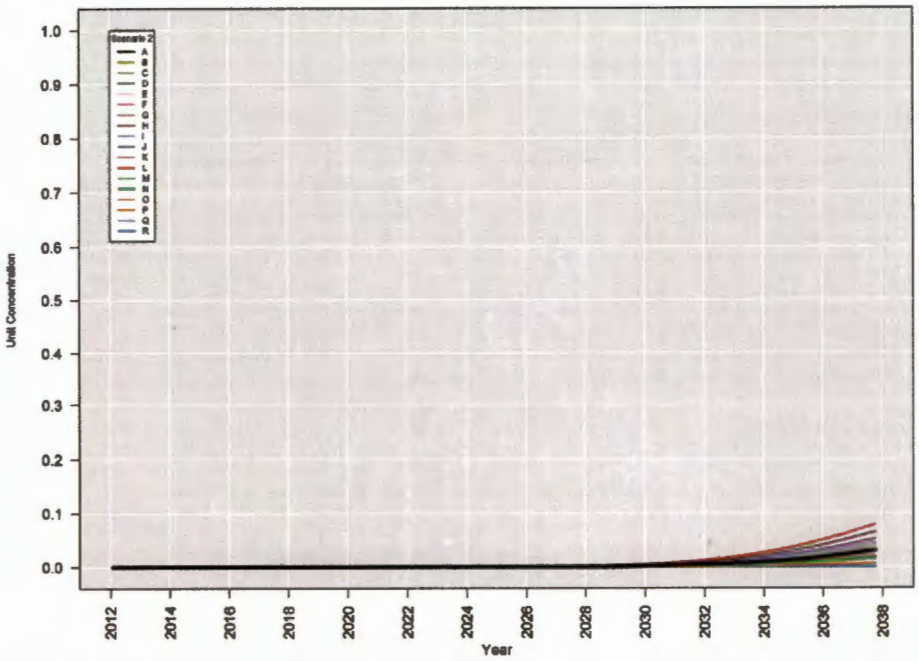

Figure 7-78. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W23-19

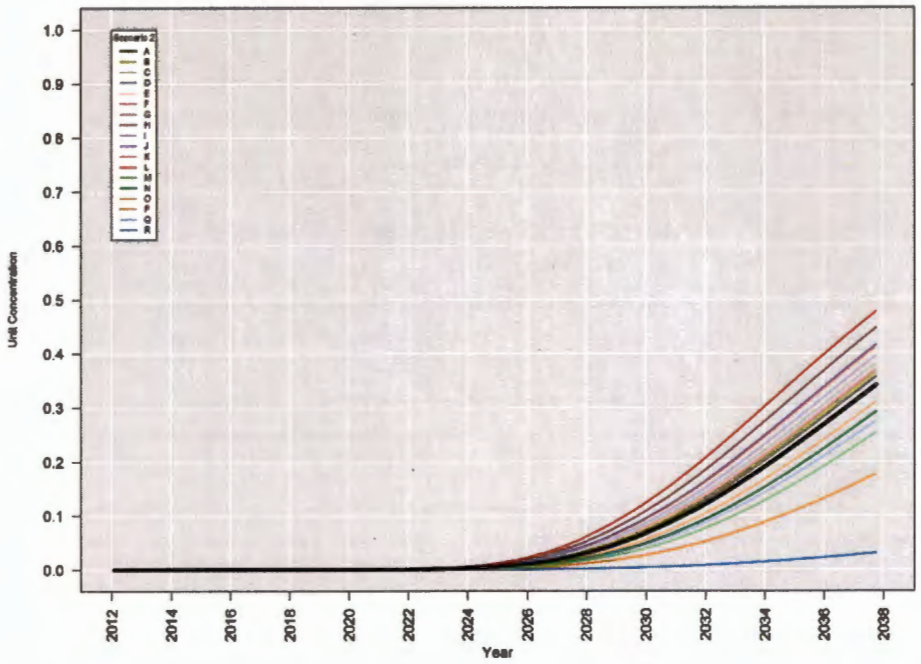

Figure 7-79. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W23-20

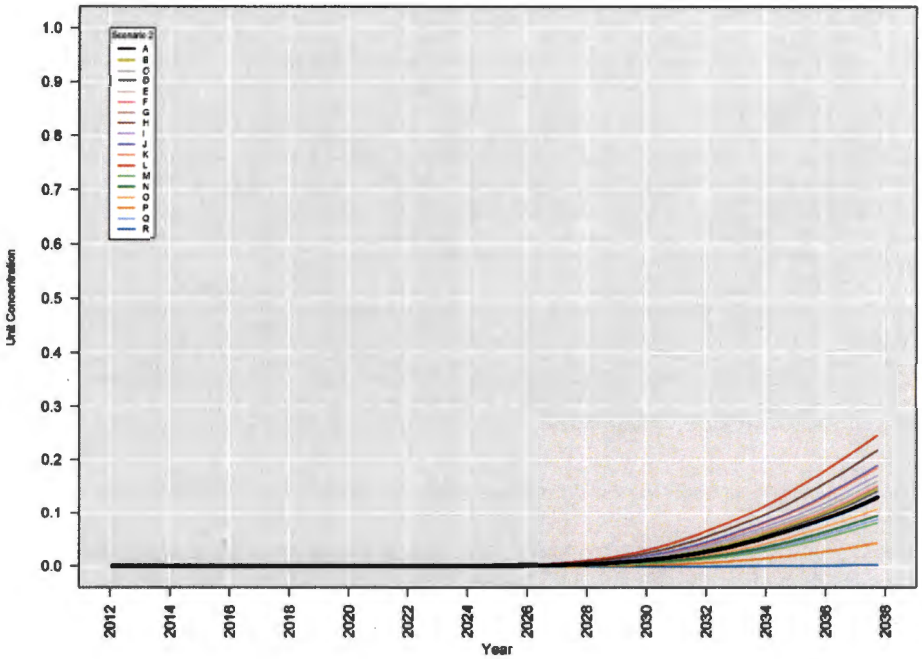

Figure 7-80. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W23-21

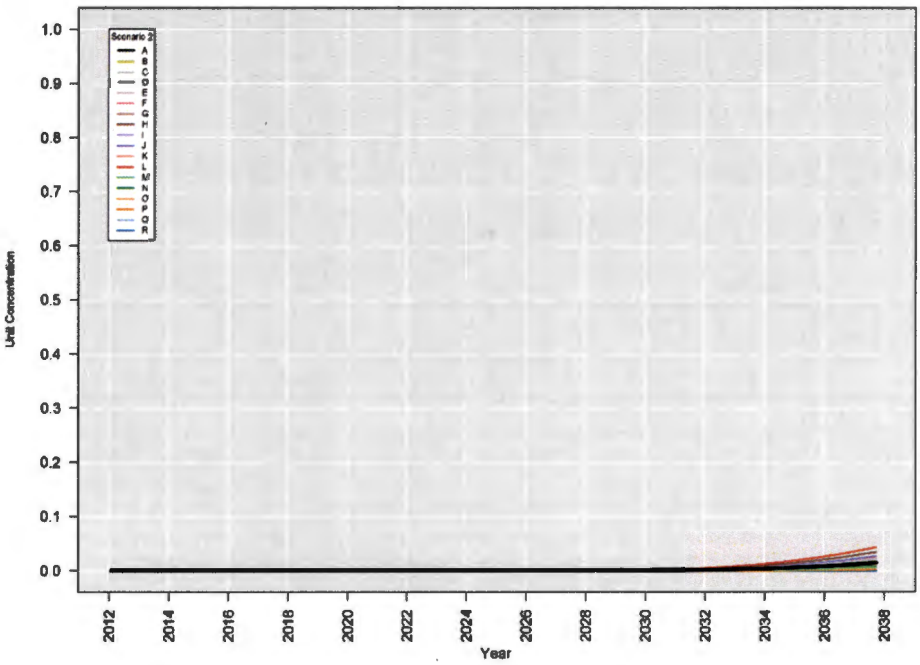

Figure 7-81. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W23-236

7.2.2 Release Concentration Breakthrough Curves

Figures 7-82 through 7-102 depict the simulated breakthrough of a unit-source water table release from WMA S-SX at monitoring wells 299-W22-47, 299-W22-69, 299-W22-72, 299-W22-80, 299-W22-81, 299-W22-82, 299-W22-83, 299-W22-84, 299-W22-85, 299-W22-86, 299-W22-89, 299-W22-93, 299-W22-94, 299-W22-95, 299-W22-113, 299-W22-115, 299-W22-116, 299-W23-19, 299-W23-20, 299-W23-21, and 299-W23-236, respectively. The release time (represented on the figures as arrival time year 0) corresponds to October 1, 2017. The bold black line on the figures represents sub-scenario A, which reflects the most likely operating conditions.

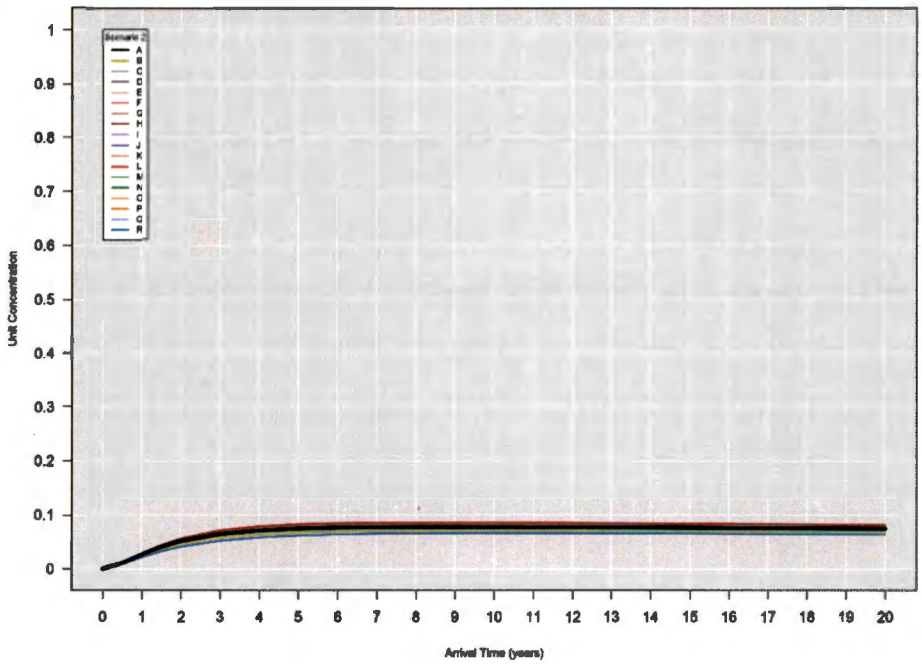

Figure 7-82. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-47

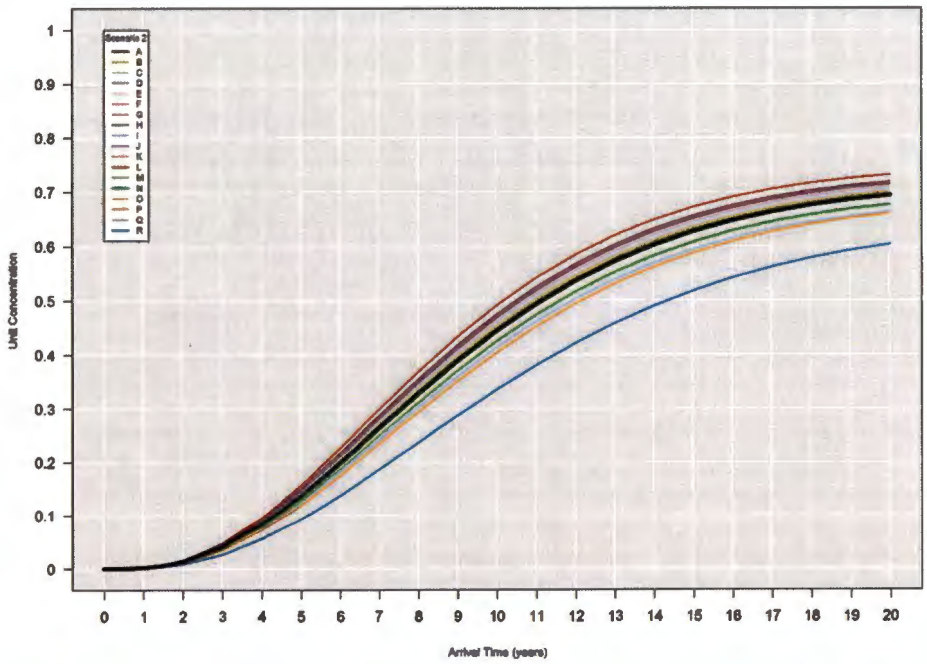

Figure 7-83. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-69

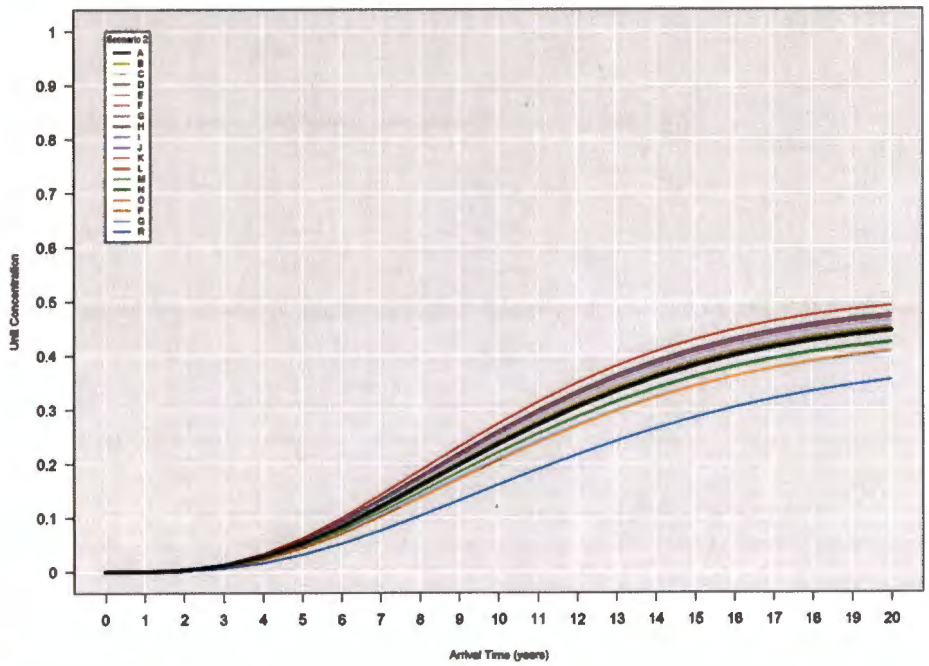

Figure 7-84. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-72

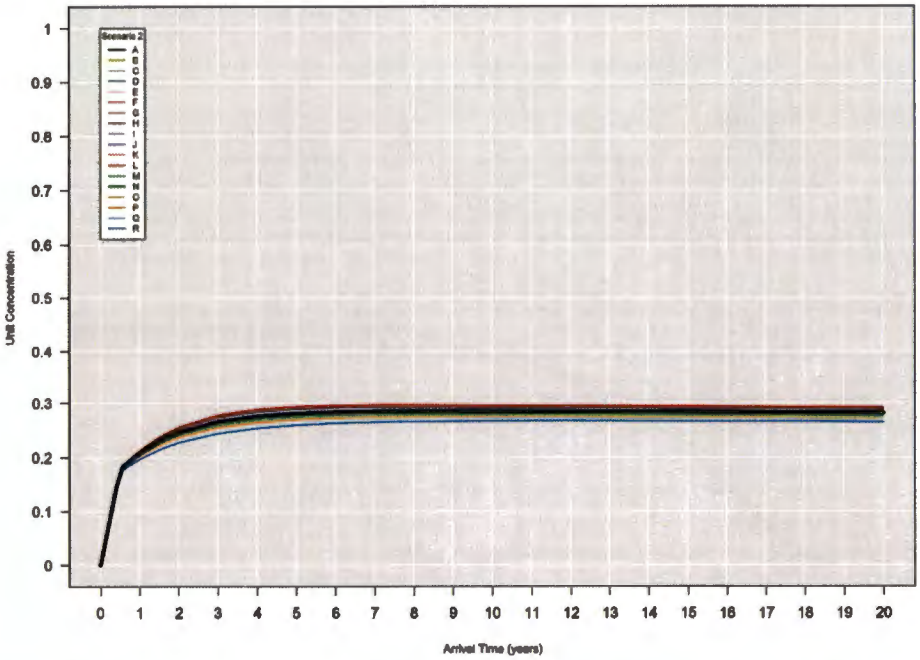

Figure 7-85. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-80

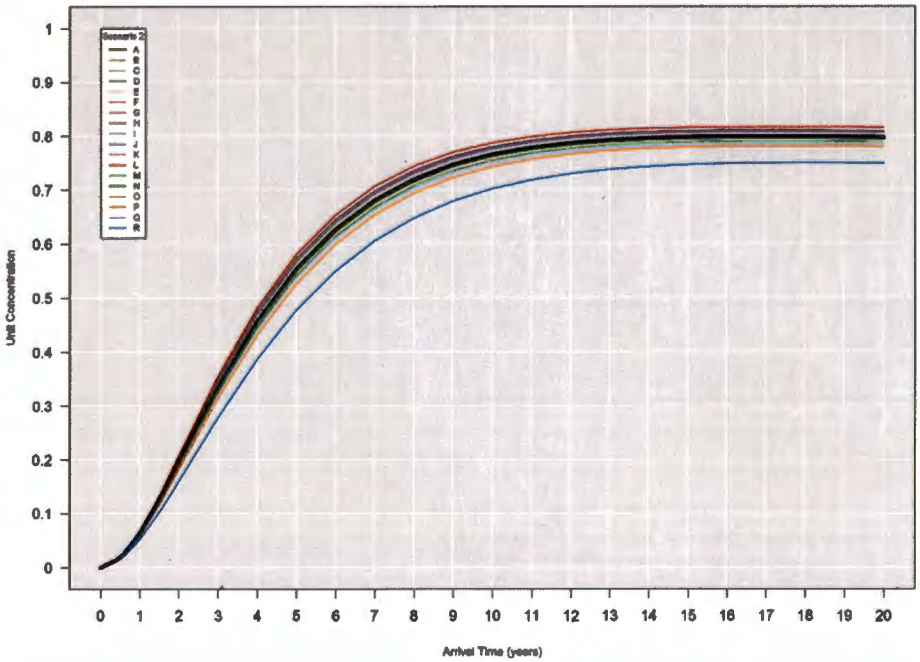

Figure 7-86. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-81

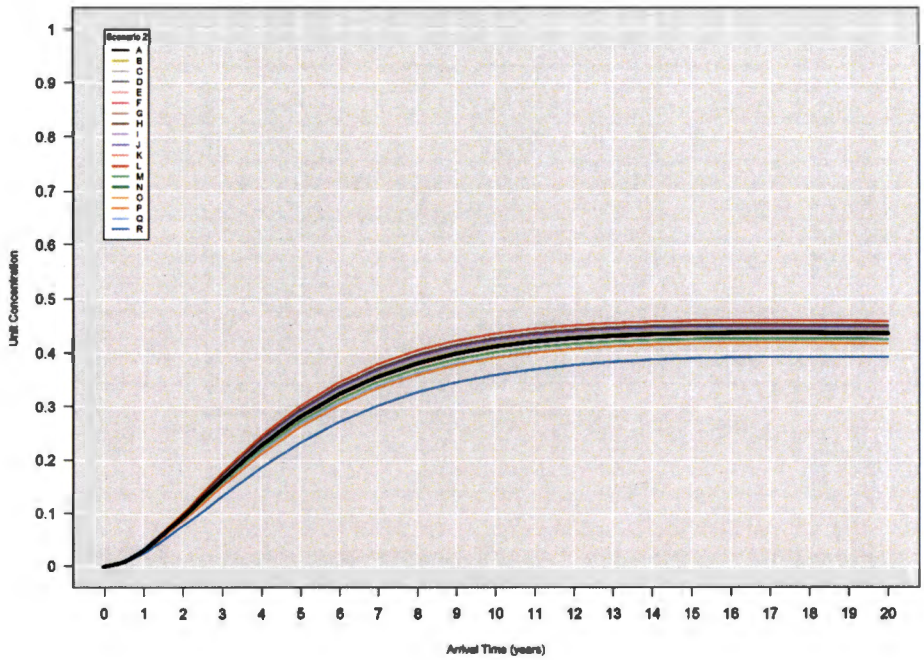

Figure 7-87. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-82

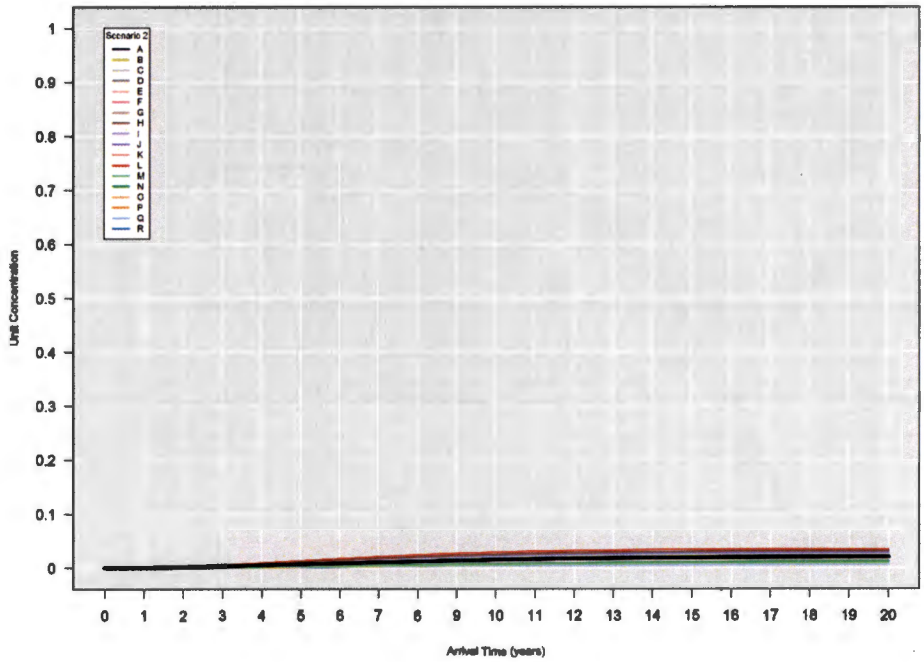

Figure 7-88. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-83

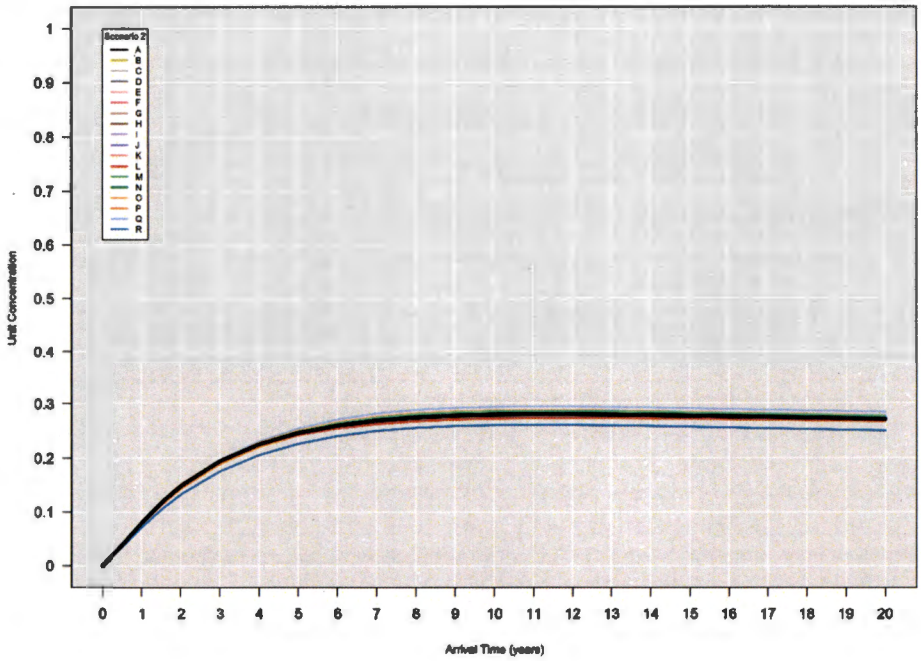

Figure 7-89. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-84

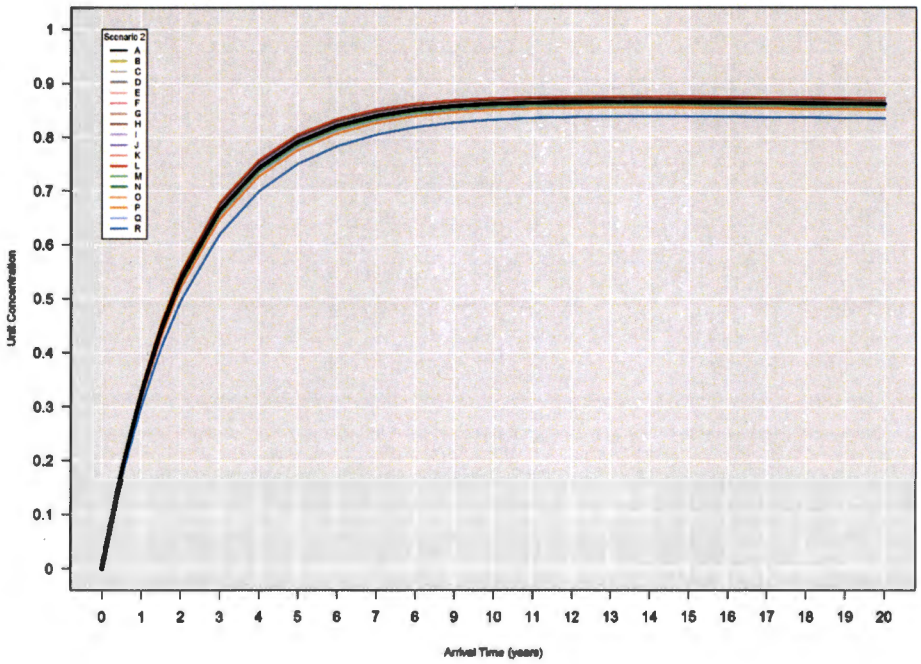

Figure 7-90. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-85

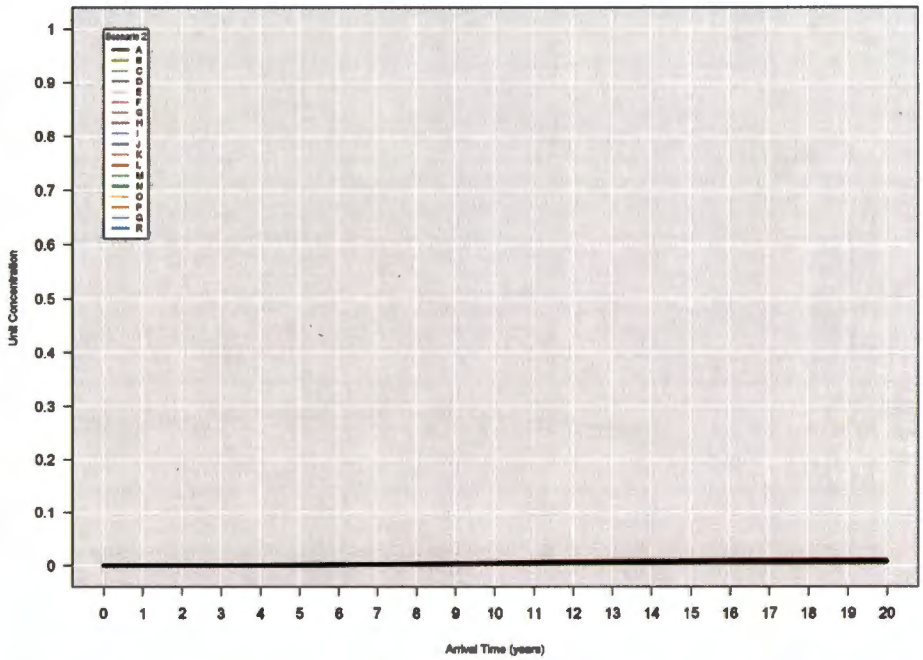

Figure 7-91. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-86

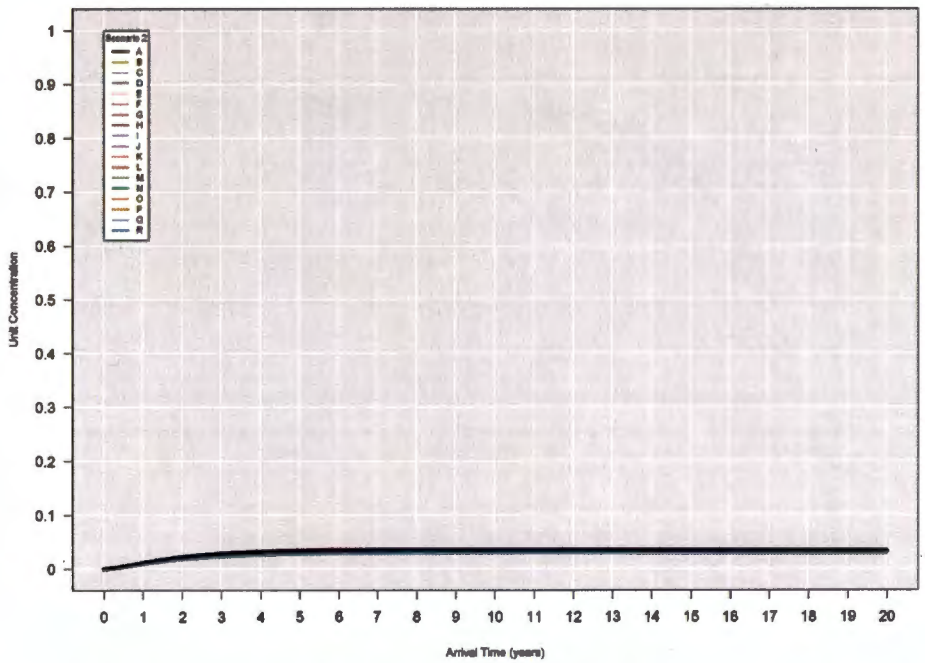

Figure 7-92. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-89

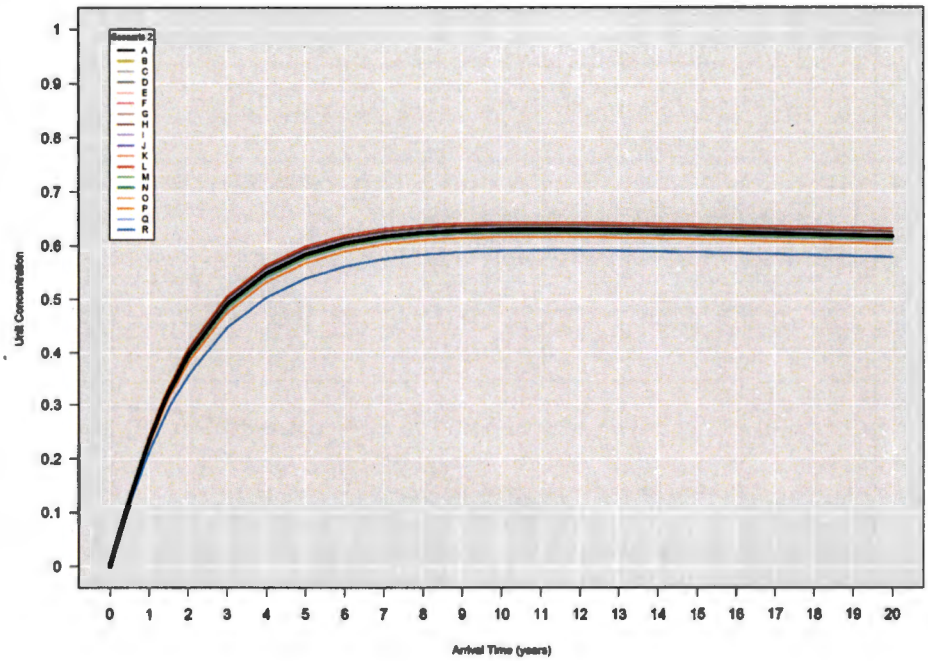

Figure 7-93. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-93

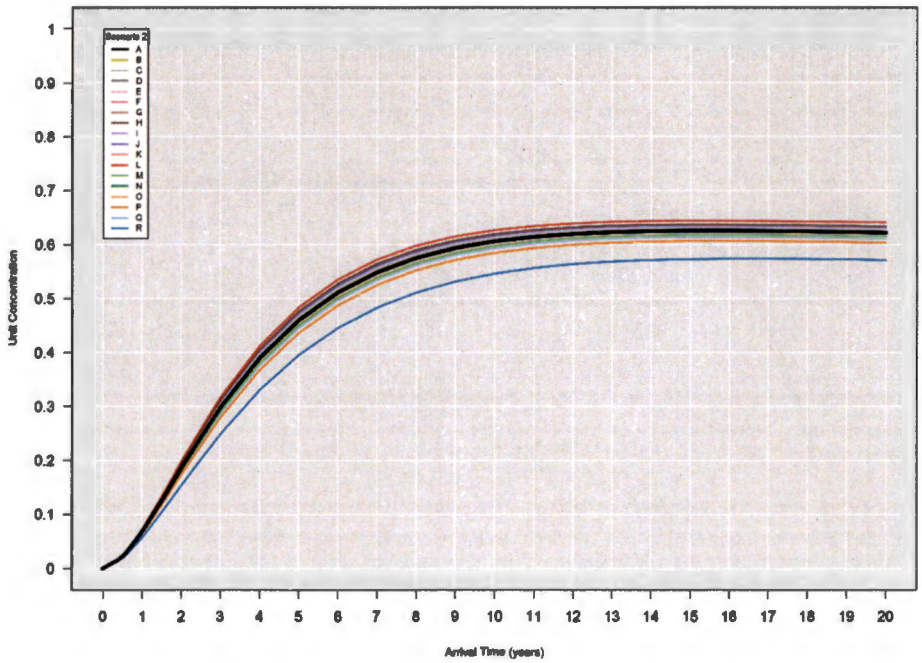

Figure 7-94. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-94

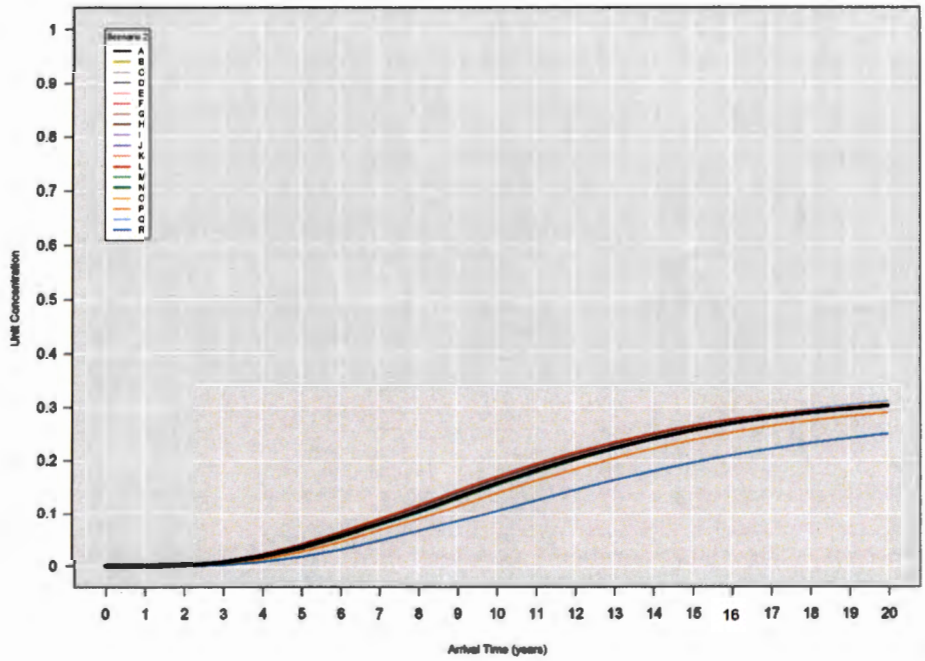

Figure 7-95. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-95

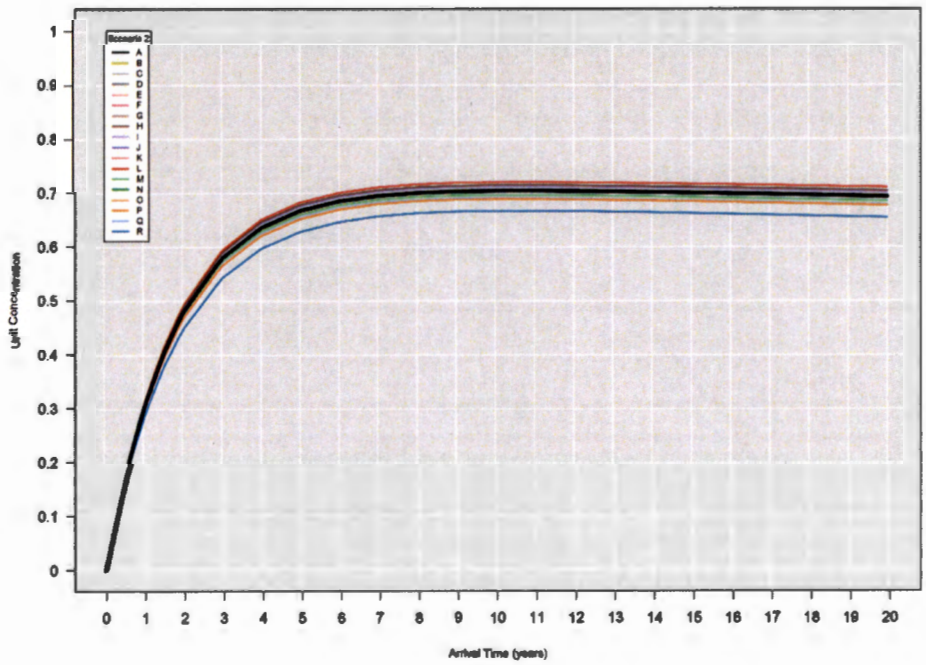

Figure 7-96. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-113

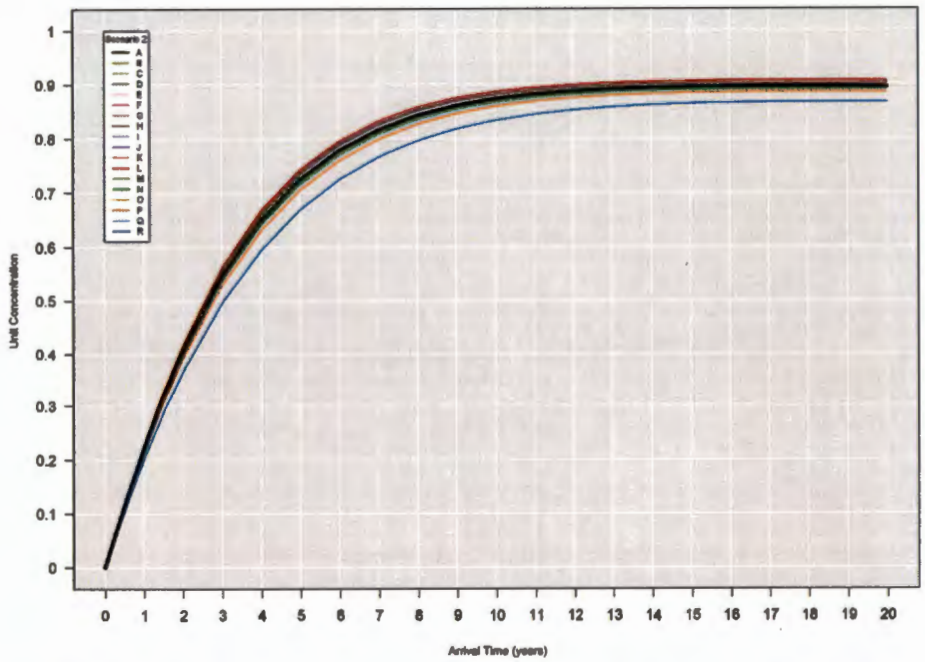

Figure 7-97. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-115

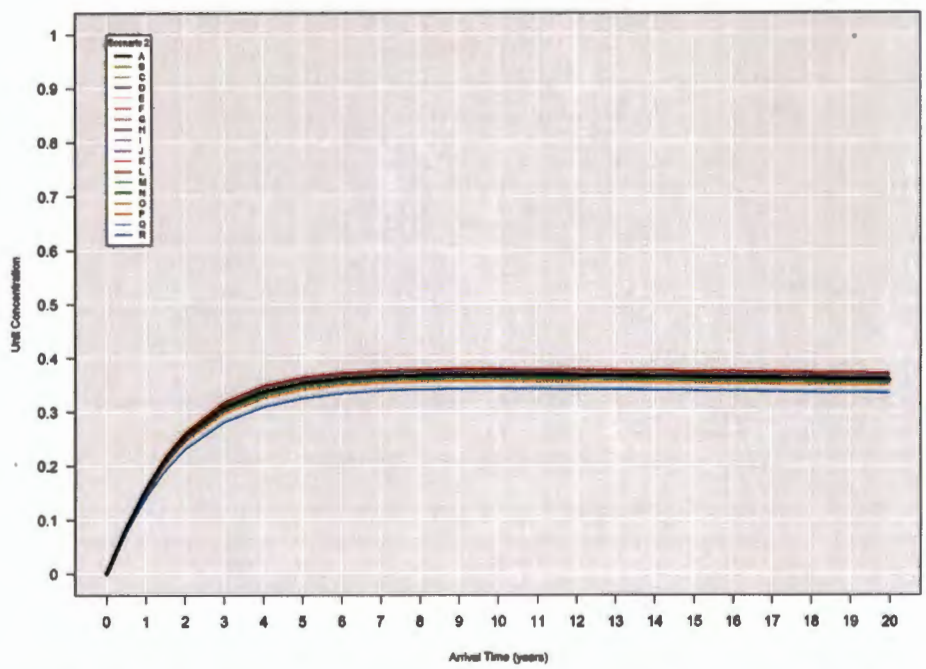

Figure 7-98. Release Concentration Breakthrough Curves at Monitoring Well 299-W22-116

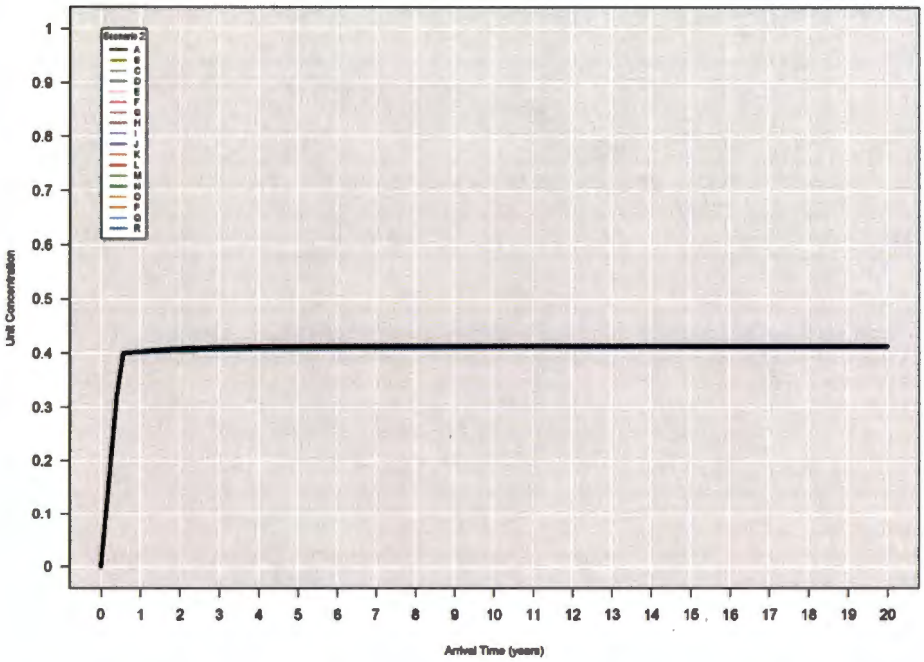

Figure 7-99. Release Concentration Breakthrough Curves at Monitoring Well 299-W23-19

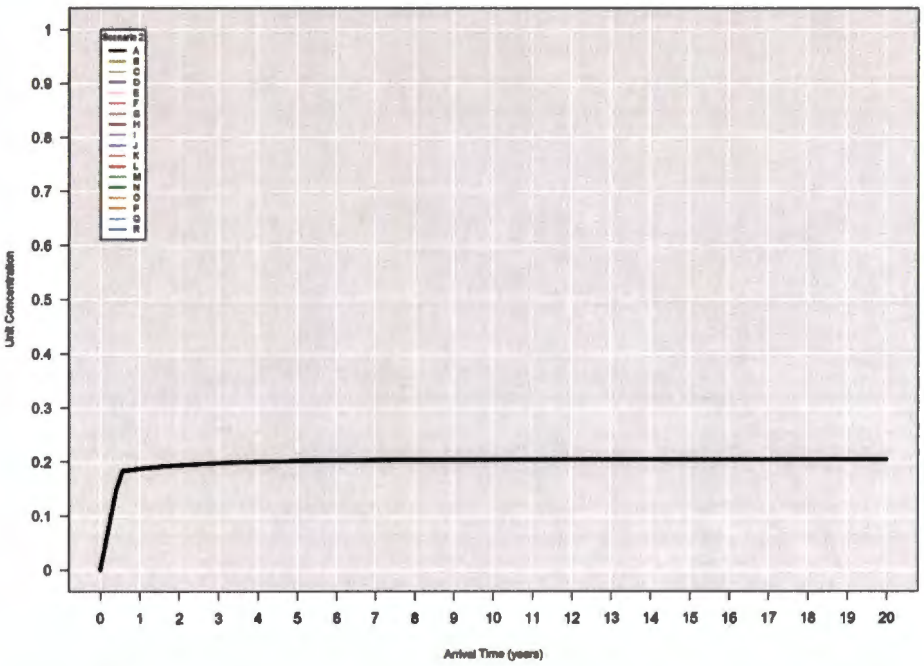

Figure 7-100. Release Concentration Breakthrough Curves at Monitoring Well 299-W23-20

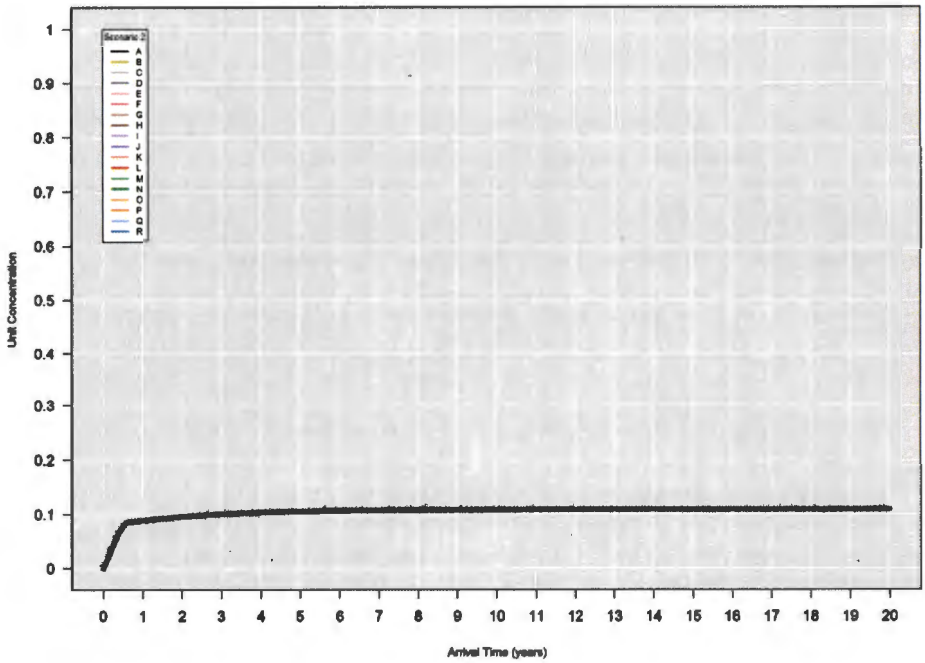

Figure 7-101. Release Concentration Breakthrough Curves at Monitoring Well 299-W23-21

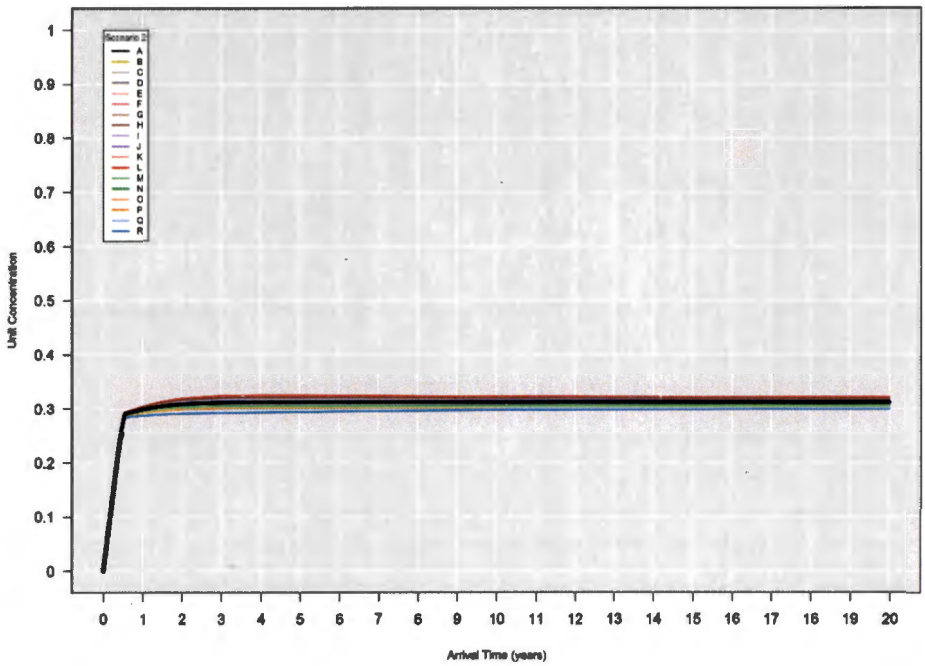

Figure 7-102. Release Concentration Breakthrough Curves at Monitoring Well 299-W23-236

7.2.3 Injected Treated Water Dilution Plumes and Release Particle Pathlines

Figures 7-103 through 7-120 depict simulated injected treated water dilution plumes, as well as the simulated pathlines, for a hypothetical water table release below WMA S-SX when considering advection and dispersion for scenario 2, sub-scenarios A through R, respectively (see Table 3-1 for scenario details). The figures represent the conditions at the end of the operation of the 200 West P&T system in 2037 and display model layer 2, which corresponds to the water table. The colored regions in the dilution plumes represent the relative fraction of injected water that is introduced at the injection wells. The dilution plume maps are interpolated and contoured in an additional post-processing step and do not show the raw output from MT3DMS.

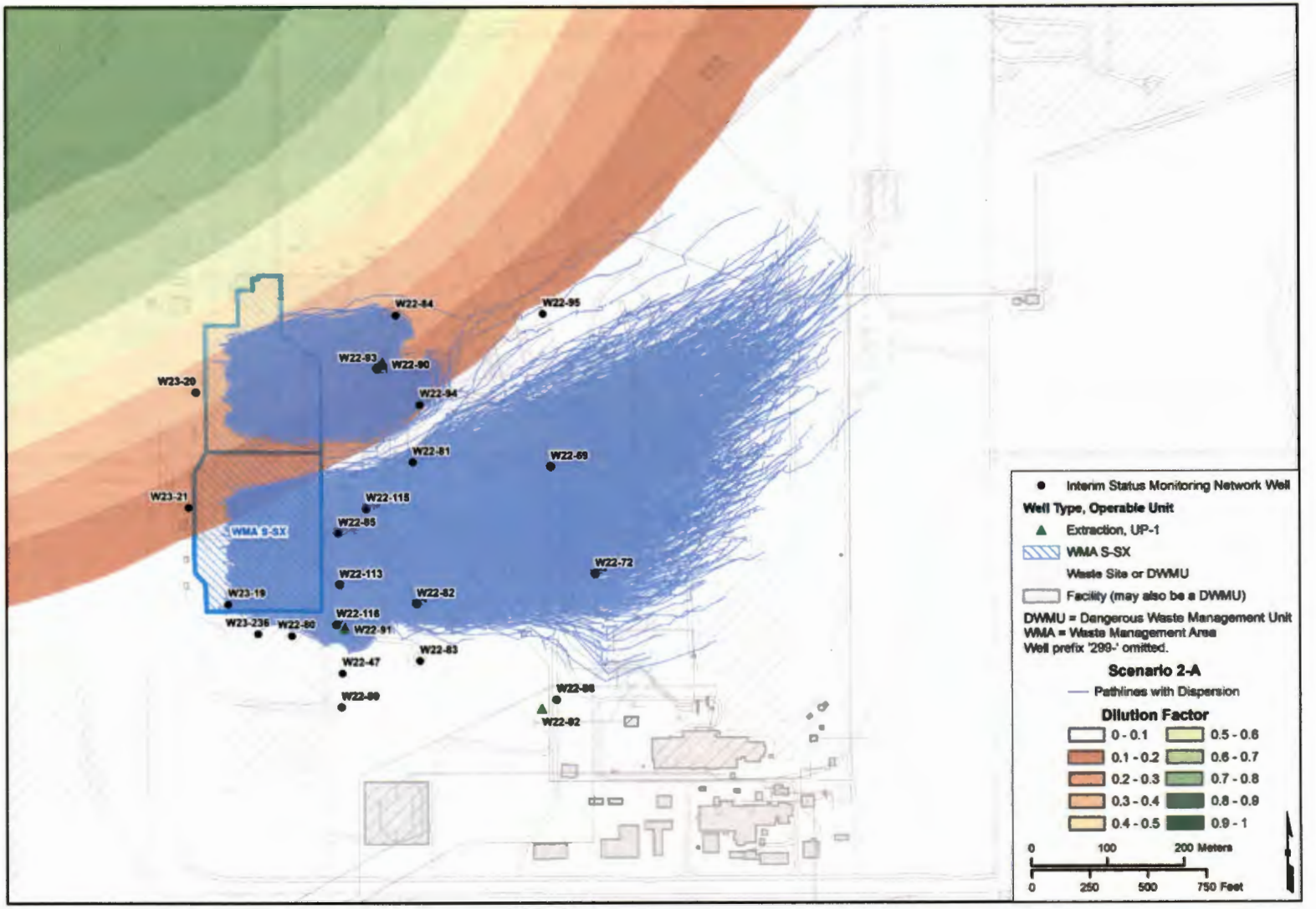

Figure 7-103. Scenario 2, Sub-scenario A Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

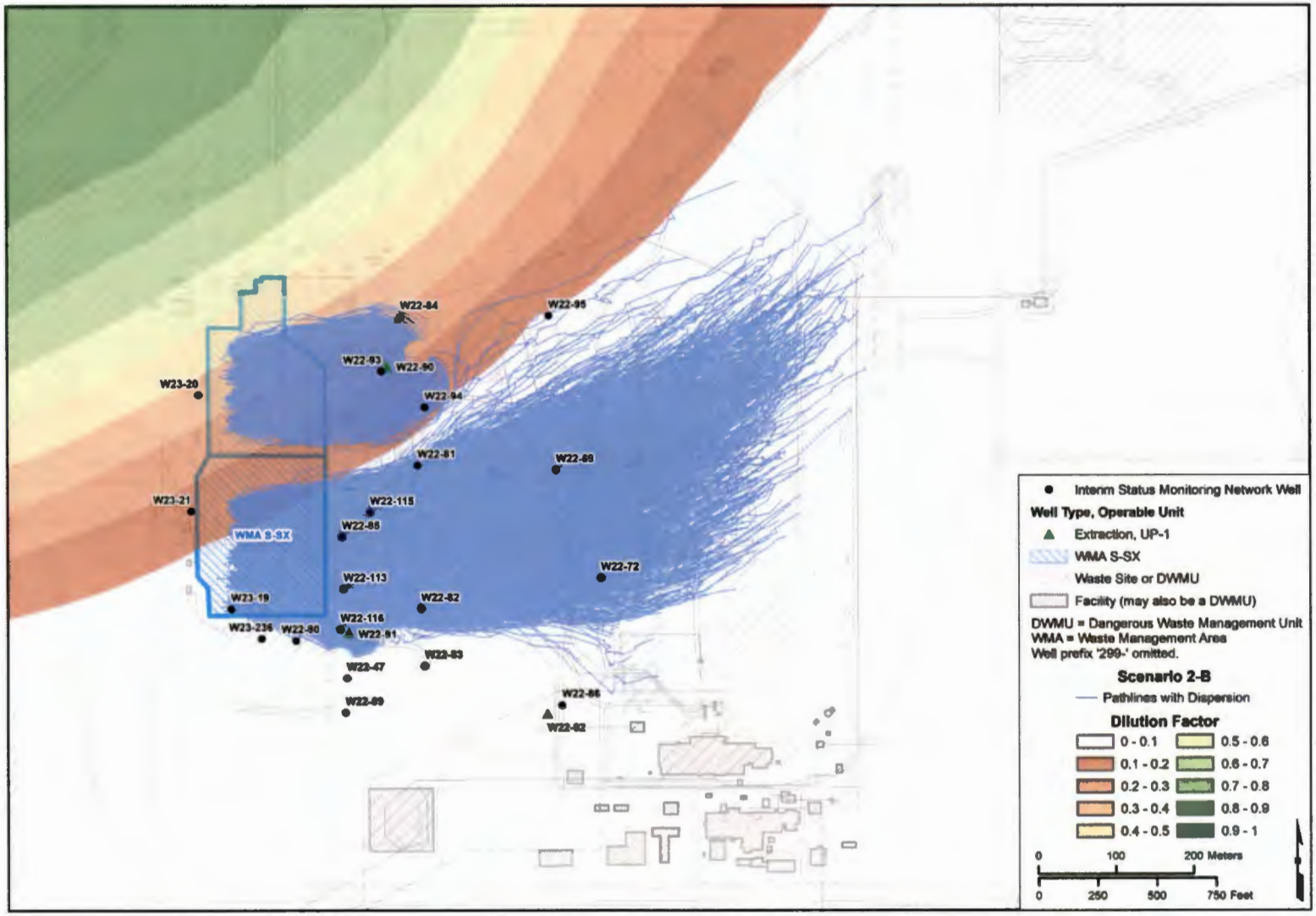

Figure 7-104. Scenario 2, Sub-scenario B Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

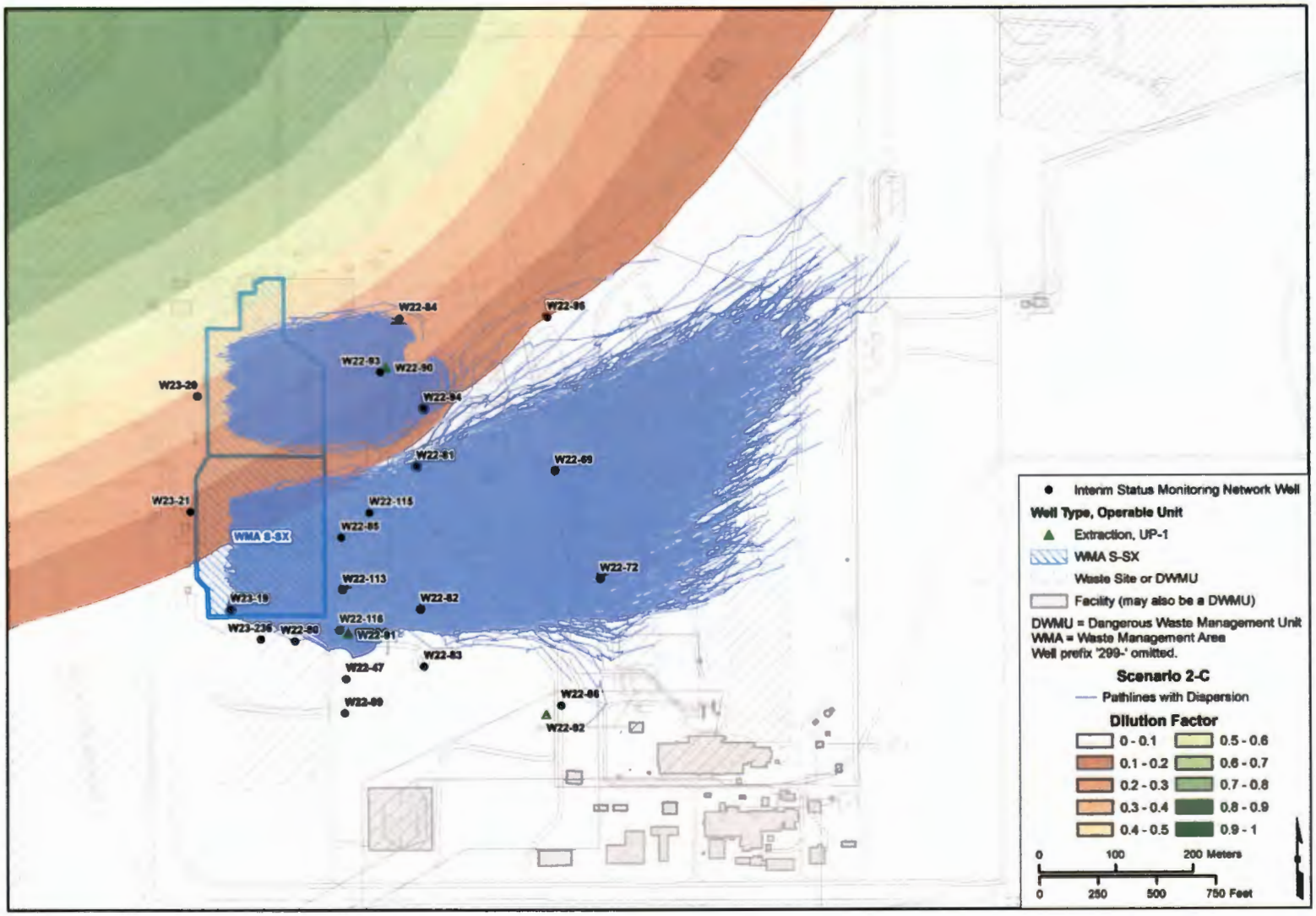

Figure 7-105. Scenario 2, Sub-scenario C Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

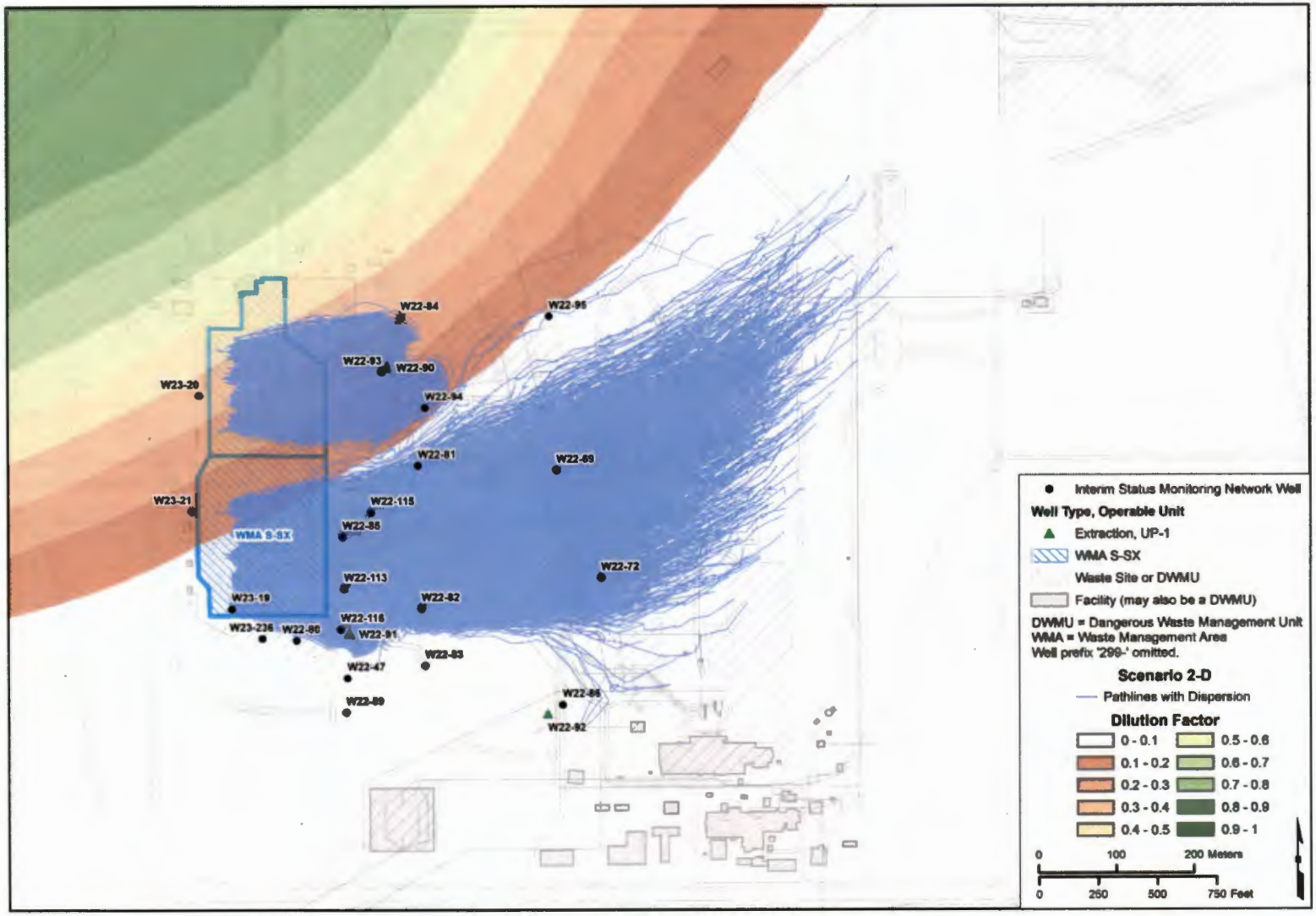

Figure 7-106. Scenario 2, Sub-scenario D Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

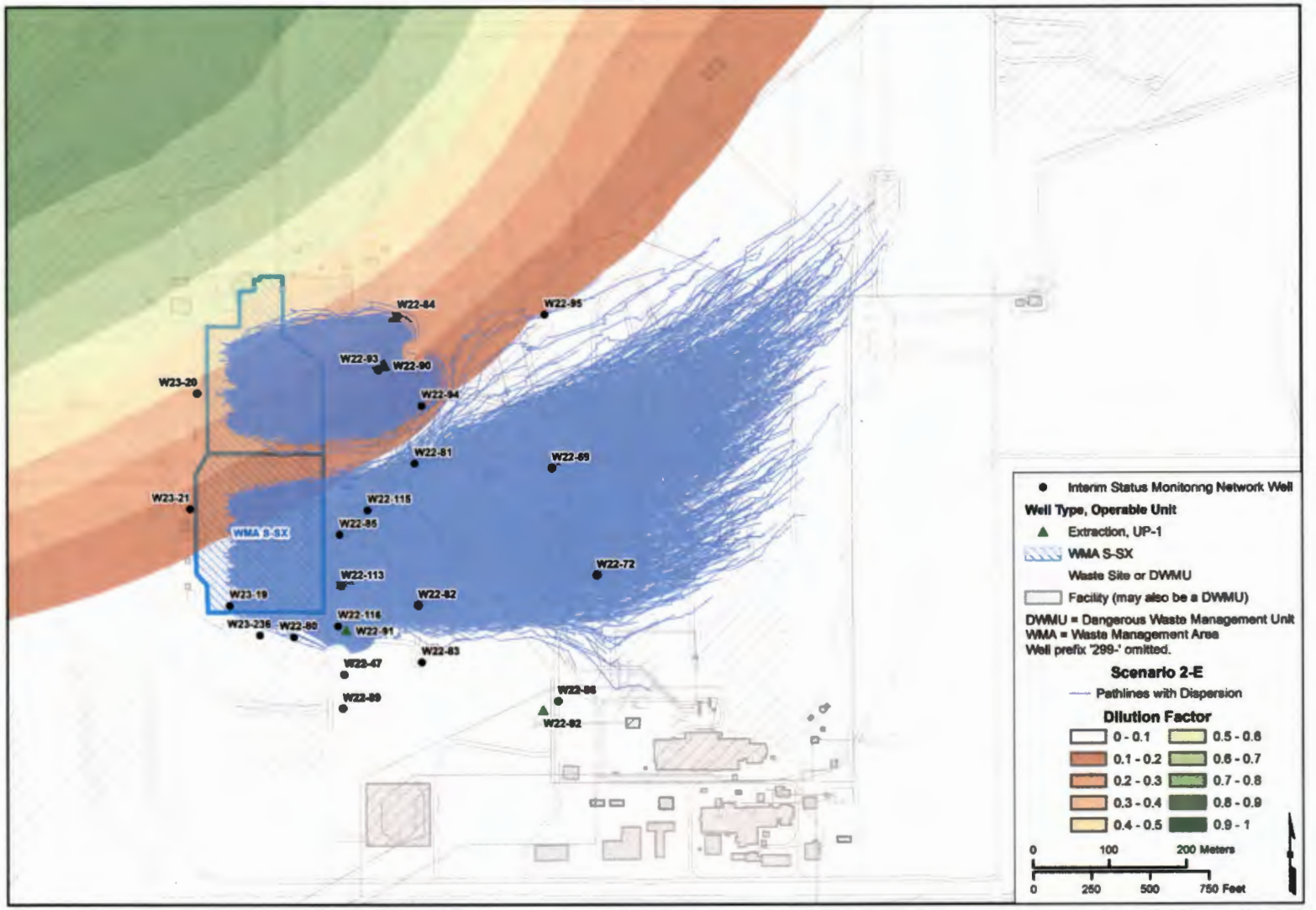

Figure 7-107. Scenario 2, Sub-scenario E Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

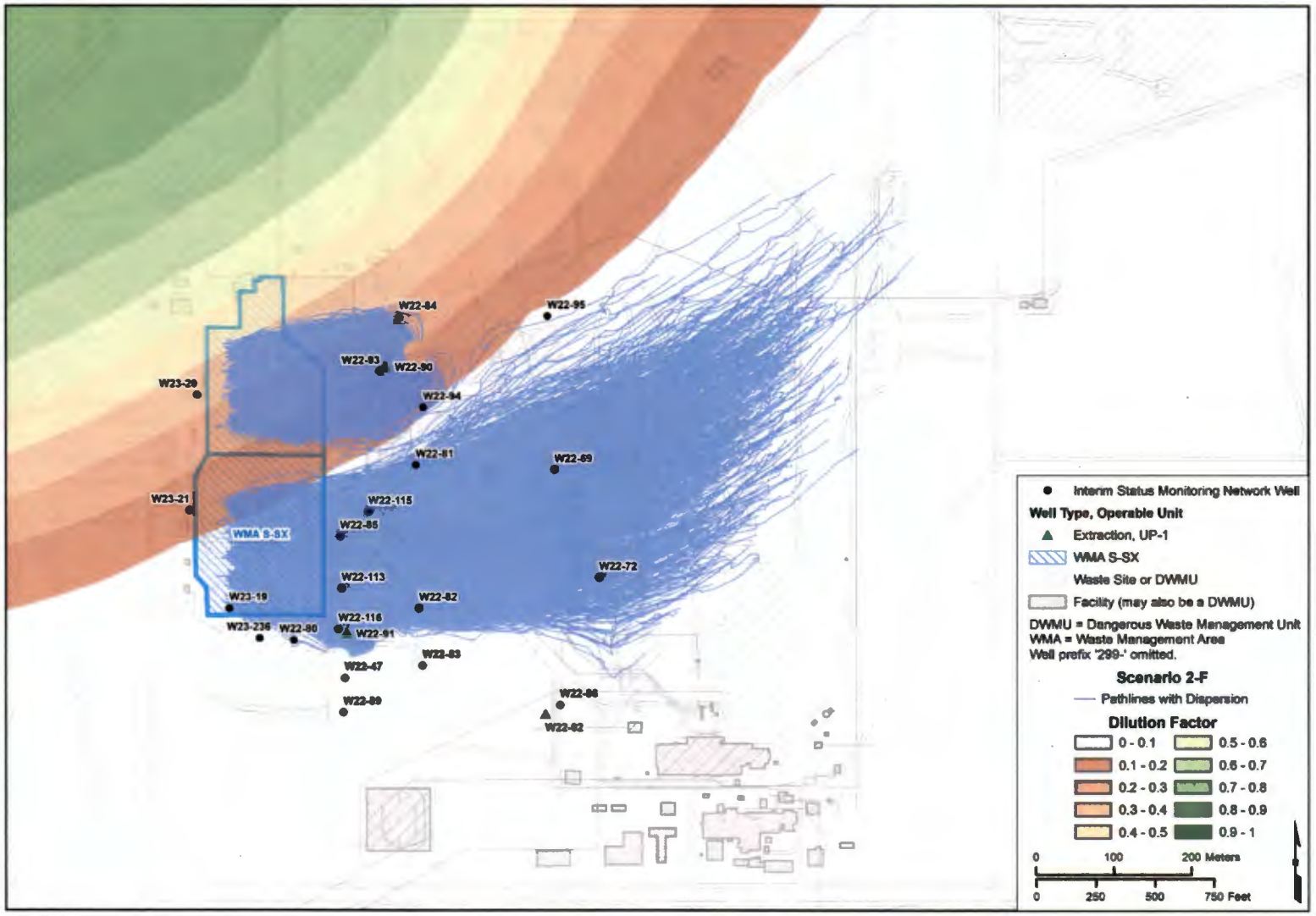

Figure 7-108. Scenario 2, Sub-scenario F Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

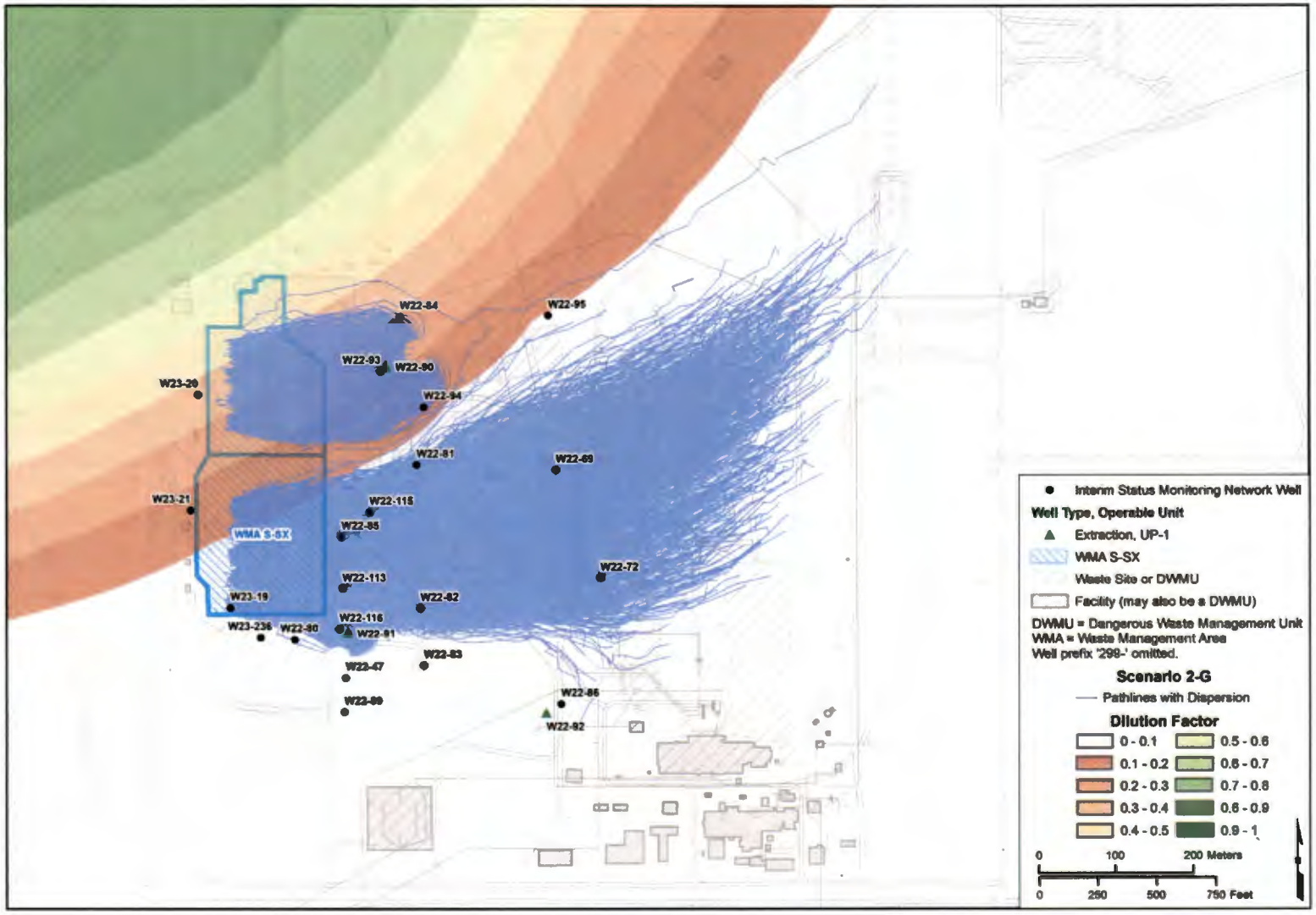

Figure 7-109. Scenario 2, Sub-scenario G Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

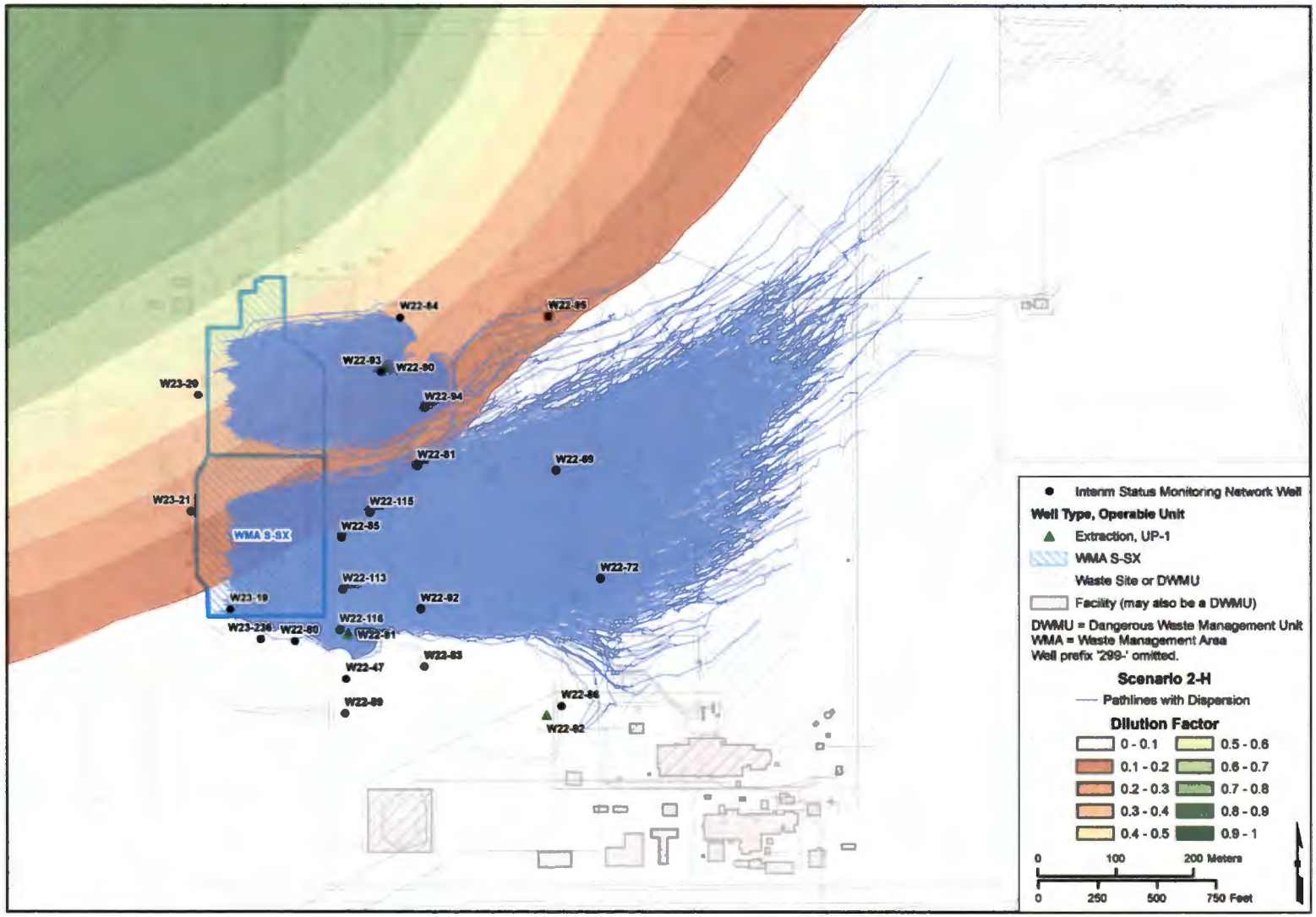

Figure 7-110. Scenario 2, Sub-scenario H Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

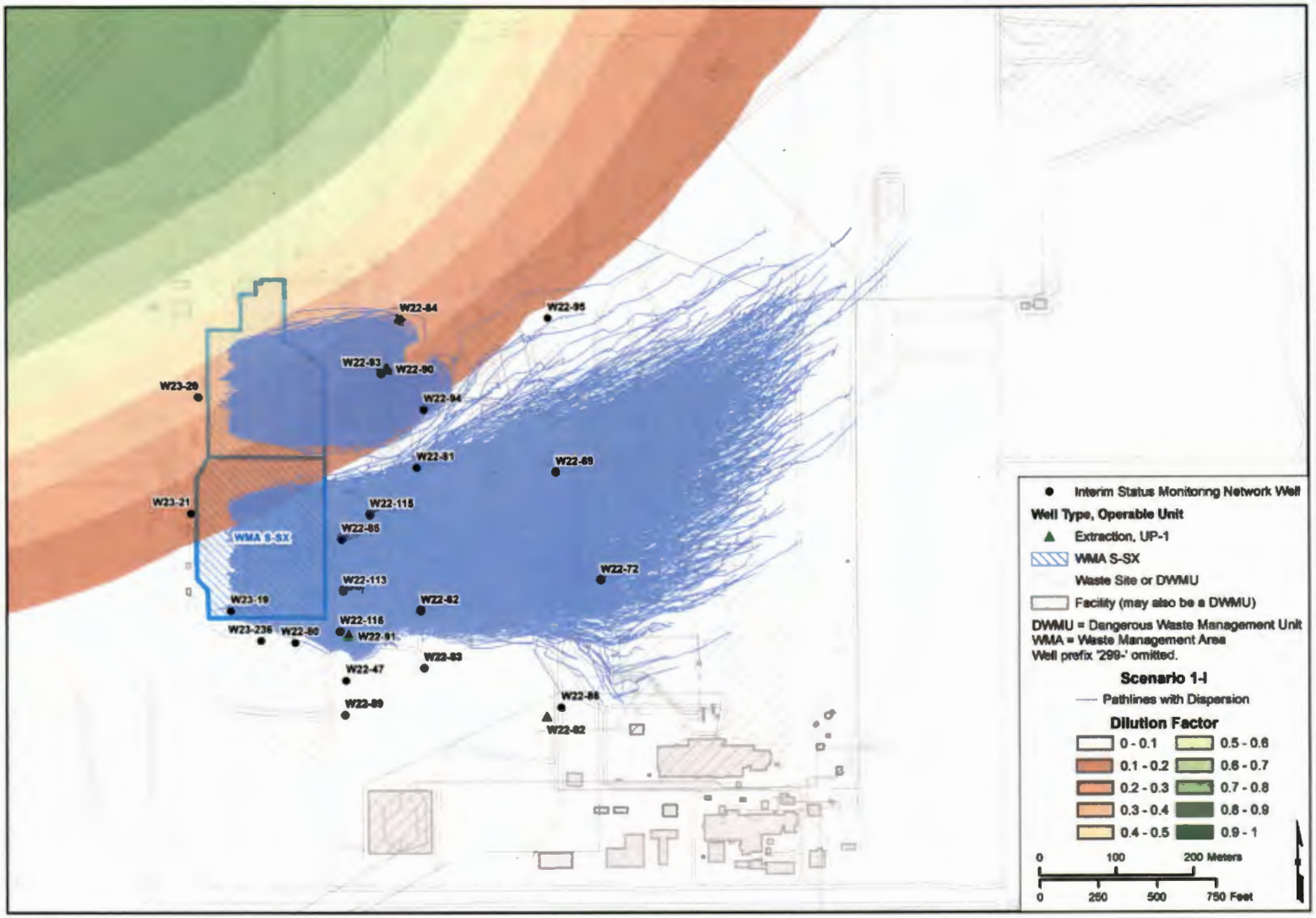

Figure 7-111. Scenario 2, Sub-scenario I Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

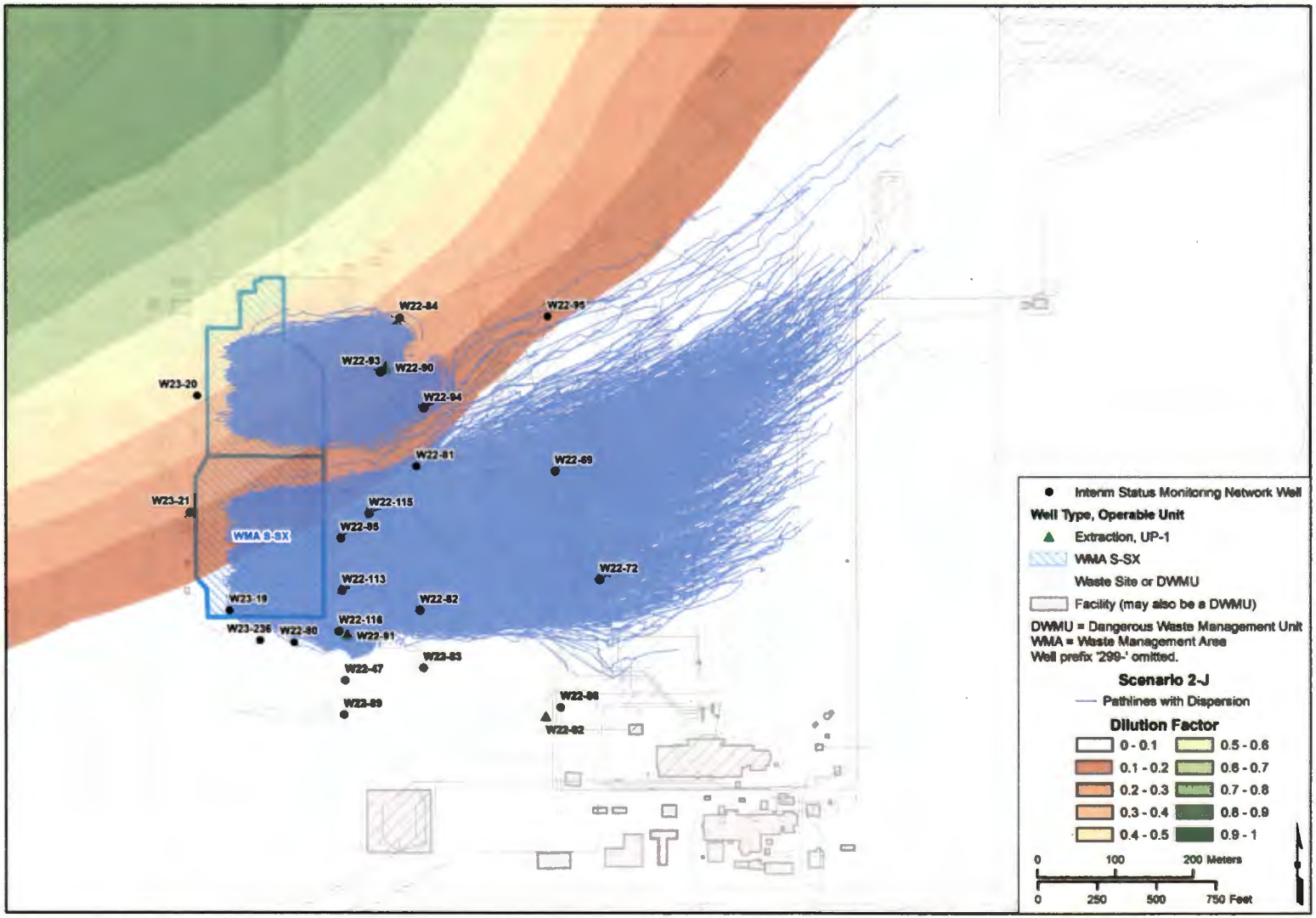

Figure 7-112. Scenario 2, Sub-scenario J Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

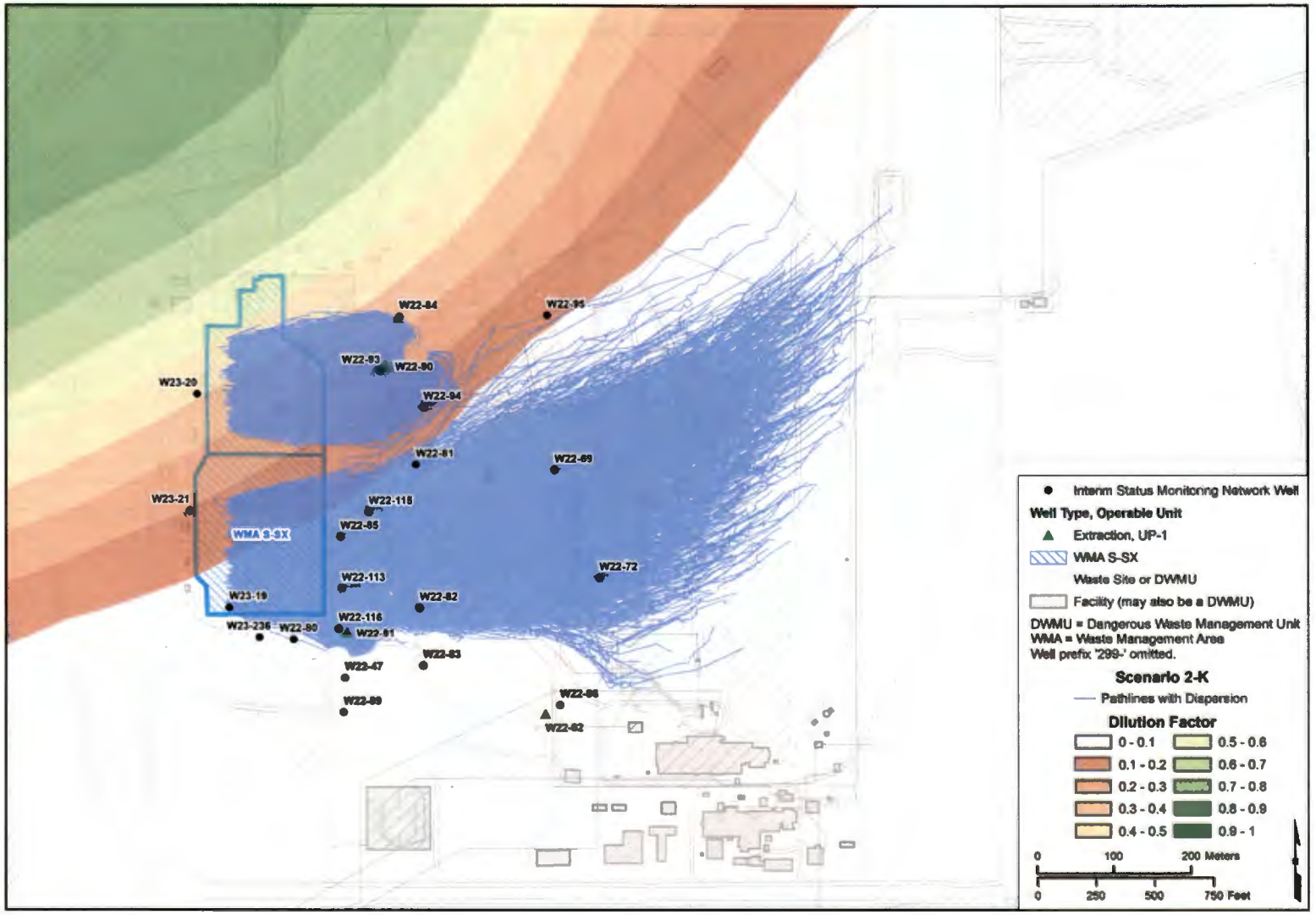

Figure 7-113. Scenario 2, Sub-scenario K Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

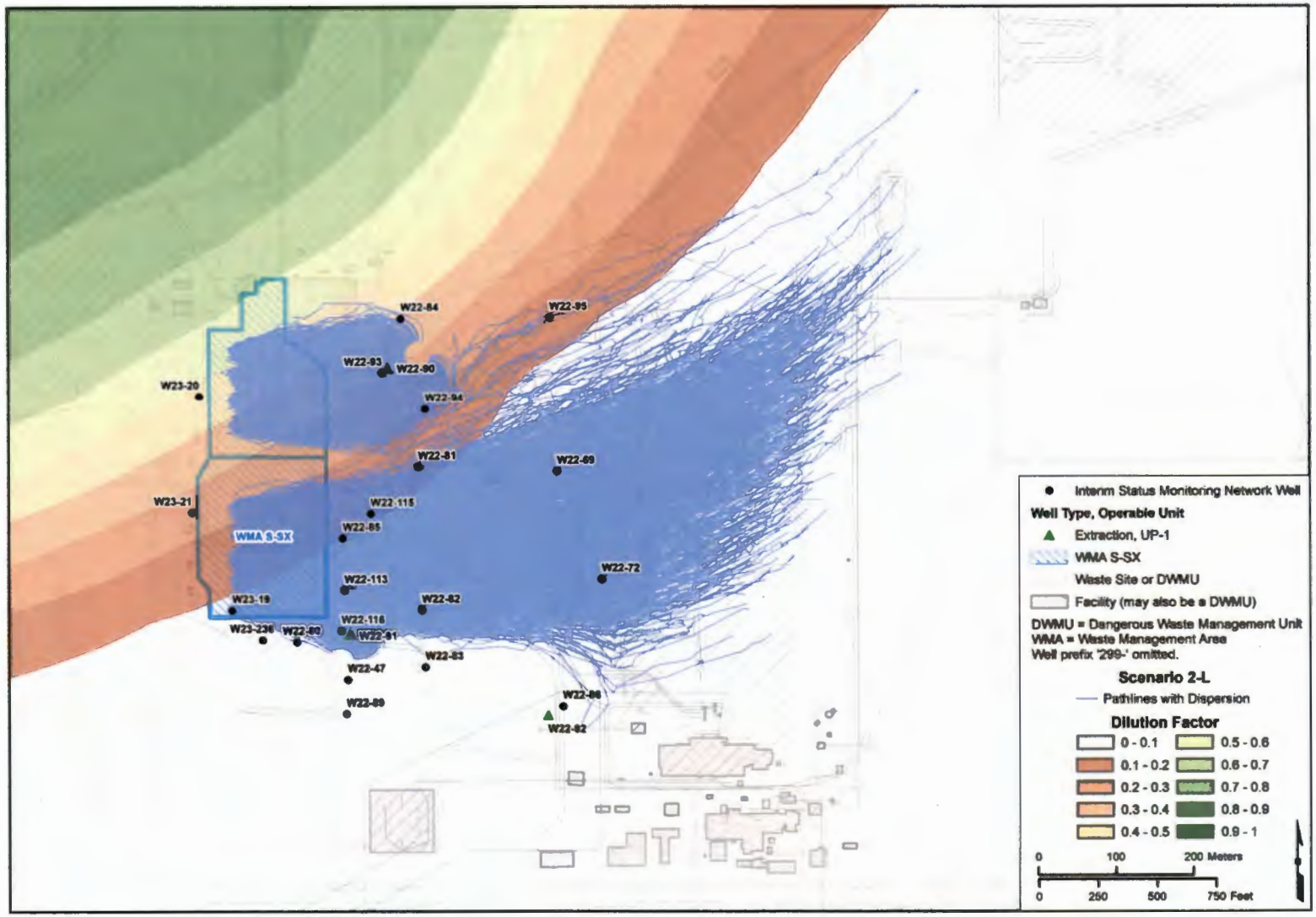

Figure 7-114. Scenario 2, Sub-scenario L Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

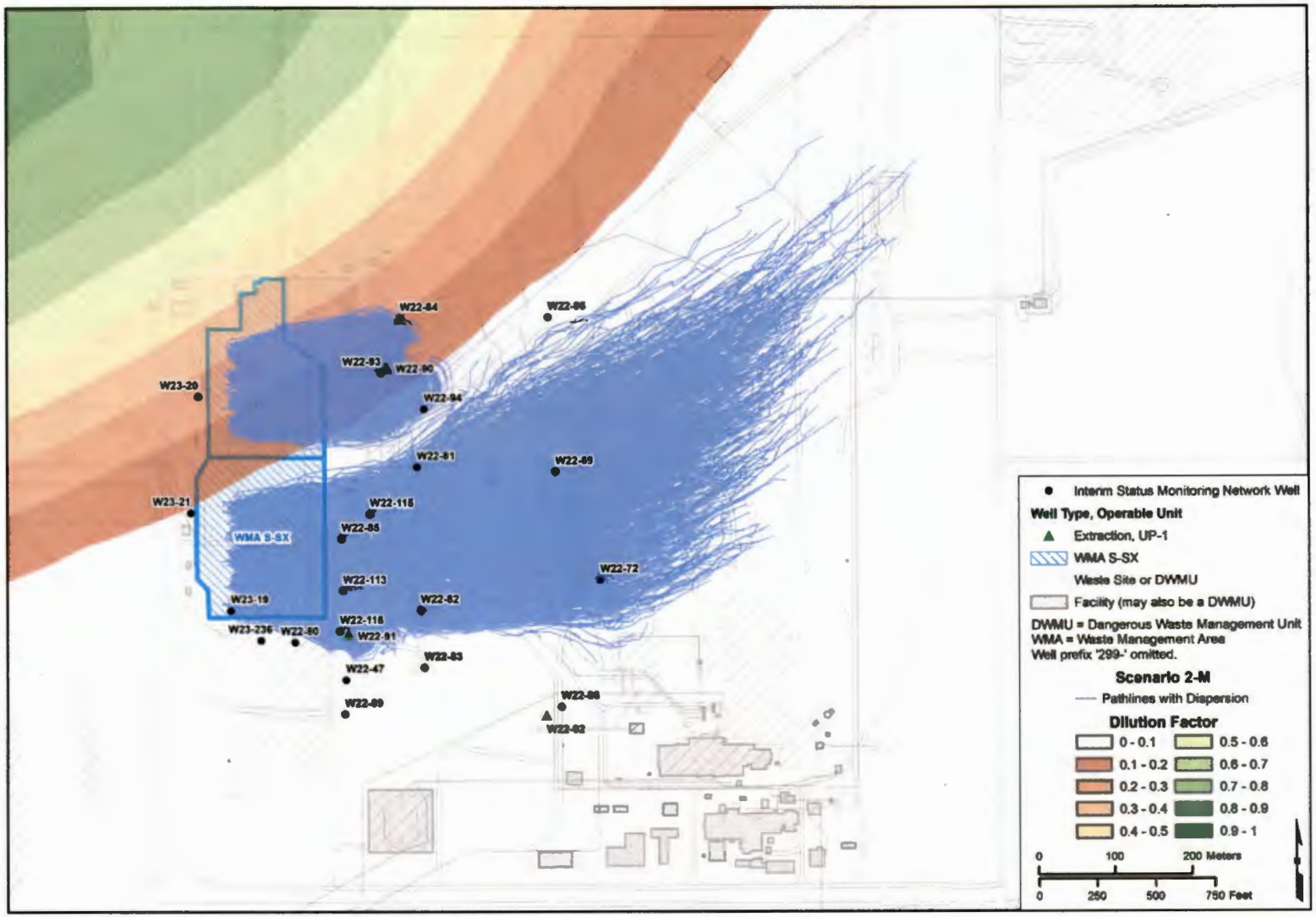

Figure 7-115. Scenario 2, Sub-scenario M Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

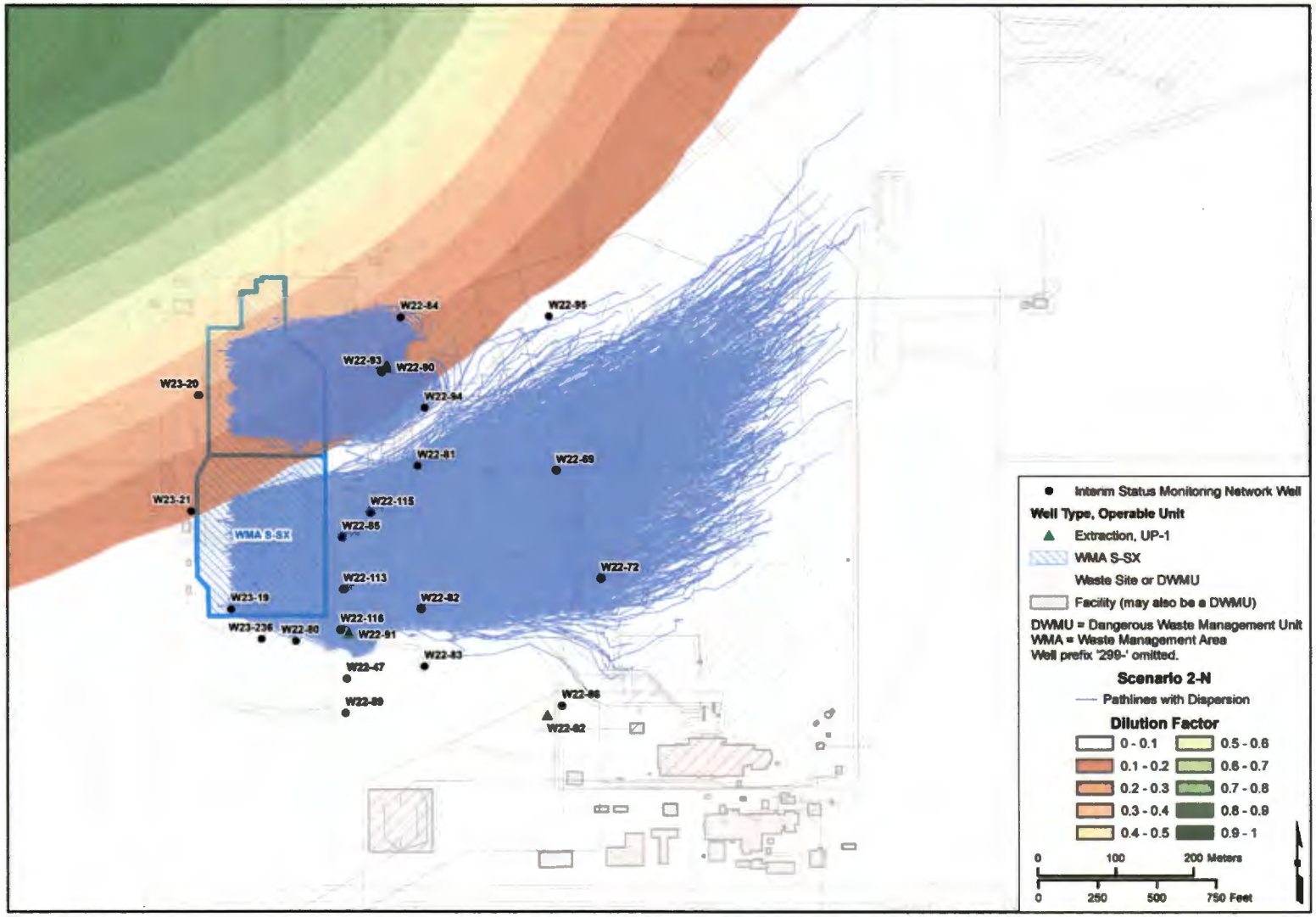

Figure 7-116. Scenario 2, Sub-scenario N Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

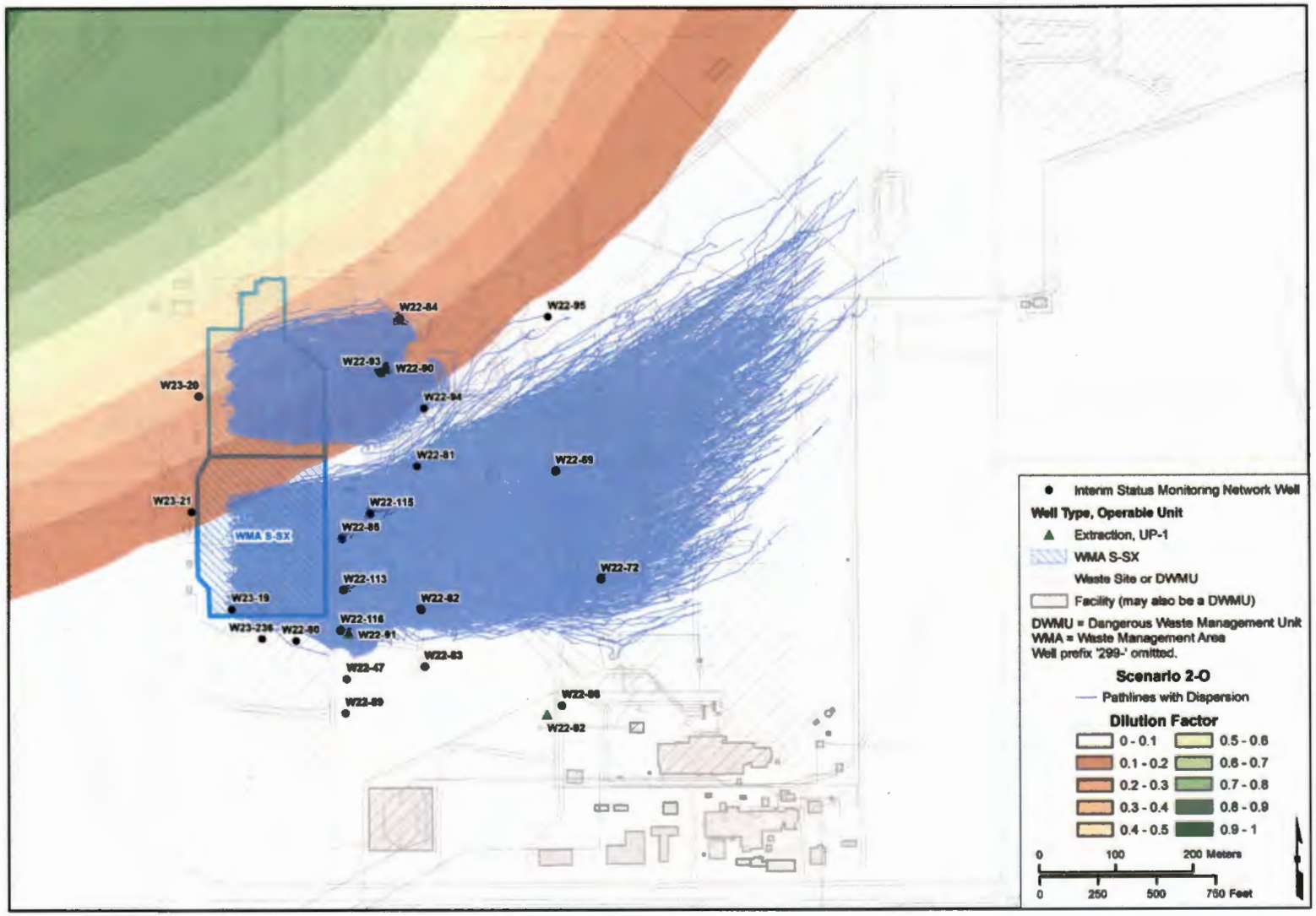

Figure 7-117. Scenario 2, Sub-scenario O Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

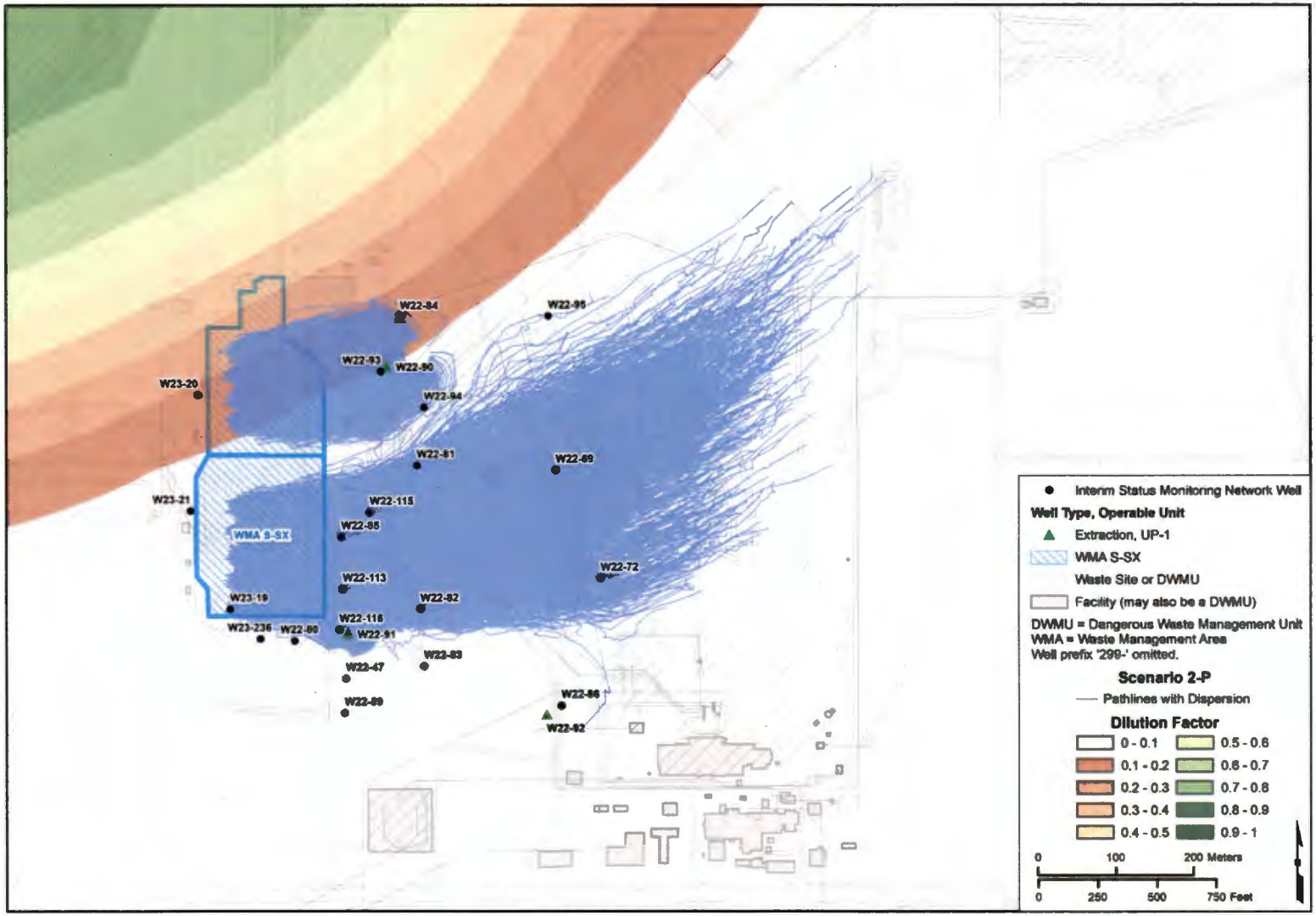

Figure 7-118. Scenario 2, Sub-scenario P Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

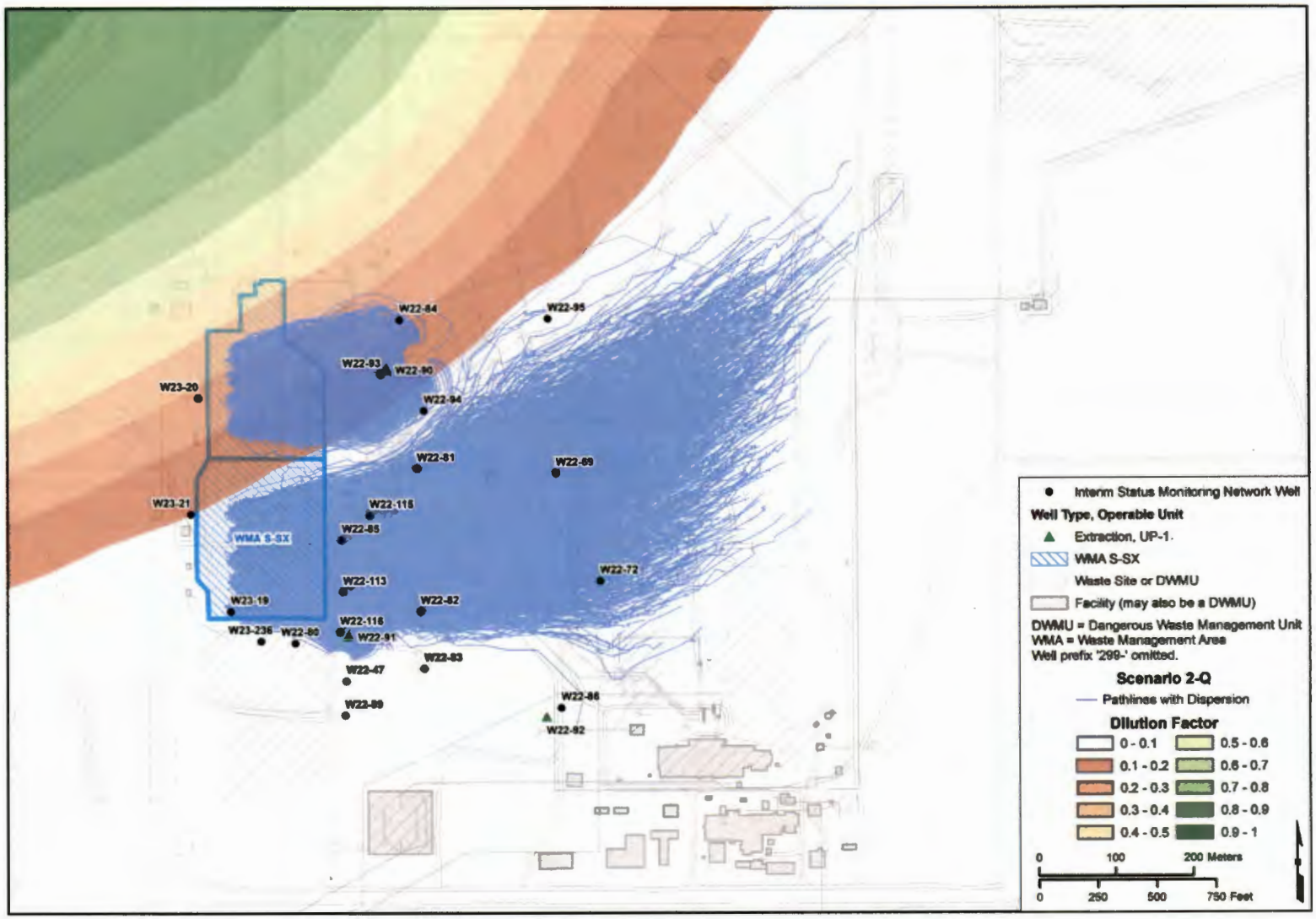

Figure 7-119. Scenario 2, Sub-scenario Q Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

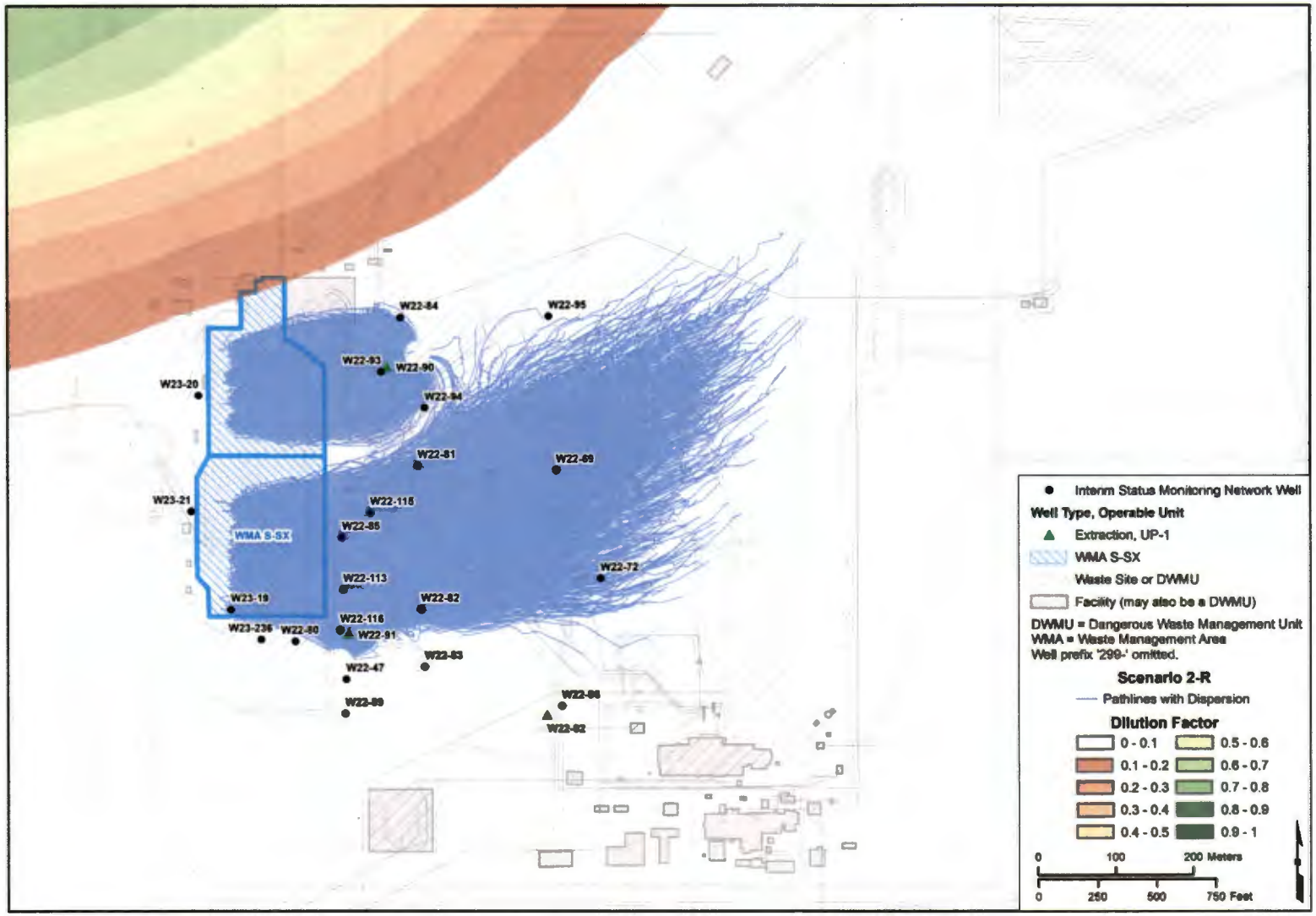

Figure 7-120. Scenario 2, Sub-scenario R Injected Treated Water Dilution Plume Superimposed with WMA S-SX Release Particle Pathlines

7.3 Scenario 3

Figure 7-121 depicts the simulated breakthrough of a unit-source water table release from WMA S-SX at monitoring wells 299-W22-47, 299-W22-69, 299-W22-72, 299-W22-80, 299-W22-81, 299-W22-82, 299-W22-83, 299-W22-84, 299-W22-85, 299-W22-86, 299-W22-89, 299-W22-93, 299-W22-94, 299-W22-95, 299-W22-113, 299-W22-115, 299-W22-116, 299-W23-19, 299-W23-20, 299-W23-21, and 299-W23-236. The release time (represented on the figure as arrival time year 0) corresponds to October 1, 2037.

Figure 7-122 depicts conditions in 2137 from the hypothetical water table release below WMA S-SX that occurs following cessation of the operation of the 200 West P&T system (i.e., initial release time follows the 200 West P&T system shutdown in 2037 [see Table 3-1 for scenario details]). A map of simulated water elevations in 2137 is included as Figure B-13 in Appendix B of ECF-200W-17-0070 to show the undisturbed groundwater system. The simulated pathlines depicted in Figure 7-122 consider both advection and dispersion.

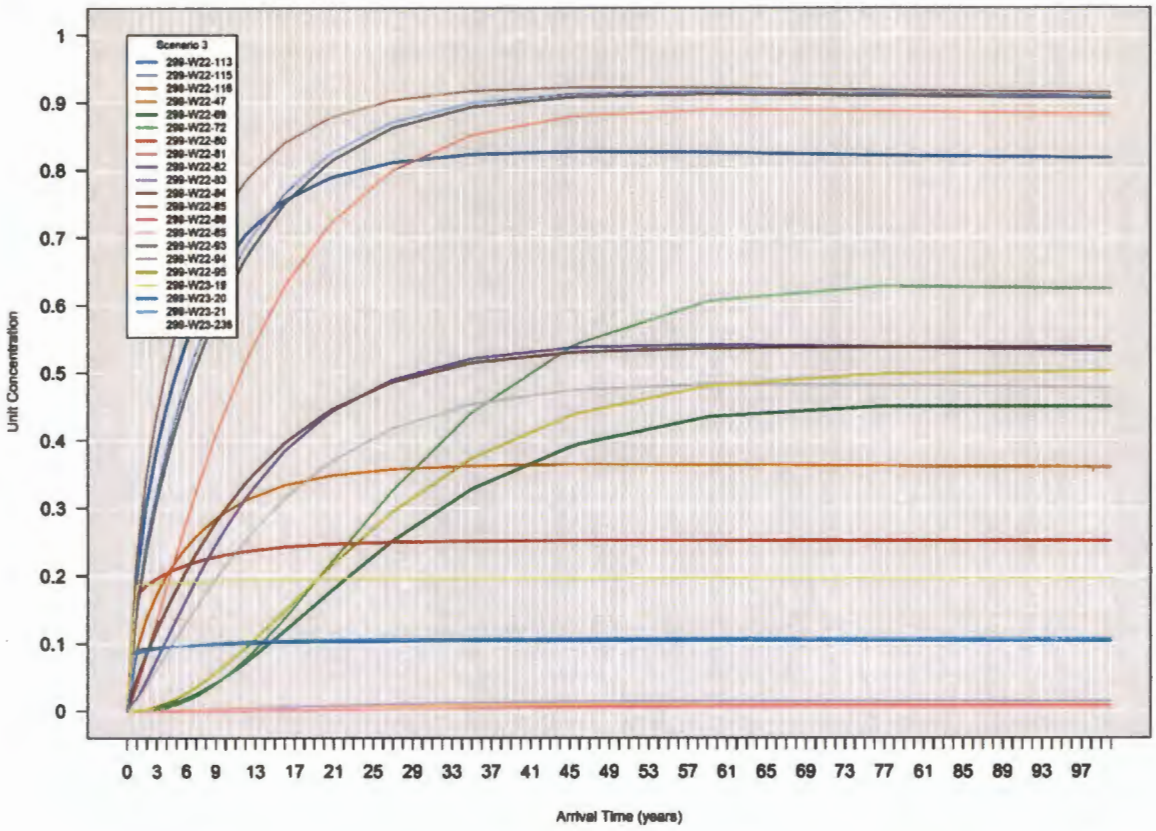

Figure 7-121. Release Concentration Breakthrough Curves at Monitoring Wells- Scenario 3

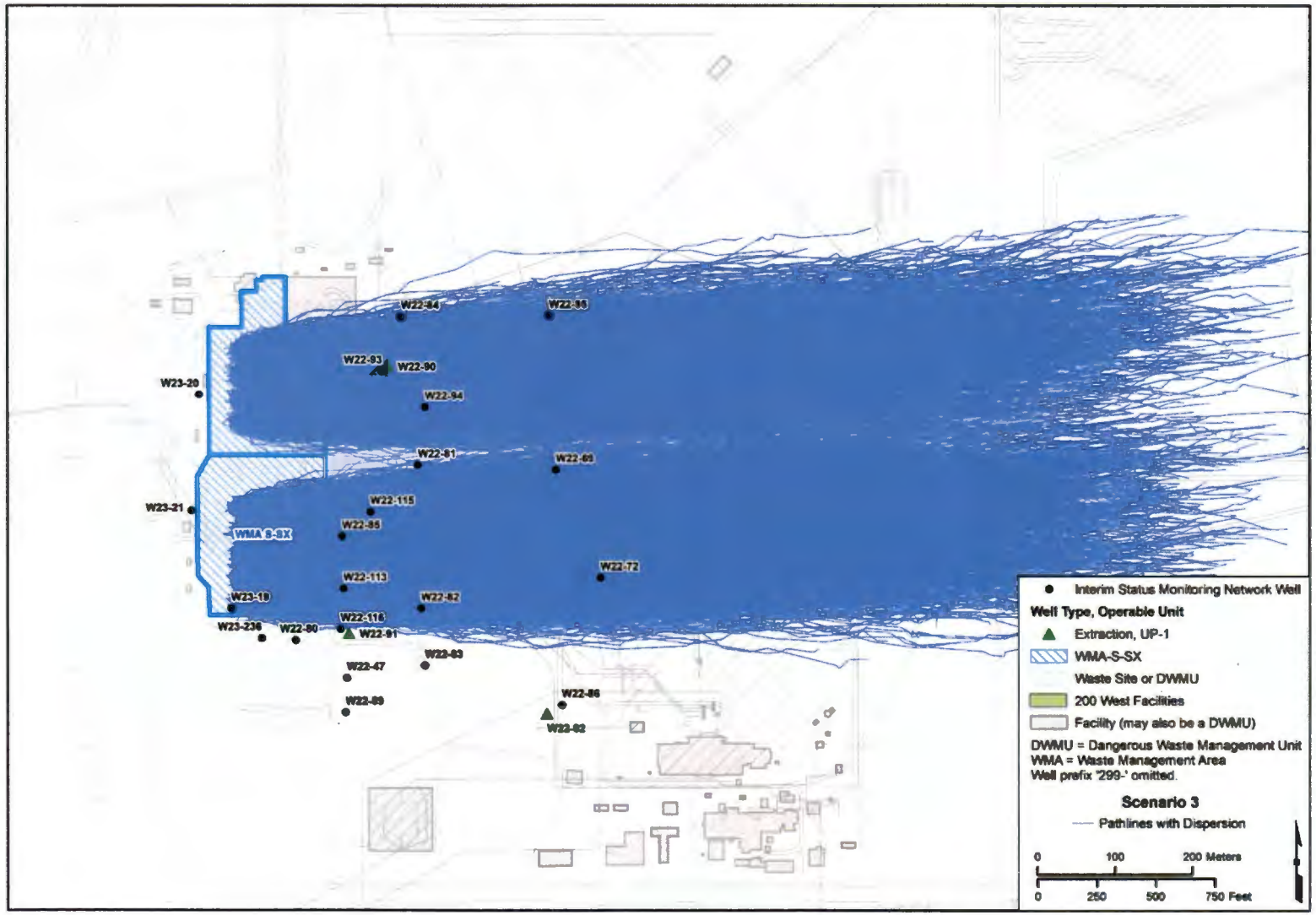

Figure 7-122. WMA S-SX Release Particle Pathlines- Scenario 3

7.4 Evaluation of System and Proposed Wells

As described earlier, the evaluation results of the particle-tracking and transport calculations can vary in some cases. Both calculation methods were considered in the evaluation of the monitoring well network. Appendix A of this ECF presents maps of the count of particles (produced using particle tracking) that traversed each cell of the refined calculation subgrid when particle tracking was simulated considering advection and dispersion for each sub-scenario of scenarios 1 and 2 and for scenario 3. Appendix B of this ECF presents the release unit plume maps (produced using transport modeling) for each sub-scenario, depicting the unit concentrations for the release to the water table under the facility. These show a spatial snapshot in model layer 2 at the end of the operation of the 200 West P&T system in 2037.

The relative detectability calculations allow more weight to be given to the more likely sub-scenarios in each scenario. The maps of relative detectability for scenarios 1, 2, and 3 were used to evaluate the existing monitoring system and identify locations where additional wells would be appropriate.
As described in Section 6.2, the relative detectability was determined for each cell of a 20 by 20 m (66 by 66 ft) calculation subgrid by calculating, for each sub-scenario, the number of released particles that traversed each subgrid cell. The calculated counts of particles for the individual cells in each sub-scenario were then used to compute a weighted sum (using the scenario weights provided in Table 3.1) for each cell for each overall scenario.

Figures 7-123 through 7-125 depict the relative detectability as calculated for scenarios 1, 2, and 3. These maps of relative detectability identify areas of the aquifer where a hypothetical release that impacts the water table beneath WMA S-SX would be most likely to migrate and be detectable. Based on the evaluations performed in this ECF, no new wells are proposed to monitor the extent of the detectable areas.

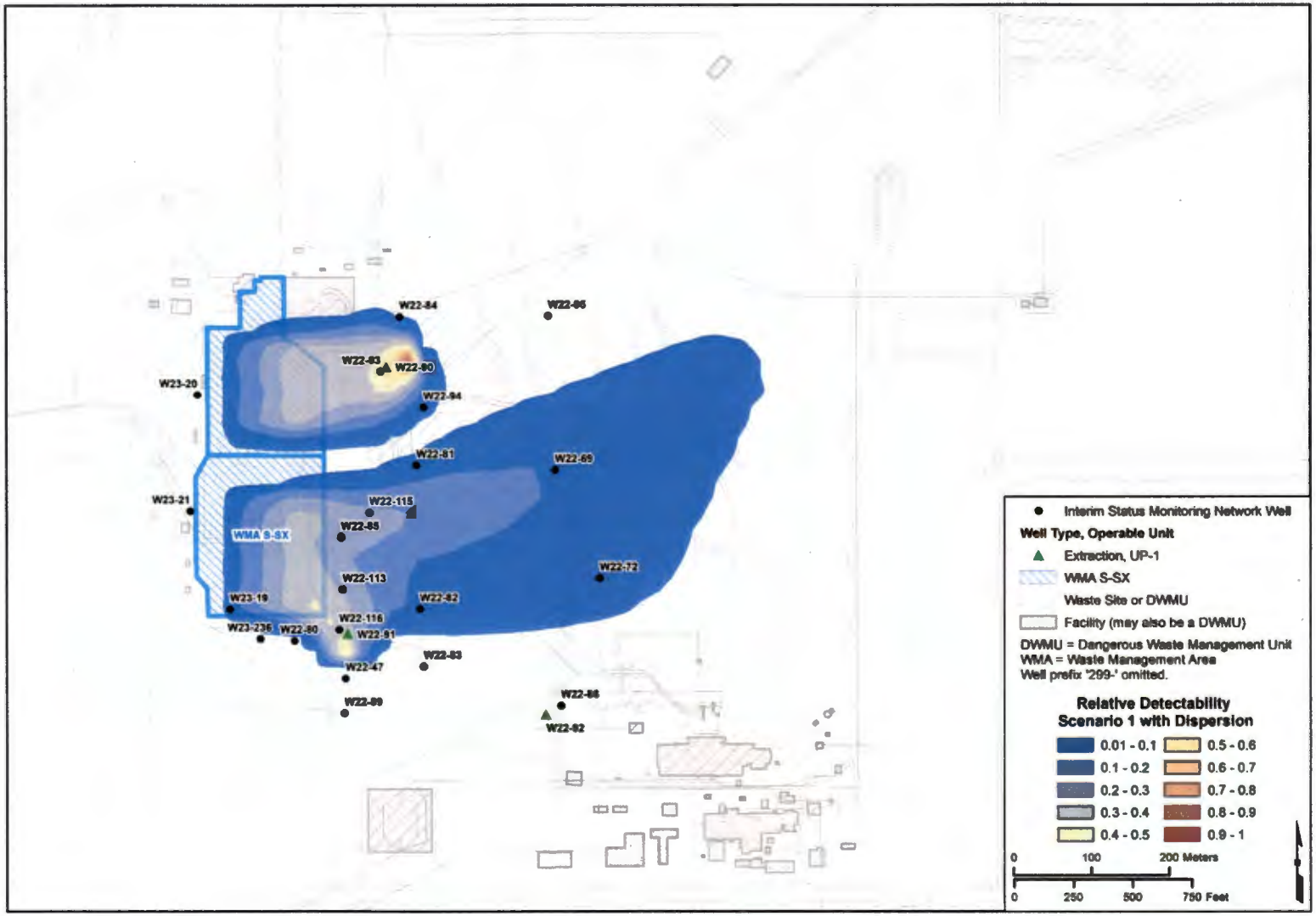

Figure 7-123. Map of Relative Detectability – Scenario 1

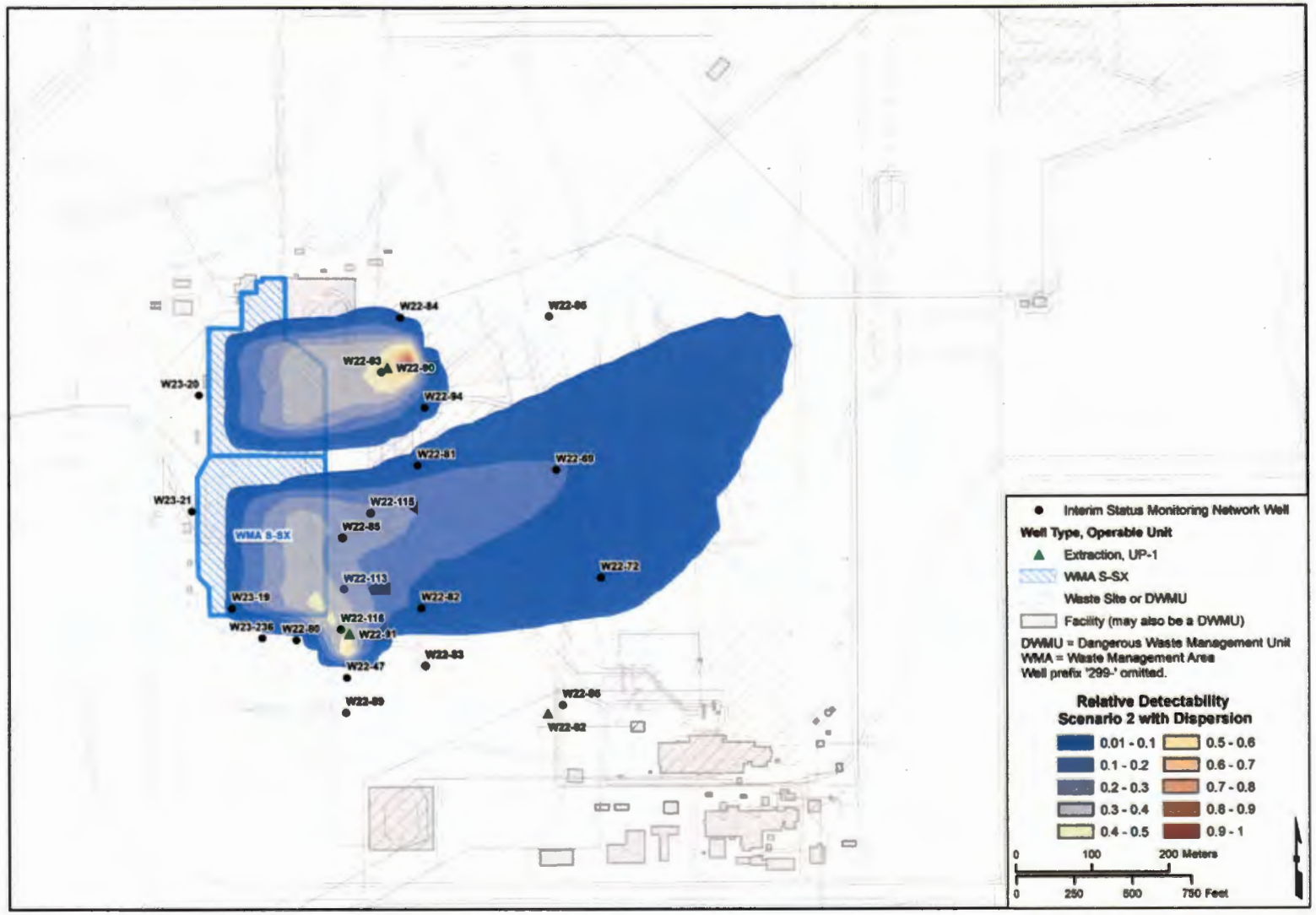

Figure 7-124. Map of Relative Detectability – Scenario 2

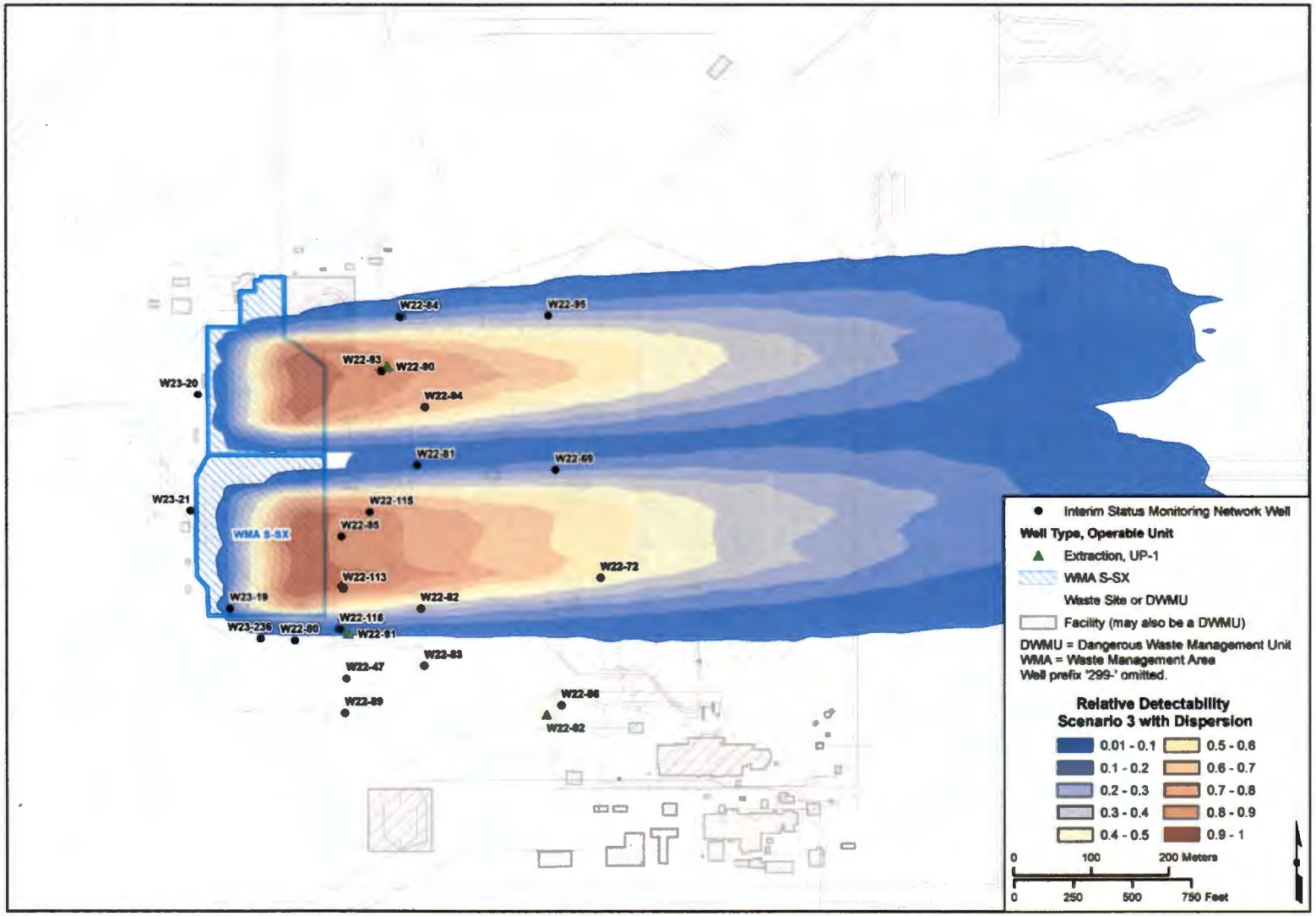

Figure 7-125. Map of Relative Detectability – Scenario 3

7.5 Vertical Migration Potential

The vertical migration of dissolved constituents was discussed in Section 7.4 of ECF-200W-17-0070. The analysis concluded that an analytical calculation, the American Petroleum Institute (API) plume diving calculation, could be used to estimate the likely rate of vertical migration of dissolved constituents downward under the influence of recharge at the water table. The API plume diving calculation estimates the anticipated slope at which the dissolved constituents will migrate, the slope of the dive:

$$Slope\ of\ Dive\ (S) = \frac{Accretion\ Rate\ (I)}{Seepage\ Velocity\ (V)} = \frac{Vertical\ velocity\ (v_v)}{Horizontal\ velocity\ (v_h)} = \frac{Recharge\ Rate\ (i)}{Darcy\ Flux\ (q)} \qquad \text{Eq. (1)}$$

The calculations performed involved dividing the recharge rate (e.g., in units of m/yr) by the Darcy Flux (in consistent units of m/yr: also known as the specific discharge). The Darcy Flux is calculated by multiplying the hydraulic conductivity by the hydraulic gradient.

The calculated slope can be used to estimate the distance beneath the water table at which dissolved concentrations will be found at a specified distance from the point of release. Thus, at each well the slope of the dive can be multiplied by the distance from the particle starting location to the well location to estimate the depth to which the dissolved constituents may be anticipated to have migrated by the time they reach the monitoring well location. This estimated depth of the plume can be compared to the depth from the water table to the bottom of the monitoring well screen. If the depth of the plume is below the bottom of the monitoring well screen, then the dissolved constituents may be anticipated to pass beneath the well screen. If it falls within the interval between the top of the water table and the bottom of the well screen, then the well depth is appropriate for detection of releases at WMA S-SX.

For each downgradient monitoring well at WMA S-SX, the distance used in the calculation was the distance from the centroid of the facility to each well location. The results of the API plume diving calculation for the downgradient wells for WMA S-SX is shown in Table 7-1

Table 7-1 Summary of Well Screen Interval Evaluation for Downgradient Wells

Monitoring Well	Existing or Proposed Well?	Distance, D, (m)[a]	Recharge, *i*, (m/yr)[b]	Slope, S, of Plume Dive[c]	Estimated Depth of Plume Below Water Table (m)[d]	Depth from Water Table to Bottom of Well Screen (m)[e]	Is Plume Depth Above Bottom of the Screen? (Yes/No/N/A)
299-W22-113	Existing	188.7	8.8E-03	0.0020	0.37	8.70	Yes
299-W22-115	Existing	149.9	8.8E-03	0.0020	0.29	9.70	Yes
299-W22-116	Existing	233.0	8.8E-03	0.0020	0.45	10.40	Yes
299-W22-80	Existing	228.9	8.8E-03	0.0020	0.45	5.80	Yes
299-W22-81	Existing	199.0	8.8E-03	0.0020	0.39	6.00	Yes
299-W22-82	Existing	274.1	8.8E-03	0.0020	0.54	5.70	Yes
299-W22-83	Existing	331.4	8.8E-03	0.0020	0.65	5.50	Yes
299-W22-84	Existing	265.1	8.8E-03	0.0020	0.52	5.90	Yes
299-W22-85	Existing	135.8	8.8E-03	0.0020	0.27	5.60	Yes
299-W22-86	Existing	494.3	8.8E-03	0.0020	0.96	7.50	Yes
299-W22-89	Existing	336.0	8.8E-03	0.0020	0.66	8.00	Yes
299-W22-93	Existing	200.3	8.8E-03	0.0020	0.39	10.70	Yes
299-W22-94	Existing	223.0	8.8E-03	0.0020	0.44	9.20	Yes
299-W22-95	Existing	419.2	1.6E-02	0.0035	1.47	11.90	Yes
299-W22-72	Existing	459.1	1.6E-02	0.0037	1.68	7.30	Yes
299-W22-69	Existing	378.3	8.8E-03	0.0020	0.74	7.70	Yes
299-W22-47	Existing	294.7	8.8E-03	0.0020	0.58	7.20	Yes
299-W23-19	Existing	188.9	8.8E-03	0.0020	0.37	4.01	Yes
299-W23-236	Existing	222.6	8.8E-03	0.0020	0.43	10.50	Yes

Table 7-1 Summary of Well Screen Interval Evaluation for Downgradient Wells

Monitoring Well	Existing or Proposed Well?	Distance, D, (m)[a]	Recharge, *i*, (m/yr)[b]	Slope, S, of Plume Dive[c]	Estimated Depth of Plume Below Water Table (m)[d]	Depth from Water Table to Bottom of Well Screen (m)[e]	Is Plume Depth Above Bottom of the Screen? (Yes/No/N/A)

a. Distance of the well from centroid of dangerous waste management unit.

b. A representative number from CPGWM. The recharge values represent fluxes from surface water discharge due to historical operations at the Hanford Site and are summarized in EMDT-BC-0002, *Vadose Zone Attenuated Recharge, Electronic Modeling Data Transmittal – Boundary Condition (Artificial Recharge) – 0002*. The anthropogenic flux is added to the natural recharge component in order to establish the final total recharge flux used in the simulations. Discharges included in EMDT-BC-0002 have been attenuated to account for travel through the vadose zone.

c. Slope of the plume dive computed using the American Petroleum Institute plume diving calculation as detailed in ECF-200W-17-0070, *Groundwater Flow and Migration Calculations to Support Assessment of the Hanford Central Plateau 200 West Facilities Monitoring Network*. The migration parameters for WMA S-SX used in the calculation of slope are:

Hydraulic conductivity: 5 m/d (a representative number from multiple sources including CPGWM)

Hydraulic gradient: 2.5E-03 (a representative number from CPGWM, and water-level maps)

d. Plume depth at monitoring well location computed from distance, D, times the slope, S.

e. Depths obtained from Table 3-11 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*.

CPGWM = Central Plateau Groundwater Model

N/A = not applicable

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Appendix A

WMA S-SX Particle Count Maps

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Figures

Figure A-1. Particle Count Scenario 1, Sub-scenario A with Dispersion A-1
Figure A-2. Particle Count Scenario 1, Sub-scenario B with Dispersion A-2
Figure A-3. Particle Count Scenario 1, Sub-scenario C with Dispersion A-3
Figure A-4. Particle Count Scenario 1, Sub-scenario D with Dispersion A-4
Figure A-5. Particle Count Scenario 1, Sub-scenario E with Dispersion A-5
Figure A-6. Particle Count Scenario 1, Sub-scenario F with Dispersion A-6
Figure A-7. Particle Count Scenario 1, Sub-scenario G with Dispersion A-7
Figure A-8. Particle Count Scenario 1, Sub-scenario H with Dispersion A-8
Figure A-9. Particle Count Scenario 1, Sub-scenario I with Dispersion A-9
Figure A-10. Particle Count Scenario 1, Sub-scenario J with Dispersion A-10
Figure A-11. Particle Count Scenario 1, Sub-scenario K with Dispersion A-11
Figure A-12. Particle Count Scenario 1, Sub-scenario L with Dispersion A-12
Figure A-13. Particle Count Scenario 1, Sub-scenario M with Dispersion A-13
Figure A-14. Particle Count Scenario 1, Sub-scenario N with Dispersion A-14
Figure A-15. Particle Count Scenario 1, Sub-scenario O with Dispersion A-15
Figure A-16. Particle Count Scenario 1, Sub-scenario P with Dispersion A-16
Figure A-17. Particle Count Scenario 1, Sub-scenario Q with Dispersion A-17
Figure A-18. Particle Count Scenario 1, Sub-scenario R with Dispersion A-18
Figure A-19. Particle Count Scenario 2, Sub-scenario A with Dispersion A-19
Figure A-20. Particle Count Scenario 2, Sub-scenario B with Dispersion A-20
Figure A-21. Particle Count Scenario 2, Sub-scenario C with Dispersion A-21
Figure A-22. Particle Count Scenario 2, Sub-scenario D with Dispersion A-22
Figure A-23. Particle Count Scenario 2, Sub-scenario E with Dispersion A-23
Figure A-24. Particle Count Scenario 2, Sub-scenario F with Dispersion A-24
Figure A-25. Particle Count Scenario 2, Sub-scenario G with Dispersion A-25
Figure A-26. Particle Count Scenario 2, Sub-scenario H with Dispersion A-26
Figure A-27. Particle Count Scenario 2, Sub-scenario I with Dispersion A-27
Figure A-28. Particle Count Scenario 2, Sub-scenario J with Dispersion A-28
Figure A-29. Particle Count Scenario 2, Sub-scenario K with Dispersion A-29
Figure A-30. Particle Count Scenario 2, Sub-scenario L with Dispersion A-30
Figure A-31. Particle Count Scenario 2, Sub-scenario M with Dispersion A-31
Figure A-32. Particle Count Scenario 2, Sub-scenario N with Dispersion A-32
Figure A-33. Particle Count Scenario 2, Sub-scenario O with Dispersion A-33
Figure A-34. Particle Count Scenario 2, Sub-scenario P with Dispersion A-34
Figure A-35. Particle Count Scenario 2, Sub-scenario Q with Dispersion A-35
Figure A-36. Particle Count Scenario 2, Sub-scenario R with Dispersion A-36

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Terms

DWMU	dangerous waste management unit
WMA	waste management area

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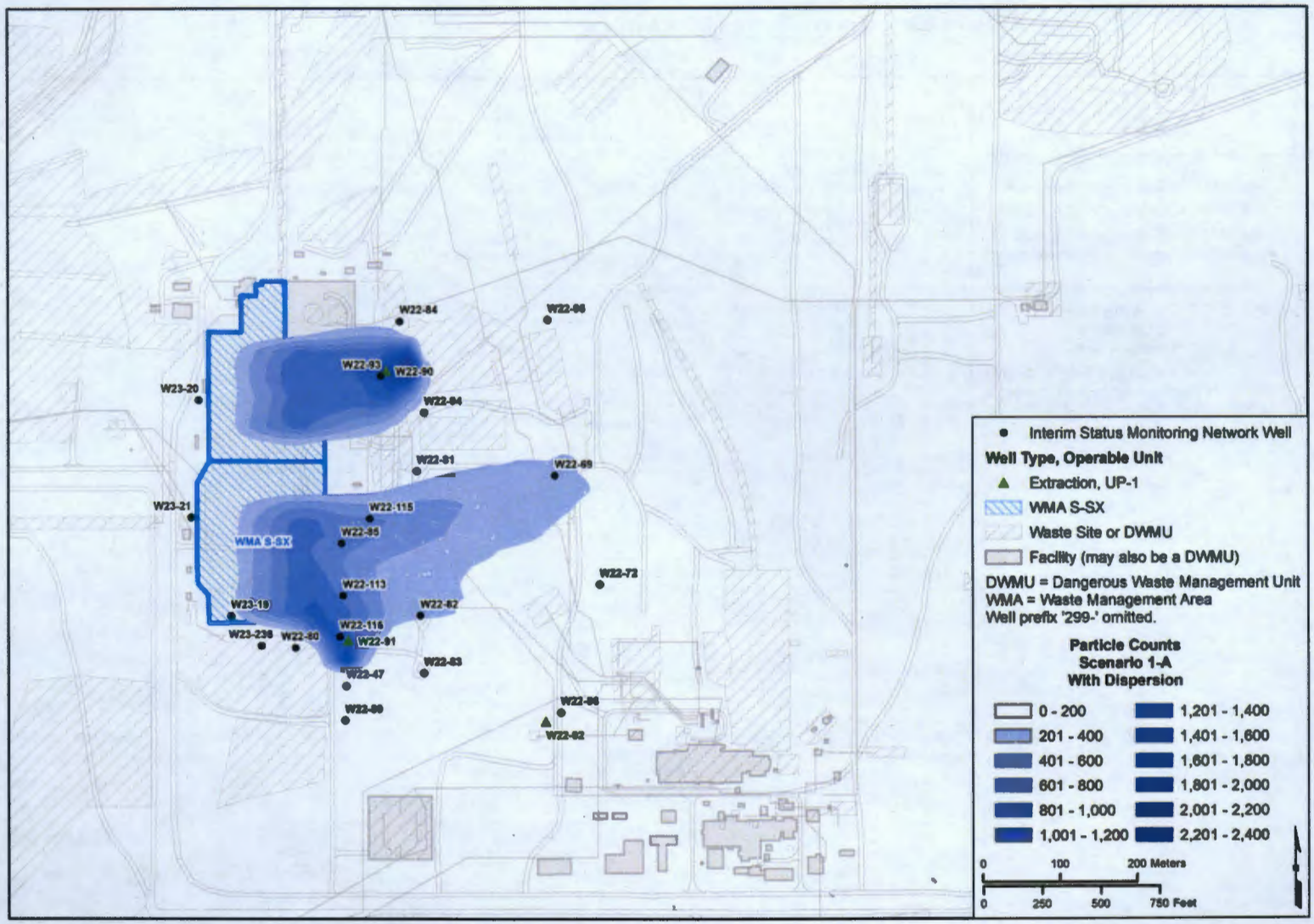

Figure A-1. Particle Count Scenario 1, Sub-scenario A with Dispersion

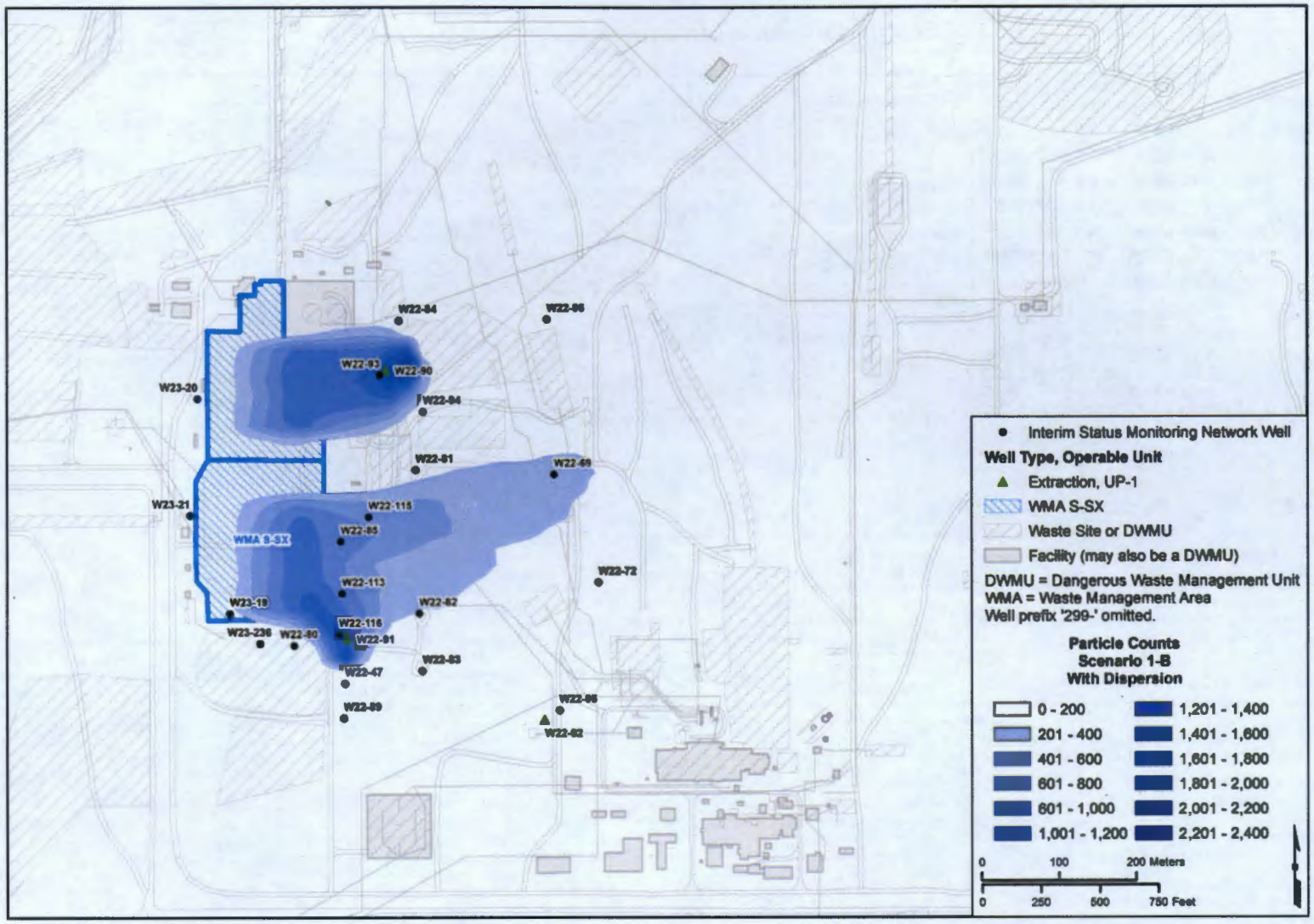

Figure A-2. Particle Count Scenario 1, Sub-scenario B with Dispersion

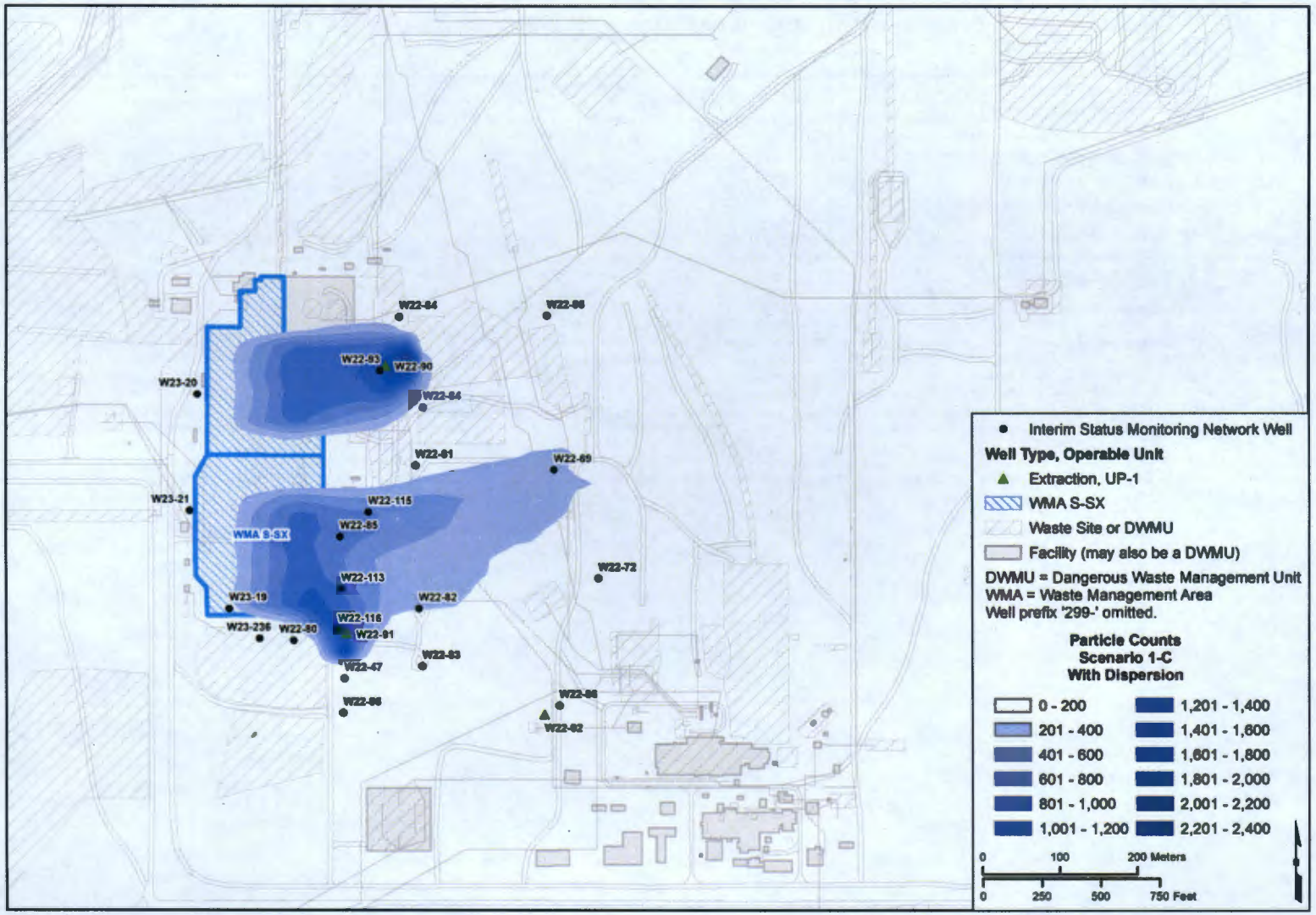

Figure A-3. Particle Count Scenario 1, Sub-scenario C with Dispersion

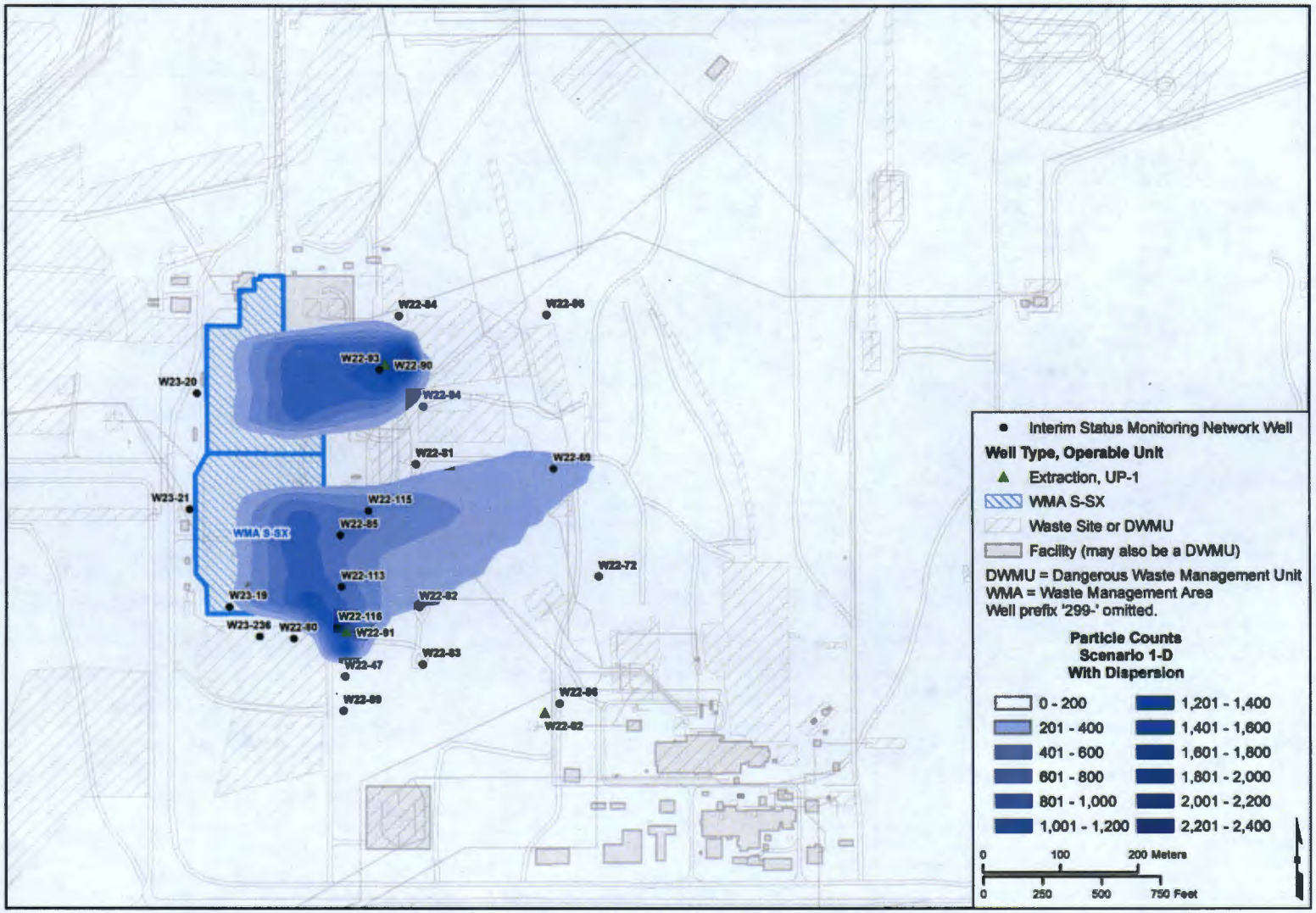

Figure A-4. Particle Count Scenario 1, Sub-scenario D with Dispersion

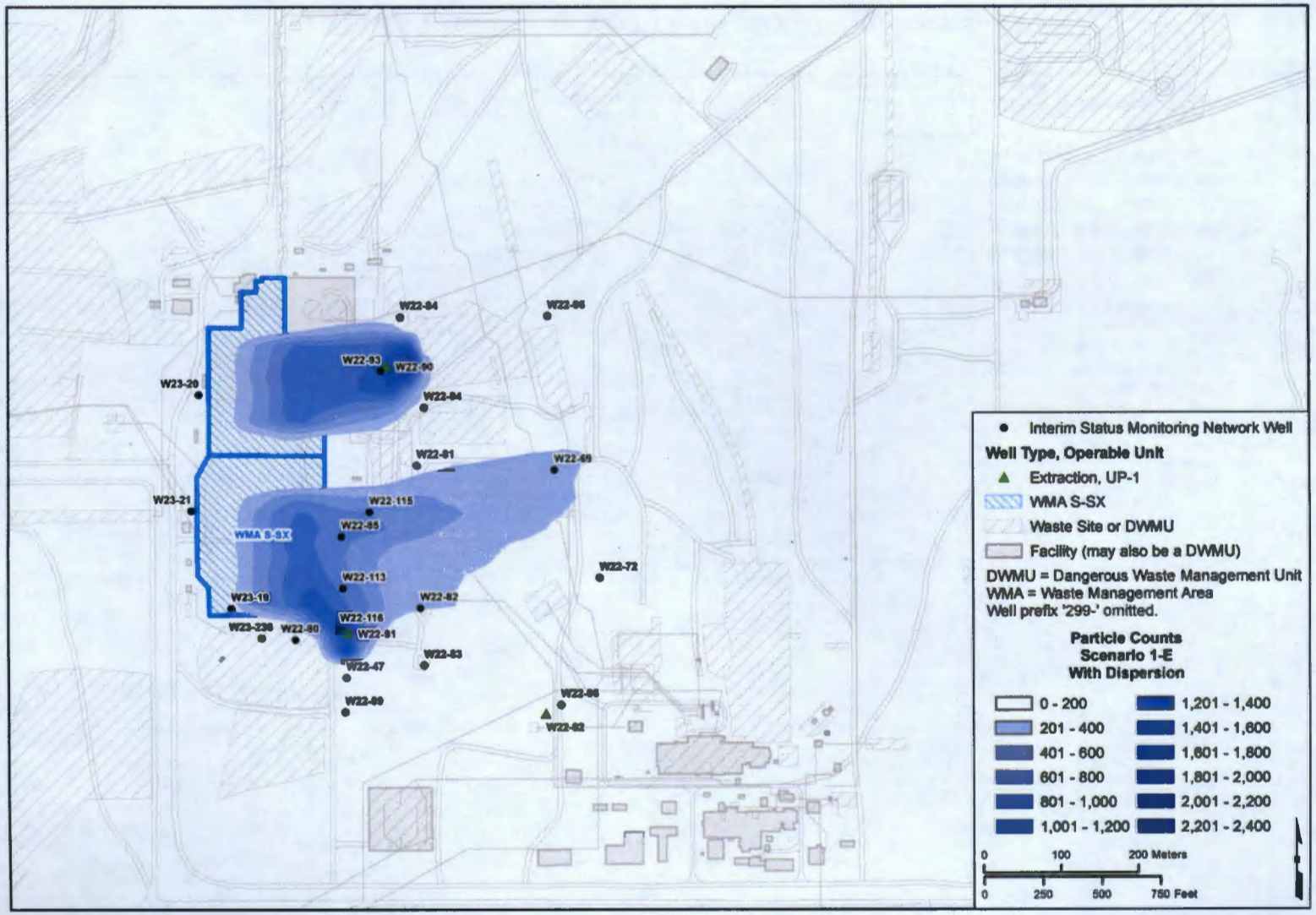

Figure A-5. Particle Count Scenario 1, Sub-scenario E with Dispersion

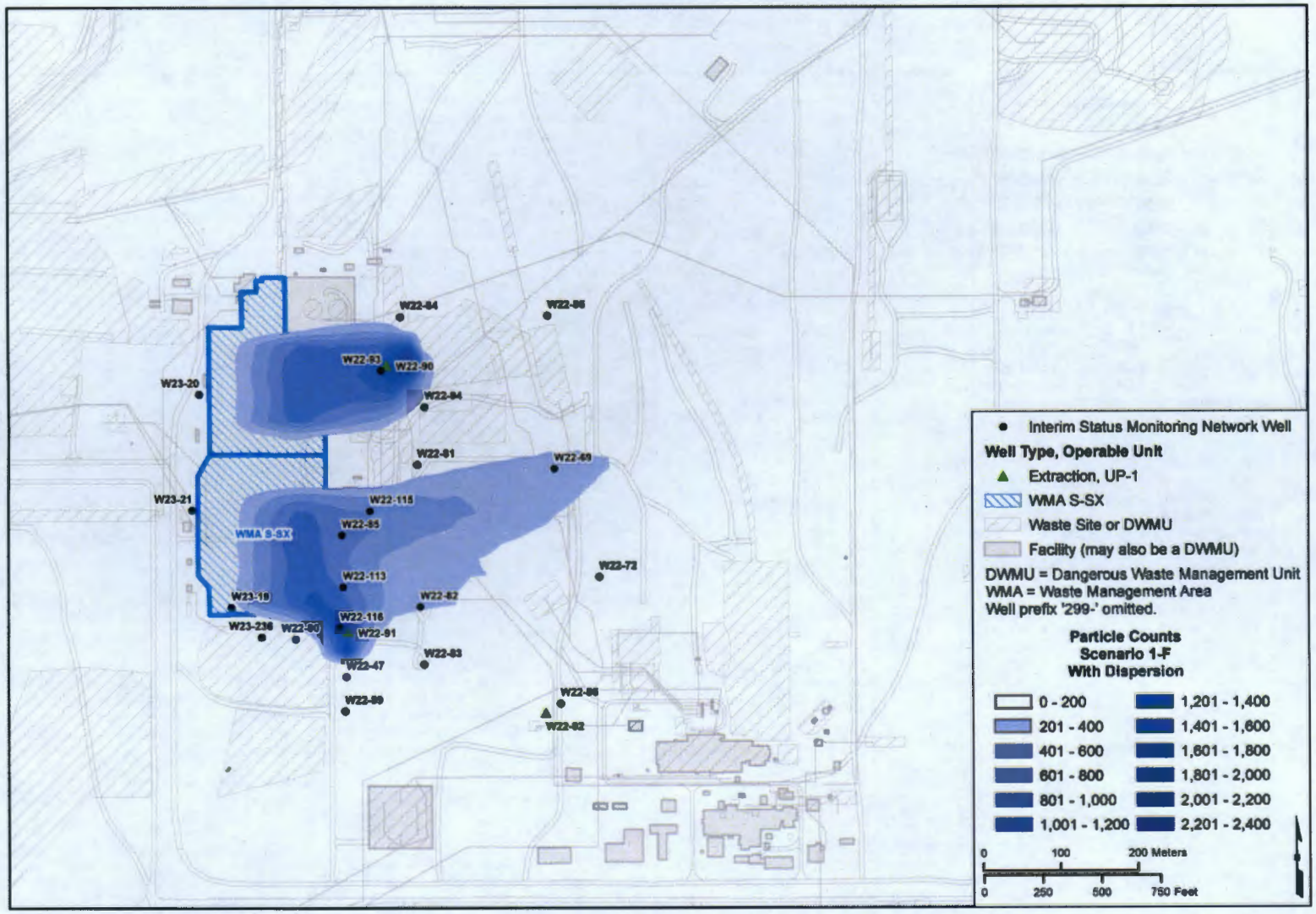

Figure A-6. Particle Count Scenario 1, Sub-scenario F with Dispersion

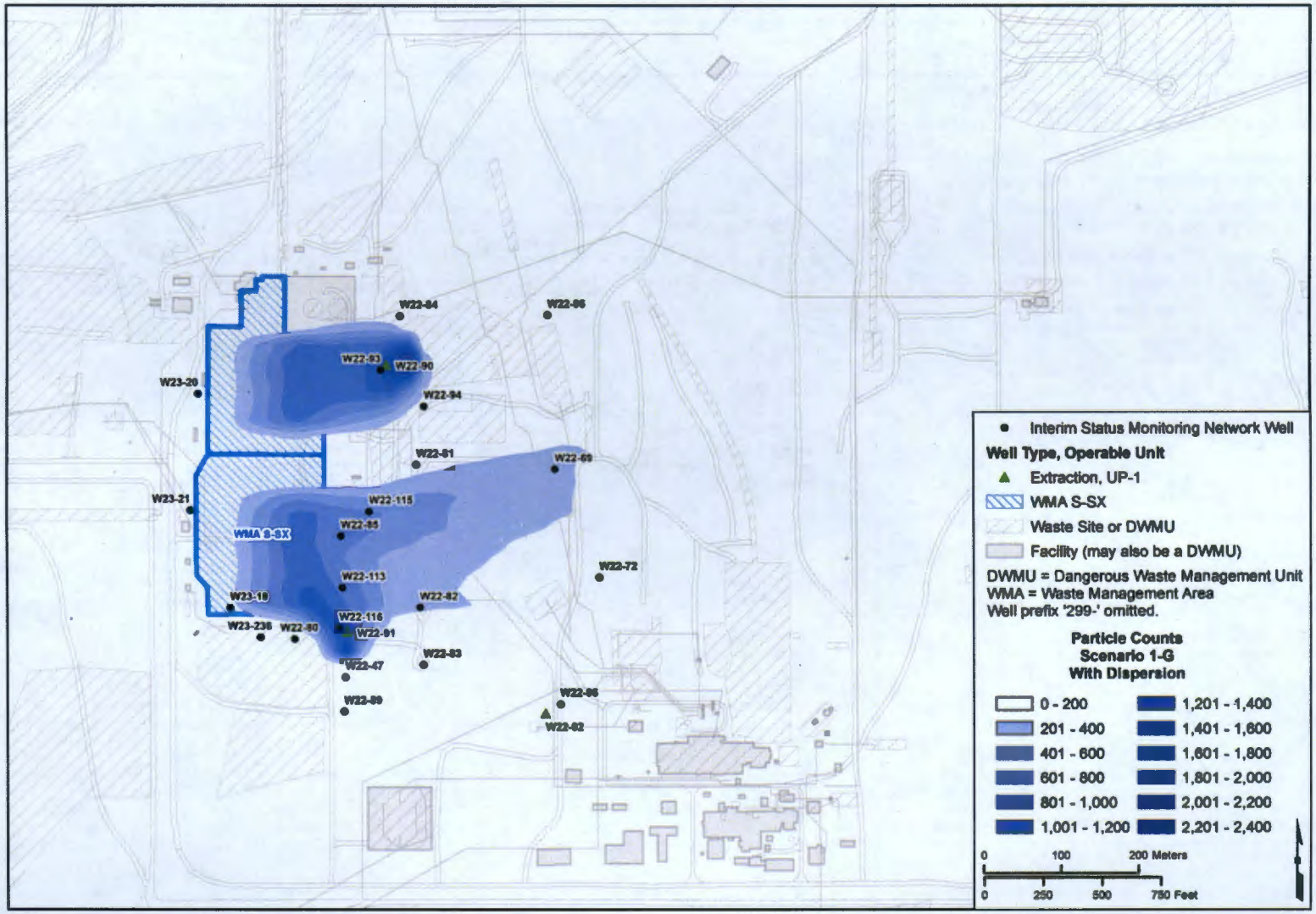

Figure A-7. Particle Count Scenario 1, Sub-scenario G with Dispersion

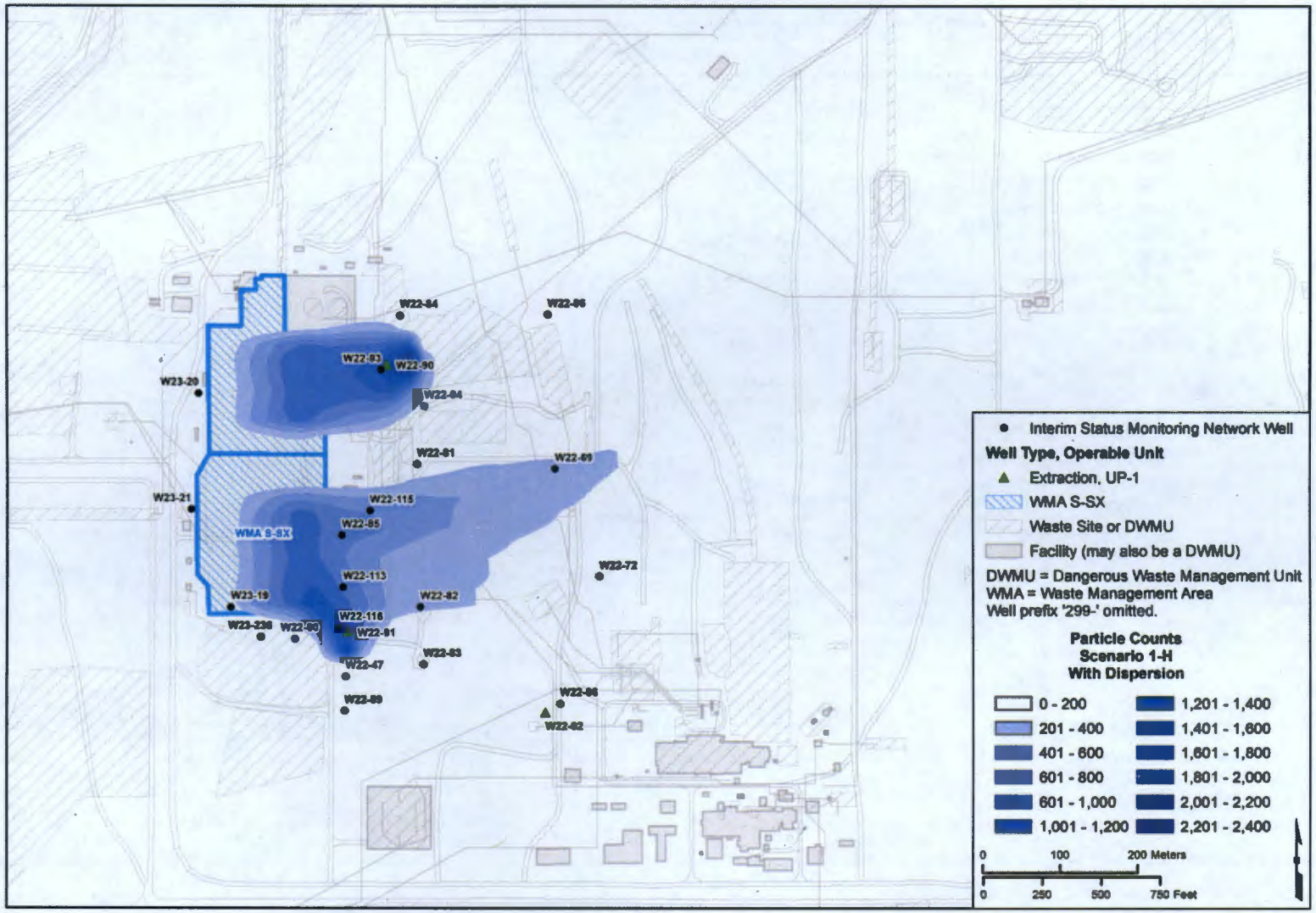

Figure A-8. Particle Count Scenario 1, Sub-scenario H with Dispersion

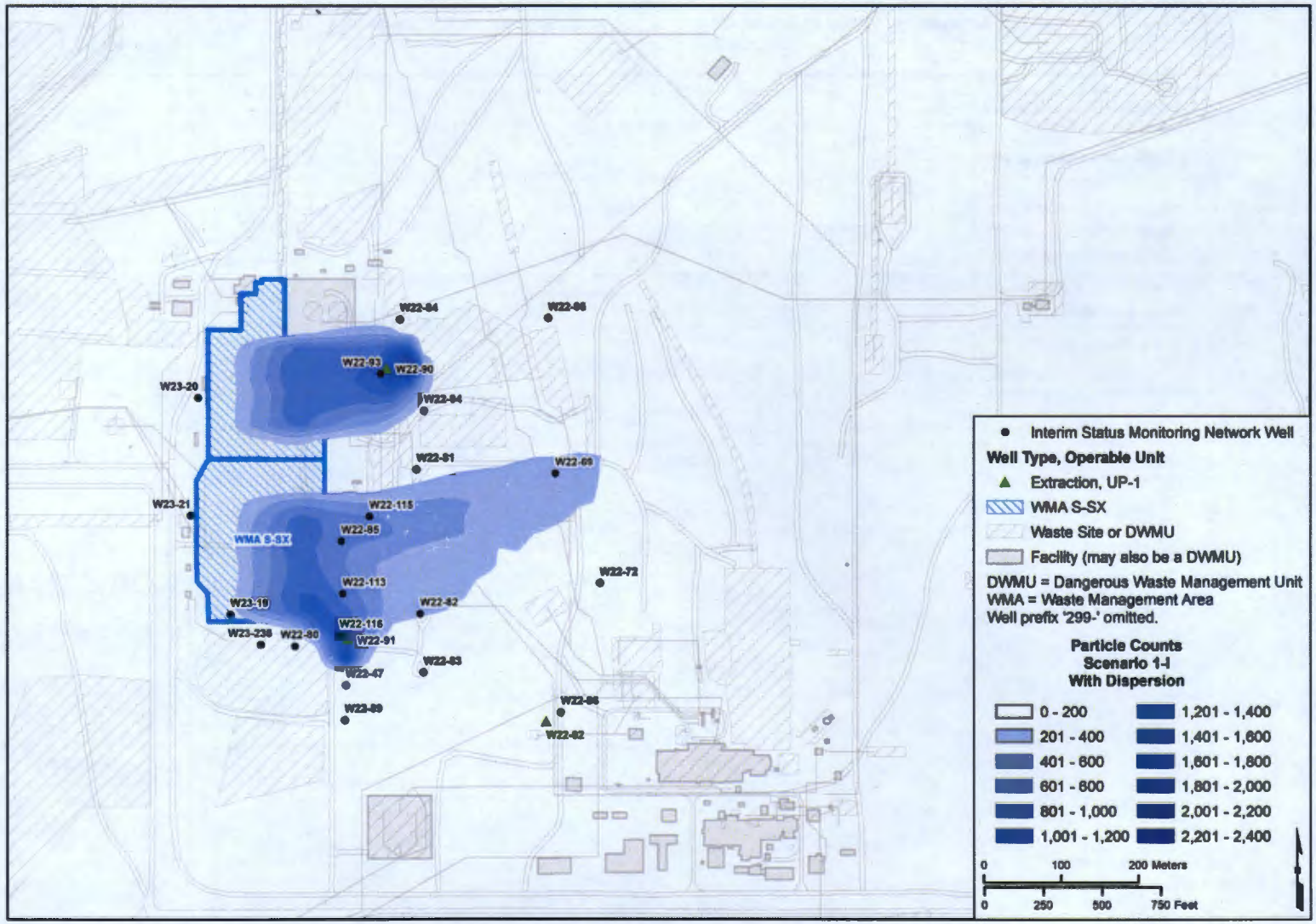

Figure A-9. Particle Count Scenario 1, Sub-scenario I with Dispersion

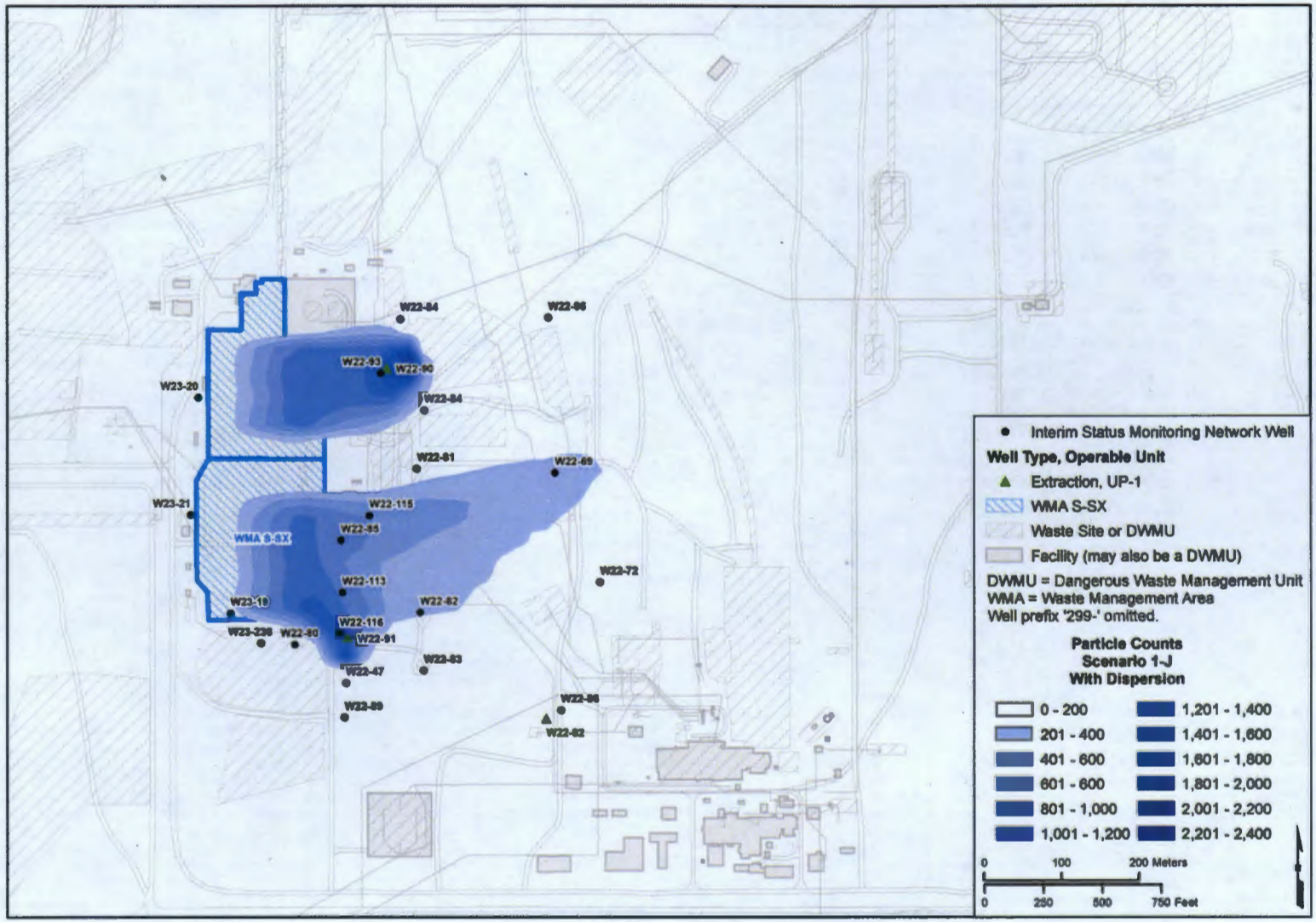

Figure A-10. Particle Count Scenario 1, Sub-scenario J with Dispersion

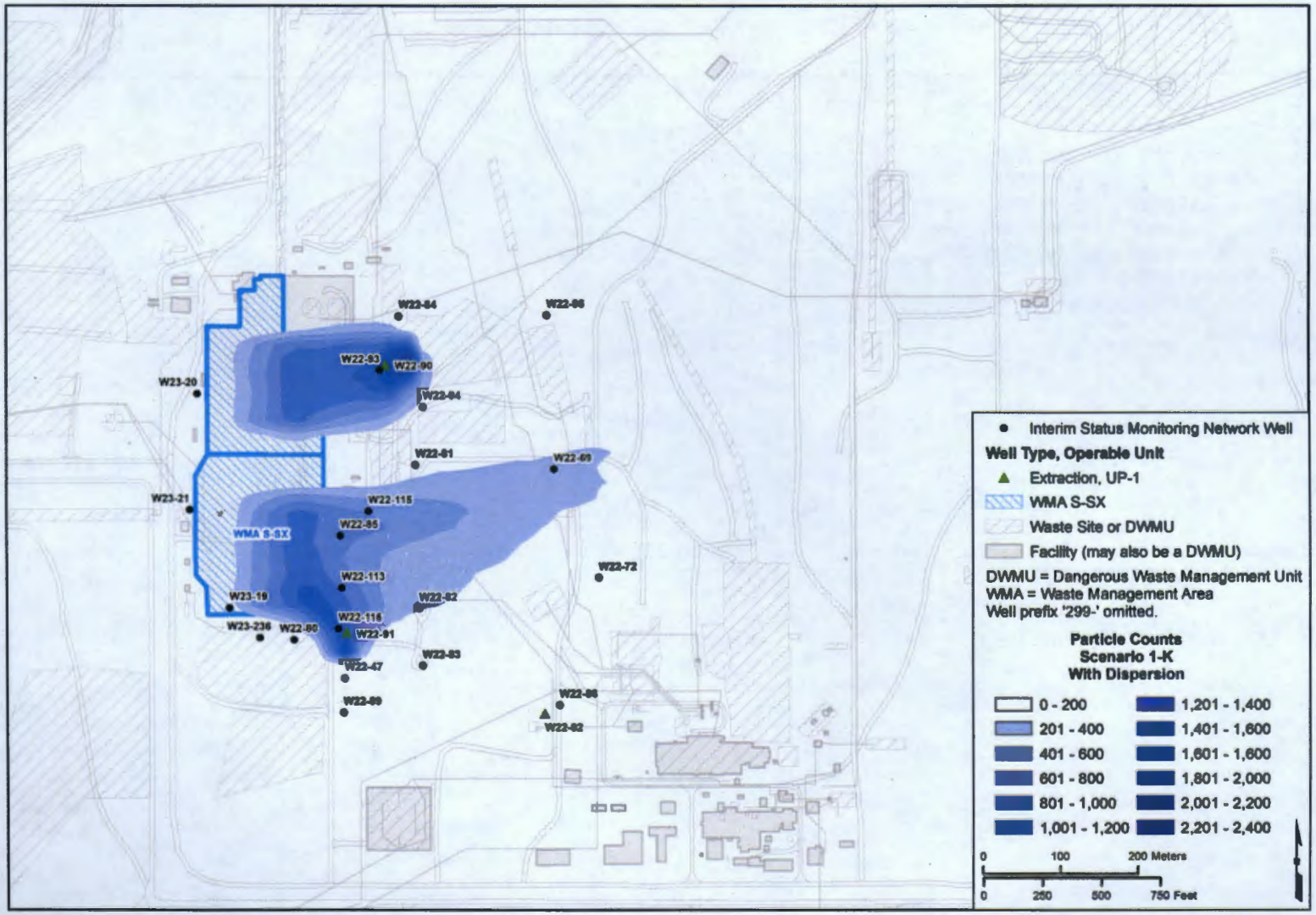

Figure A-11. Particle Count Scenario 1, Sub-scenario K with Dispersion

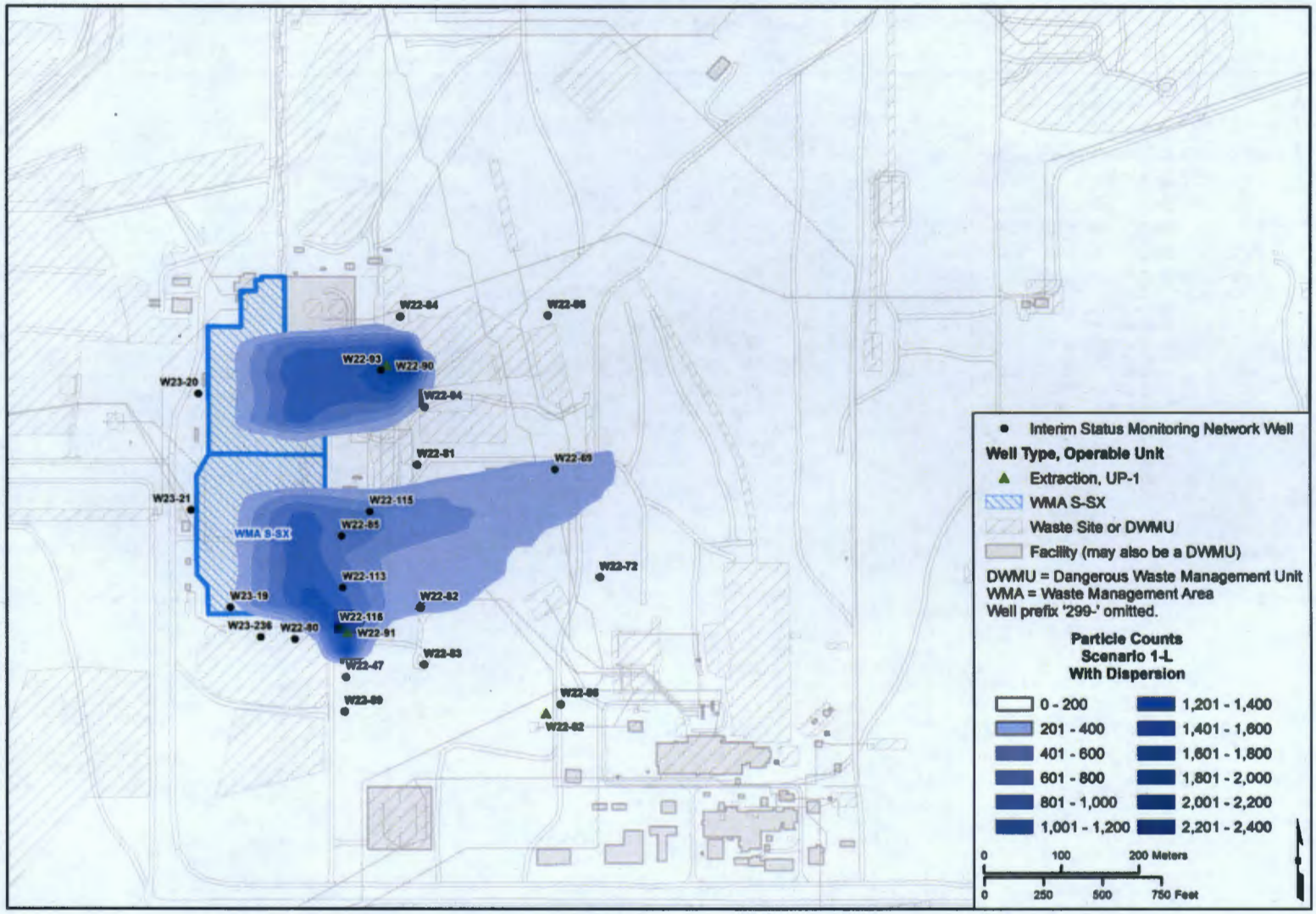

Figure A-12. Particle Count Scenario 1, Sub-scenario L with Dispersion

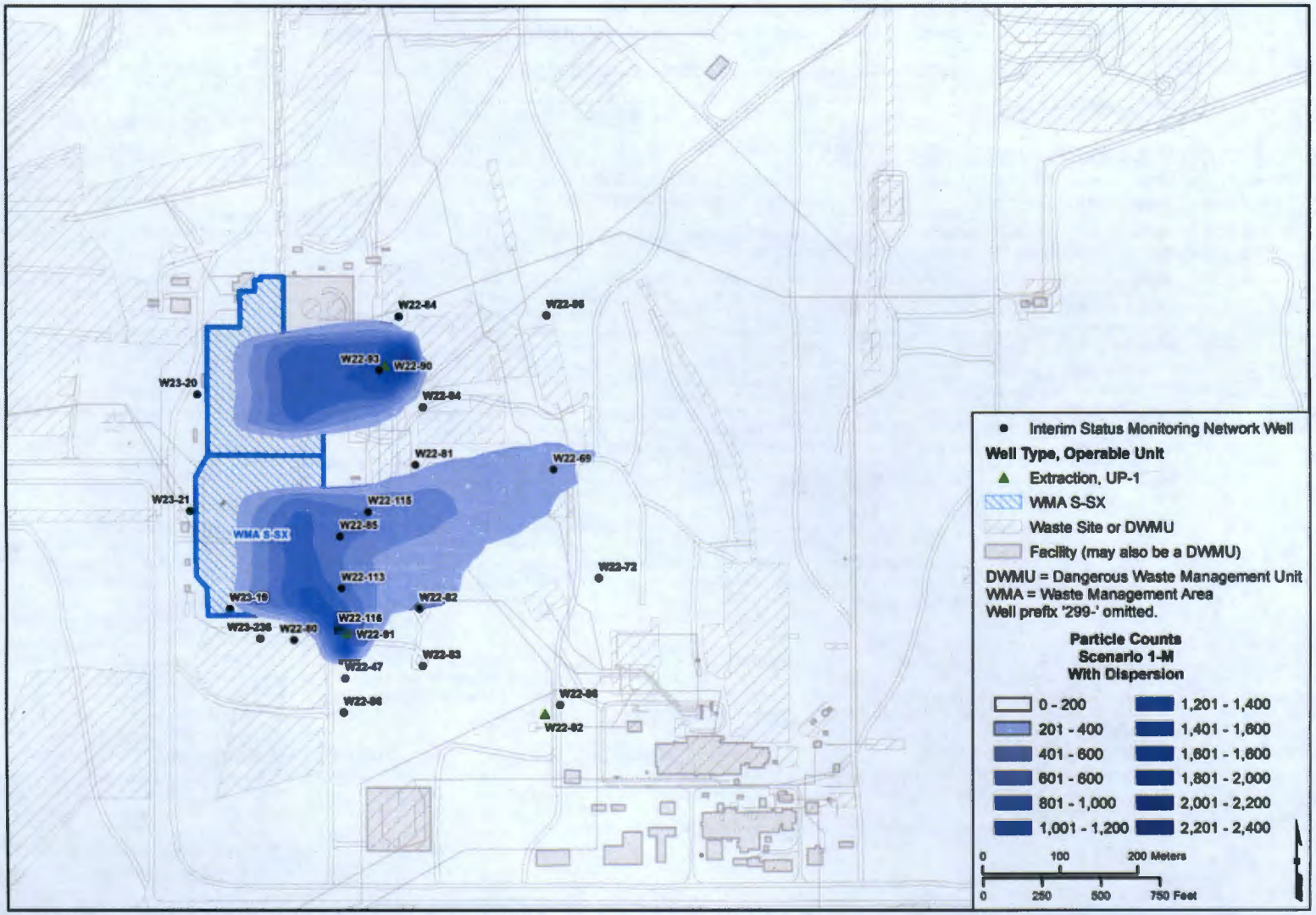

Figure A-13. Particle Count Scenario 1, Sub-scenario M with Dispersion

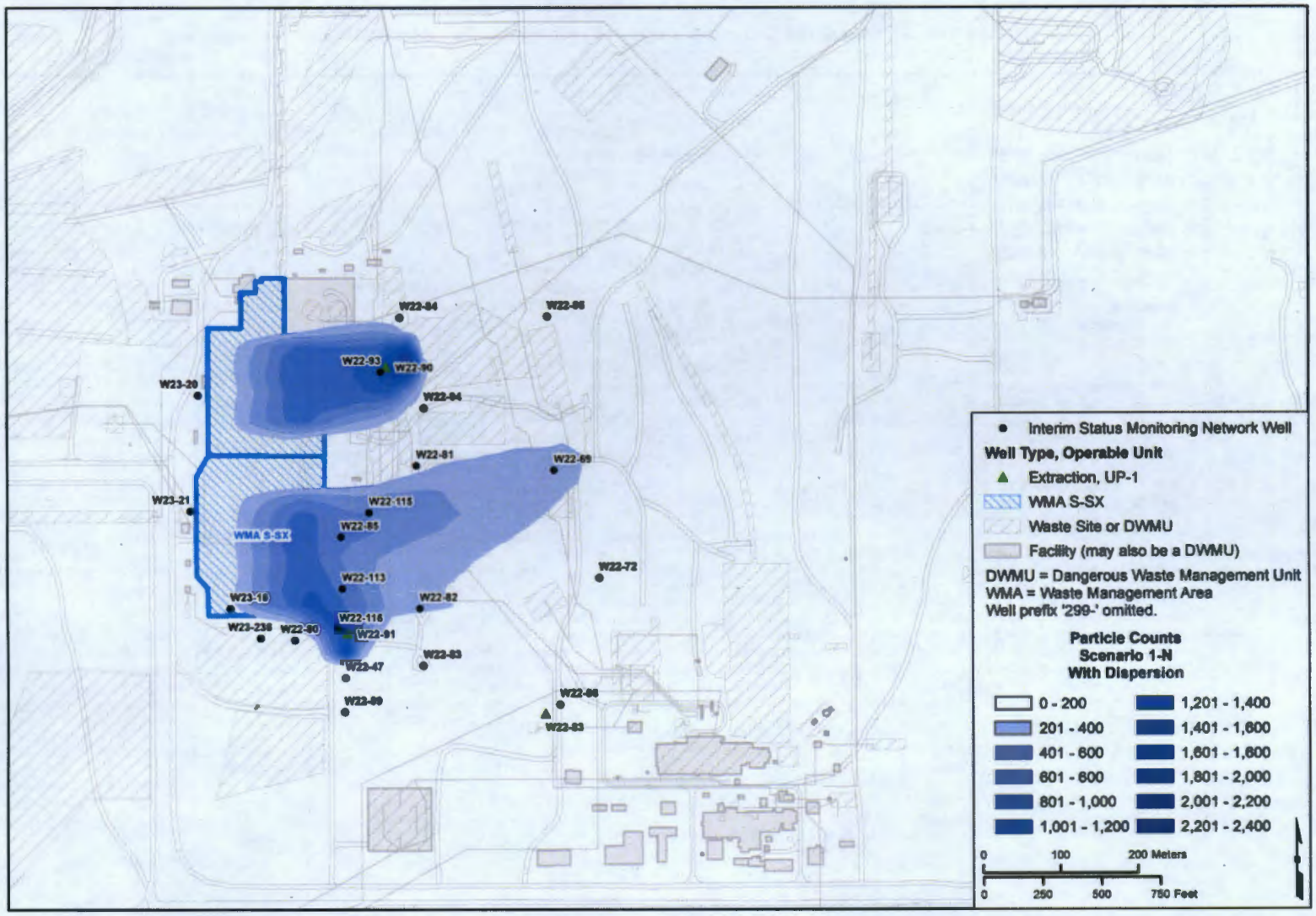

Figure A-14. Particle Count Scenario 1, Sub-scenario N with Dispersion

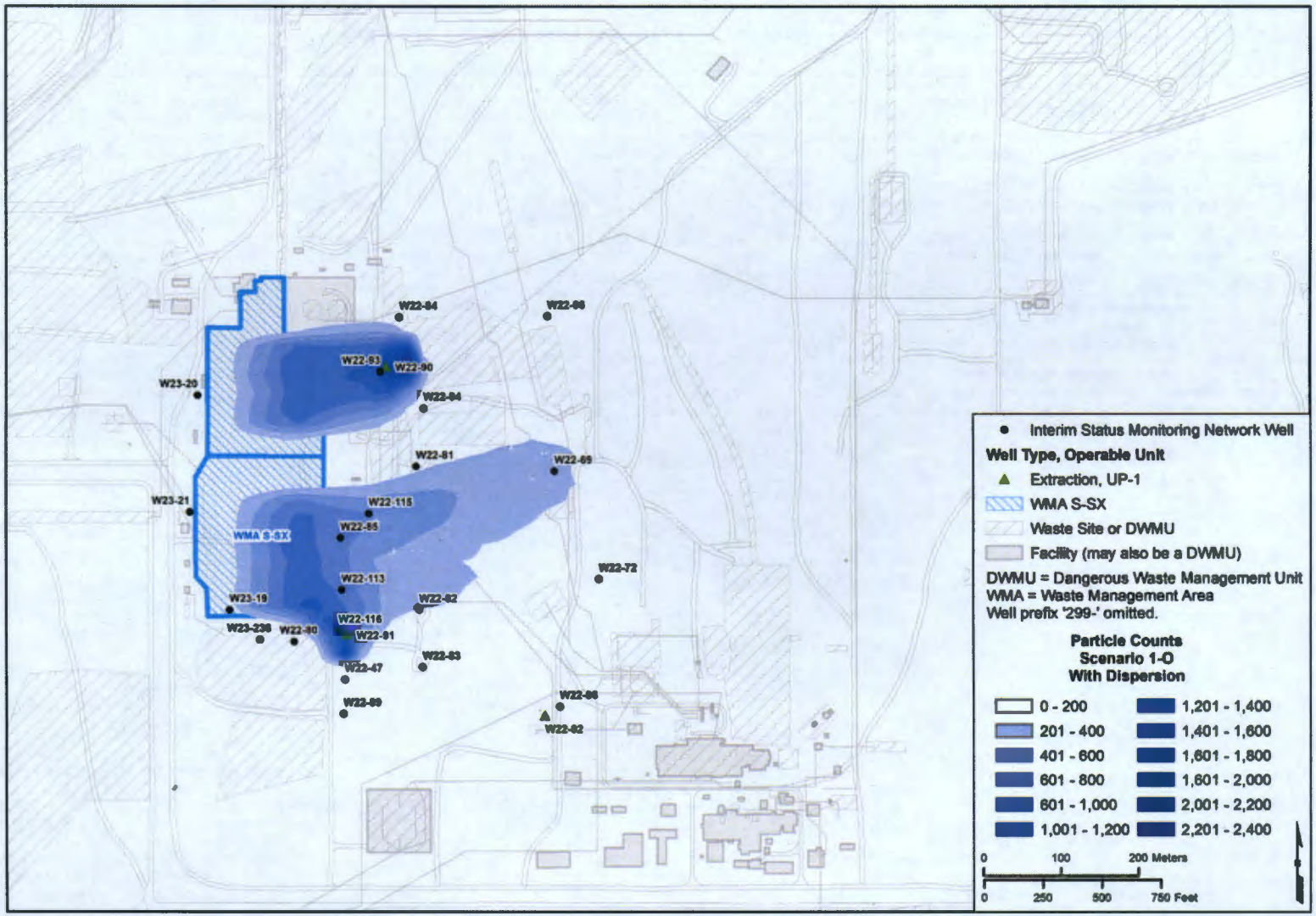

Figure A-15. Particle Count Scenario 1, Sub-scenario O with Dispersion

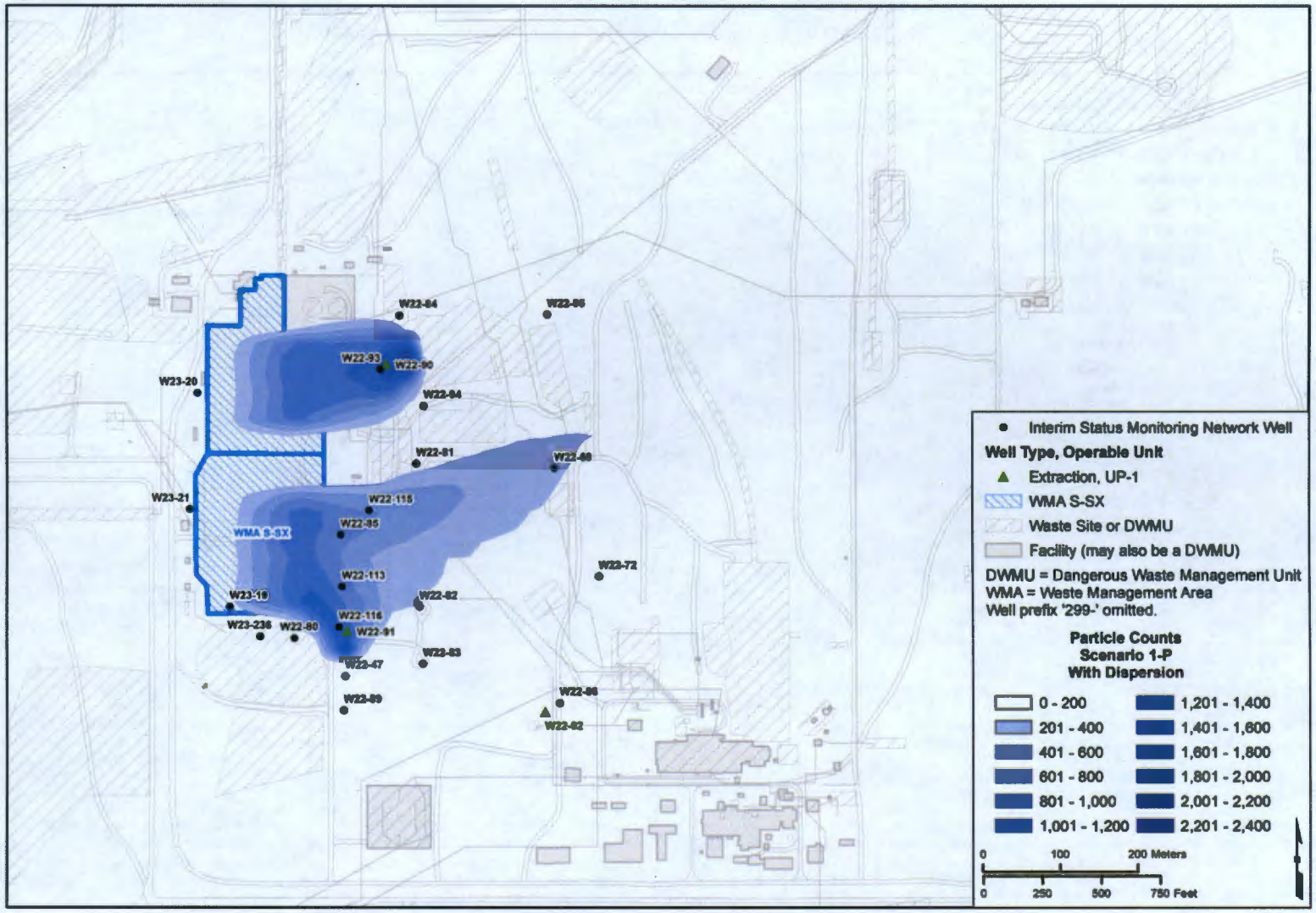

Figure A-16. Particle Count Scenario 1, Sub-scenario P with Dispersion

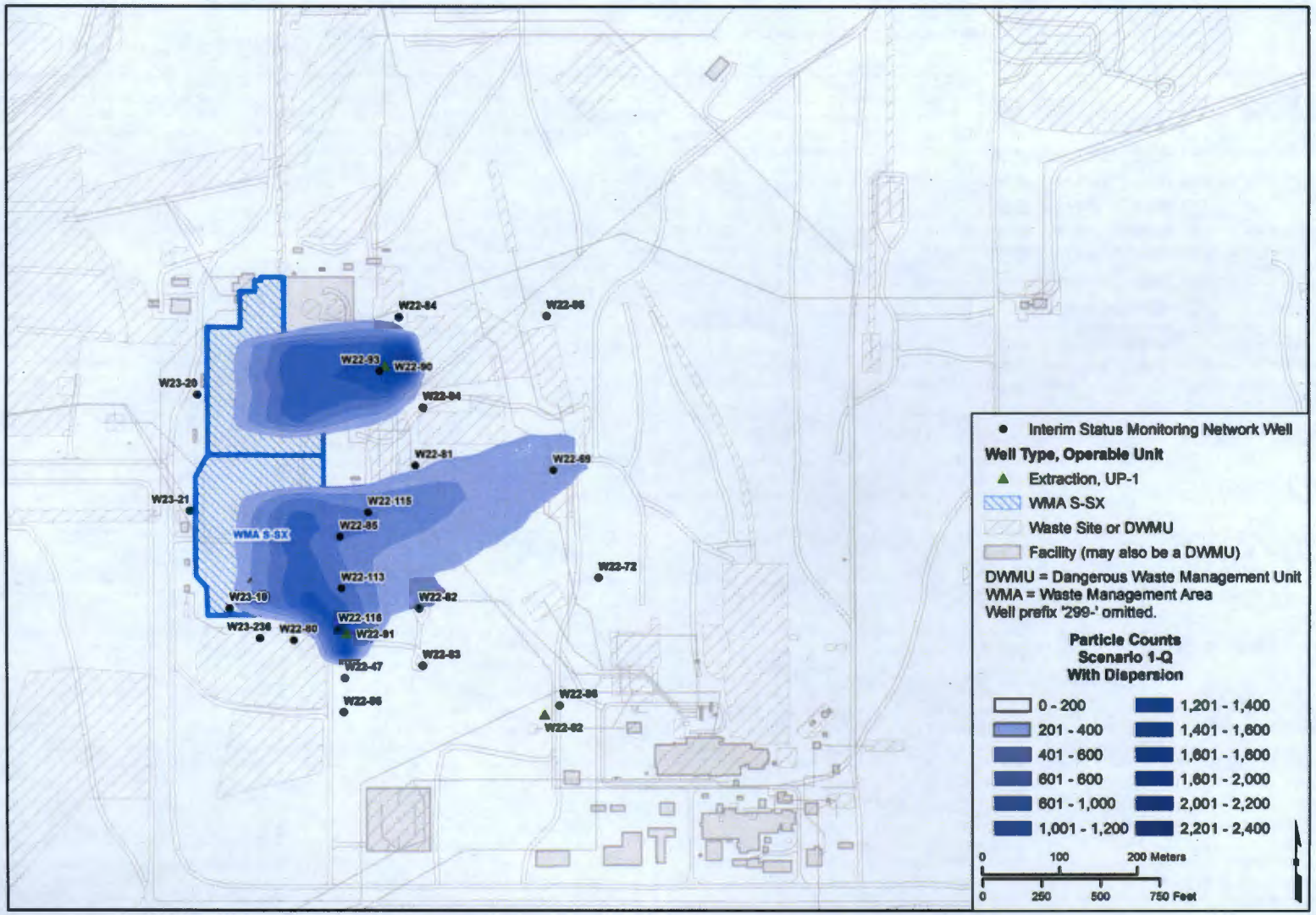

Figure A-17. Particle Count Scenario 1, Sub-scenario Q with Dispersion

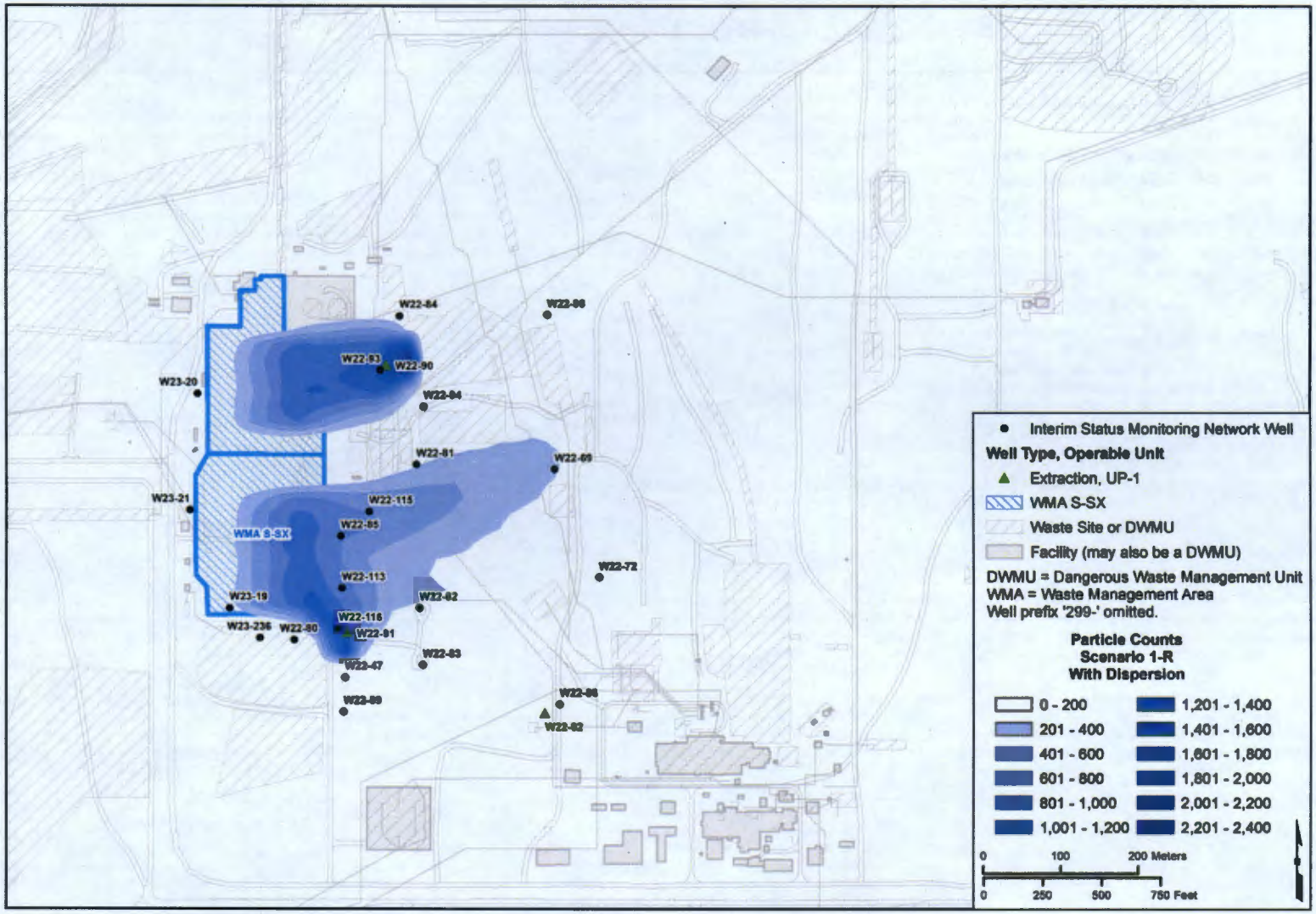

Figure A-18. Particle Count Scenario 1, Sub-scenario R with Dispersion

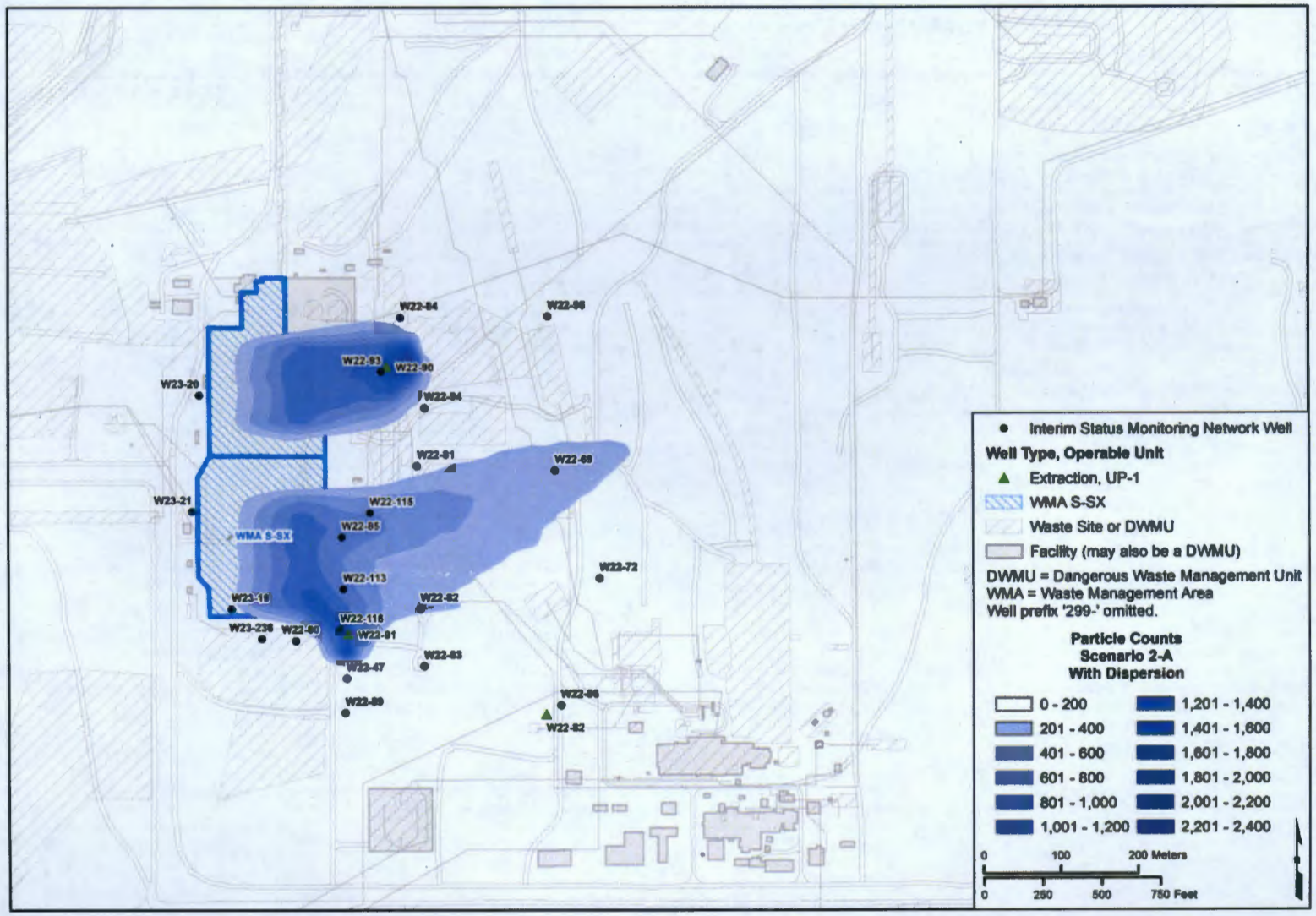

Figure A-19. Particle Count Scenario 2, Sub-scenario A with Dispersion

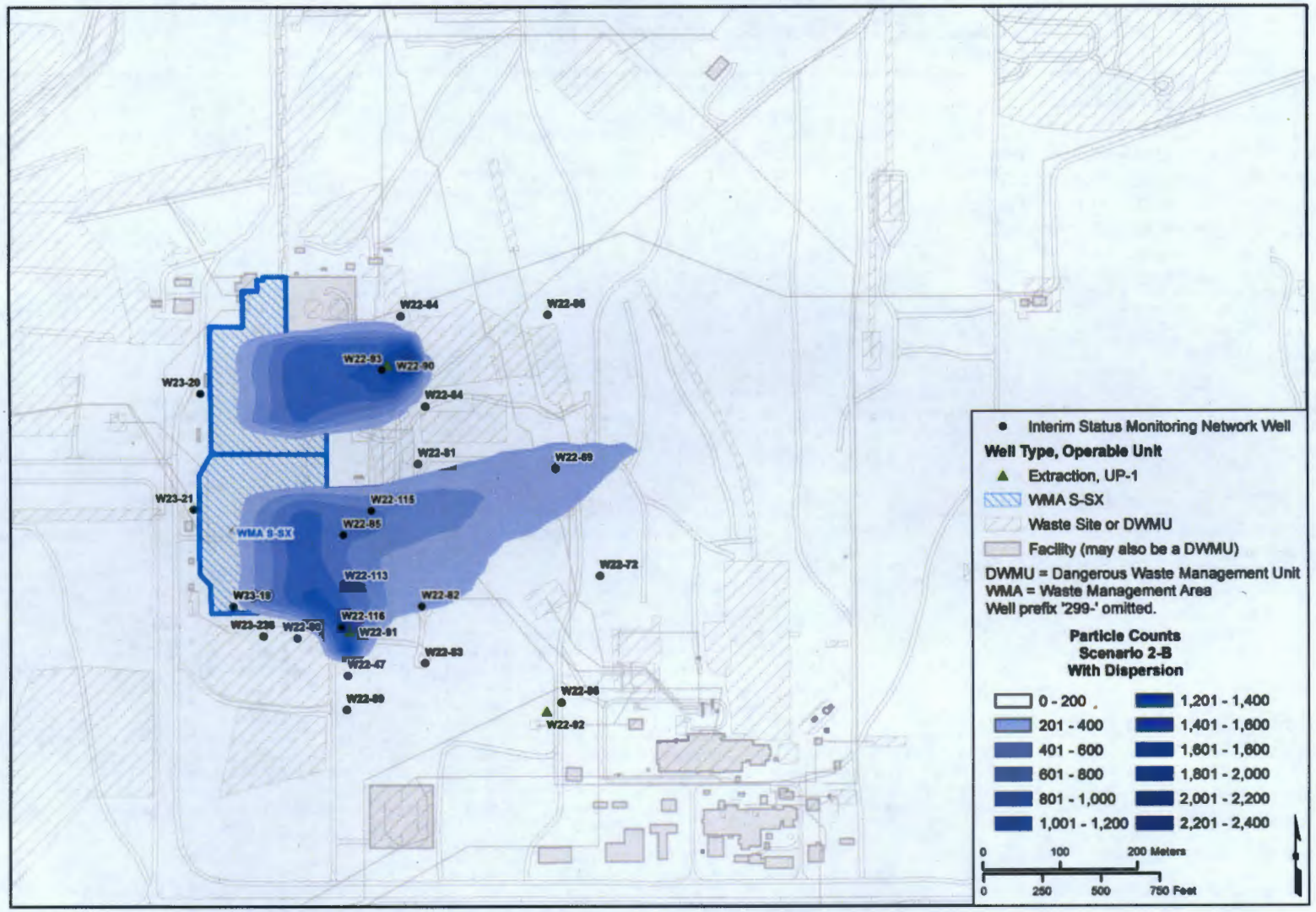

Figure A-20. Particle Count Scenario 2, Sub-scenario B with Dispersion

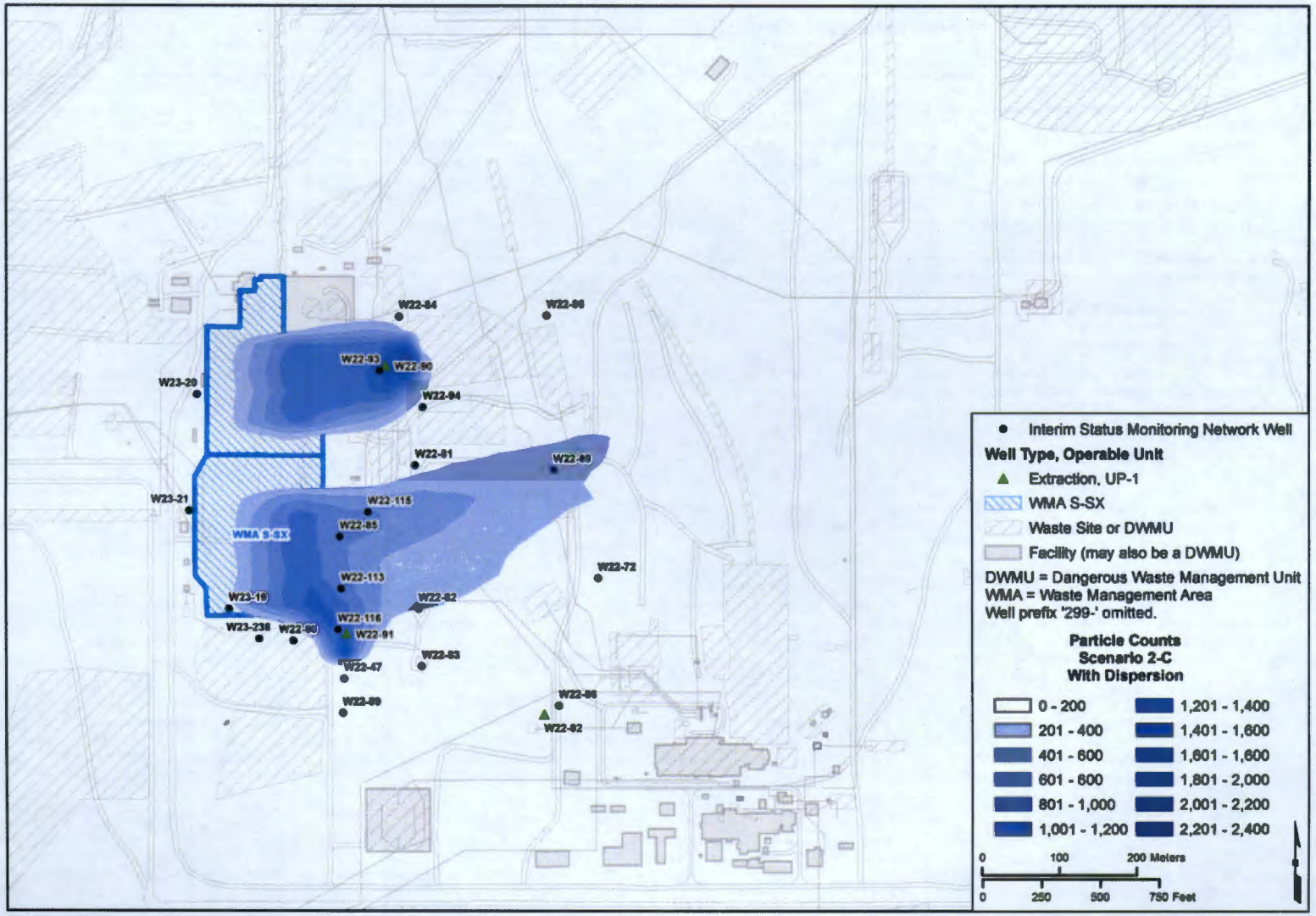

Figure A-21. Particle Count Scenario 2, Sub-scenario C with Dispersion

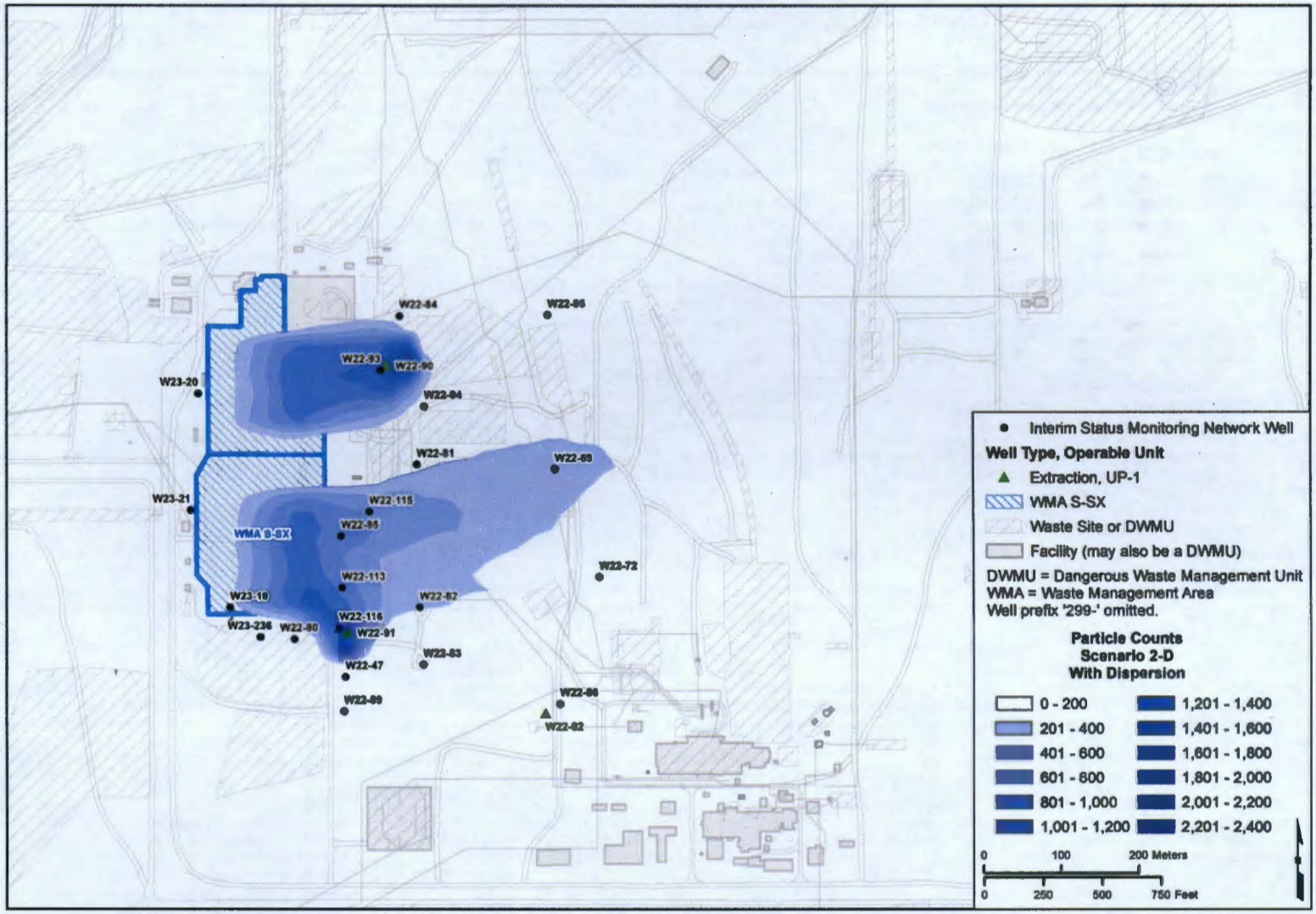

Figure A-22. Particle Count Scenario 2, Sub-scenario D with Dispersion

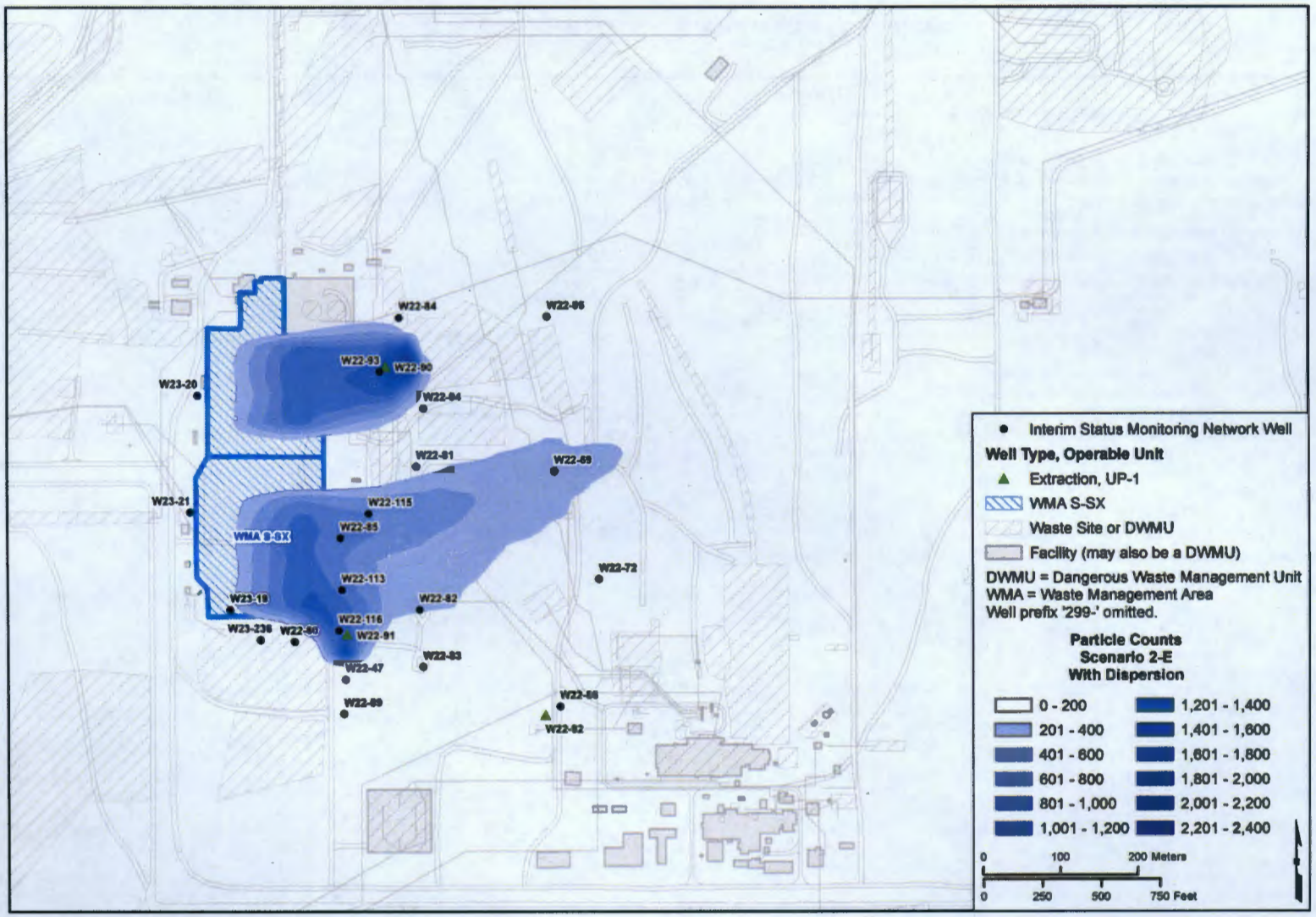

Figure A-23. Particle Count Scenario 2, Sub-scenario E with Dispersion

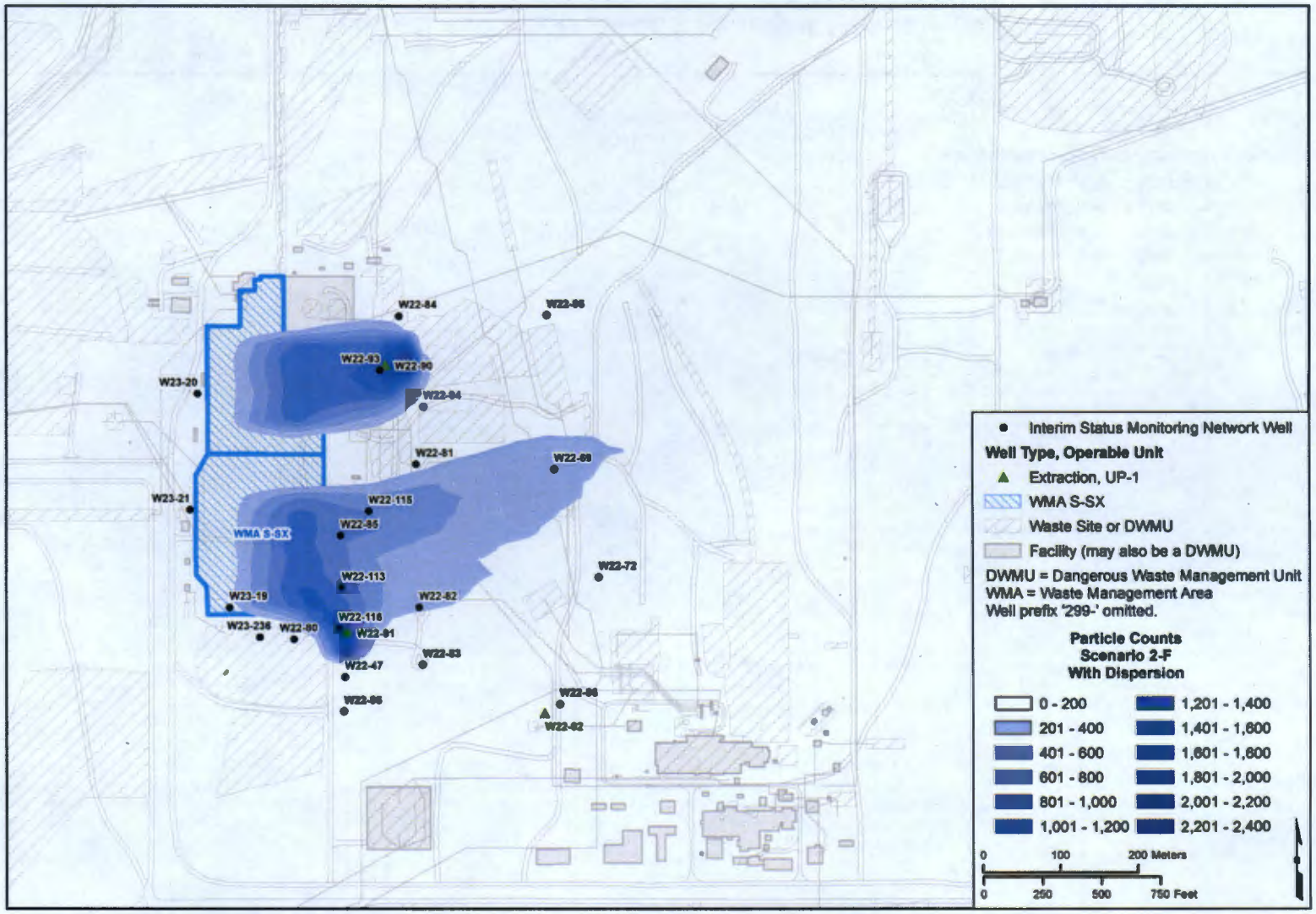

Figure A-24. Particle Count Scenario 2, Sub-scenario F with Dispersion

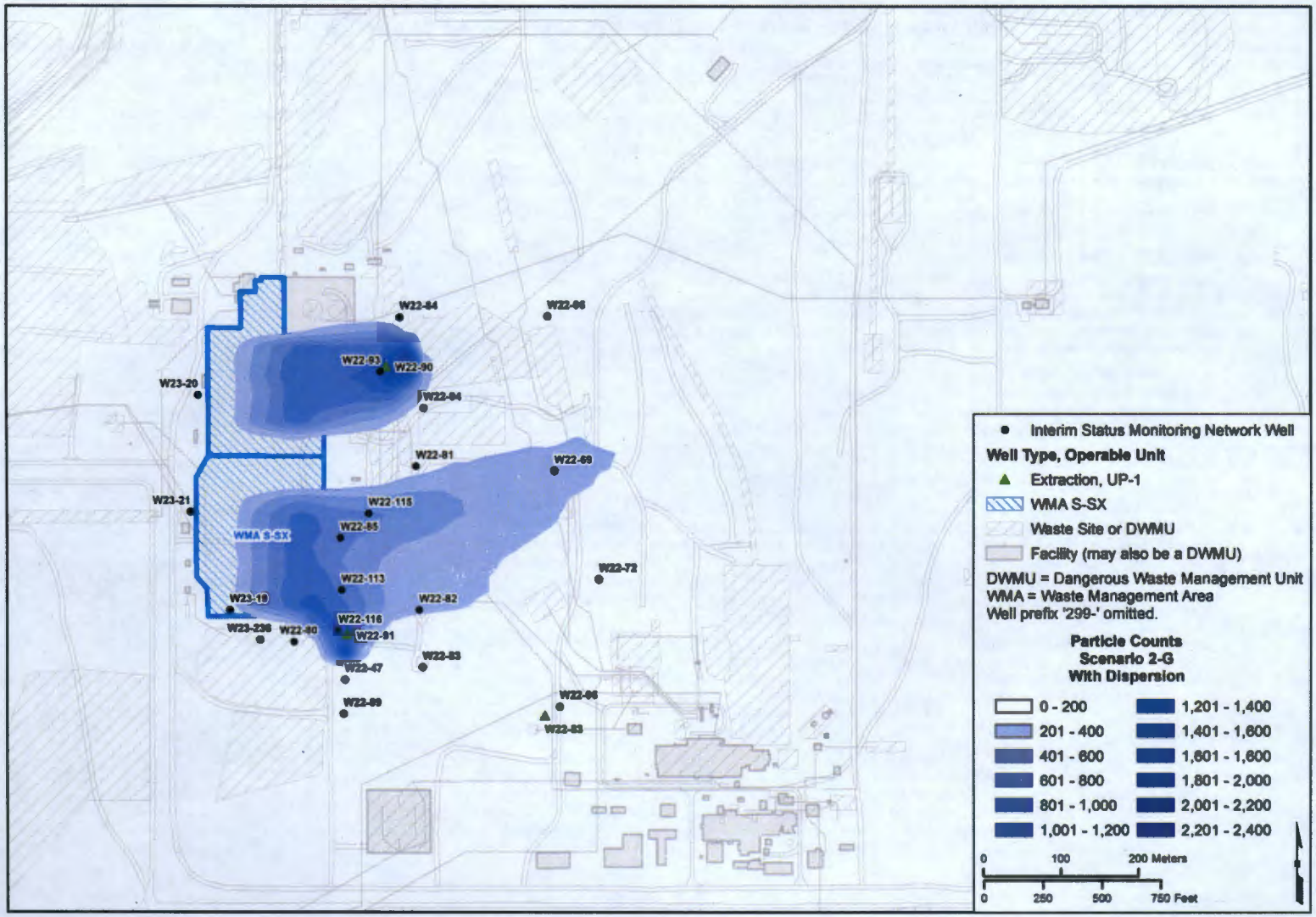

Figure A-25. Particle Count Scenario 2, Sub-scenario G with Dispersion

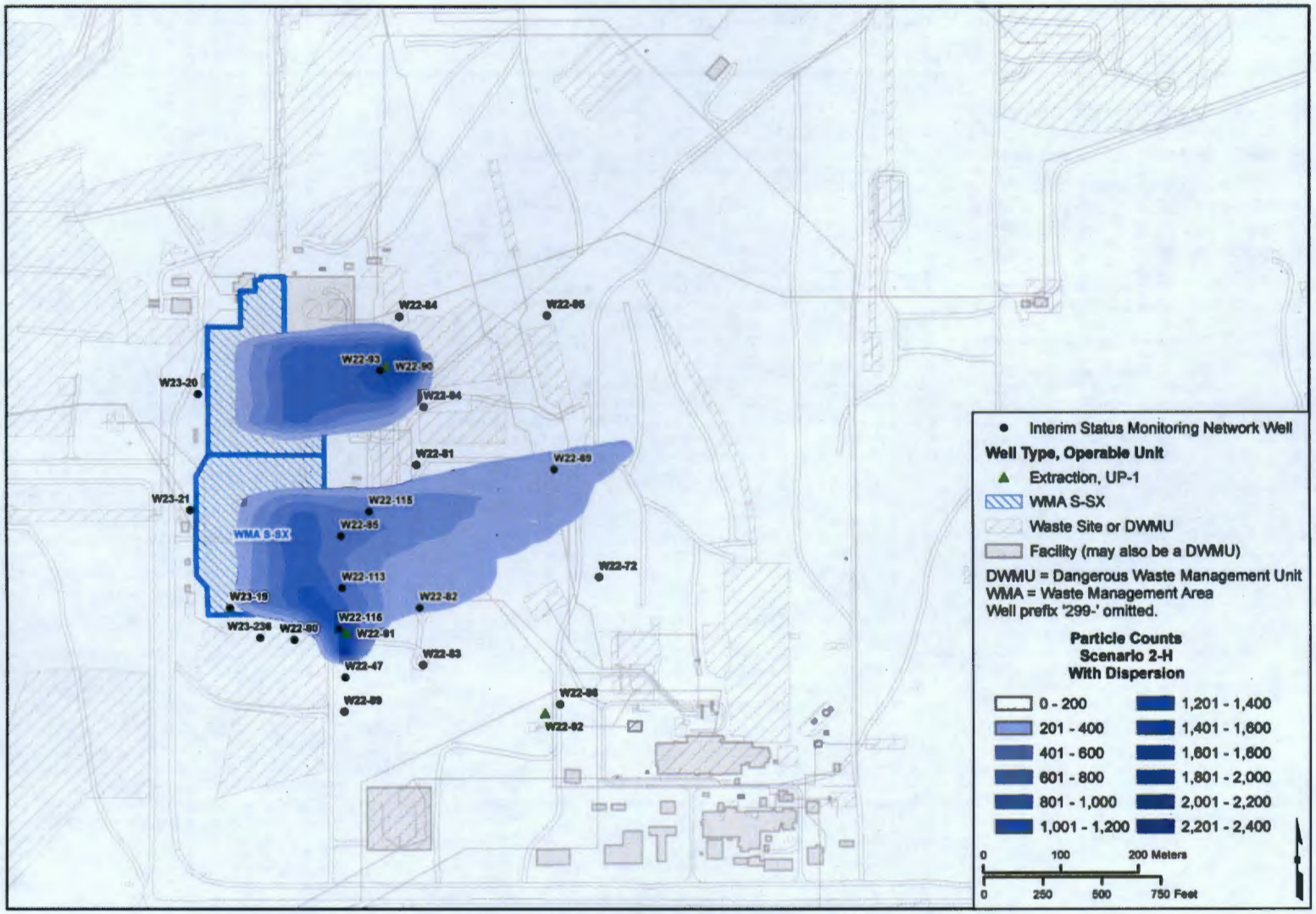

Figure A-26. Particle Count Scenario 2, Sub-scenario H with Dispersion

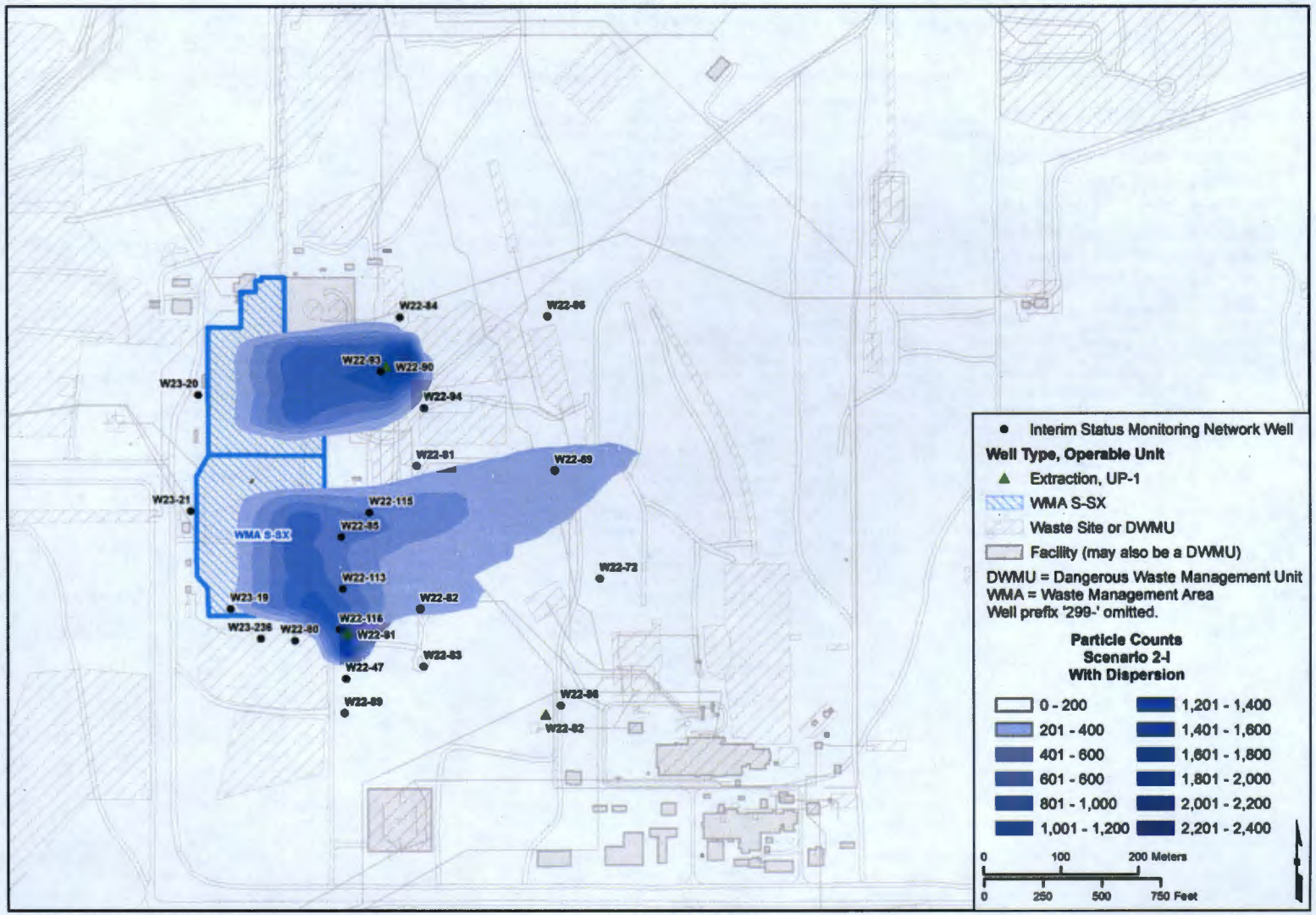

Figure A-27. Particle Count Scenario 2, Sub-scenario I with Dispersion

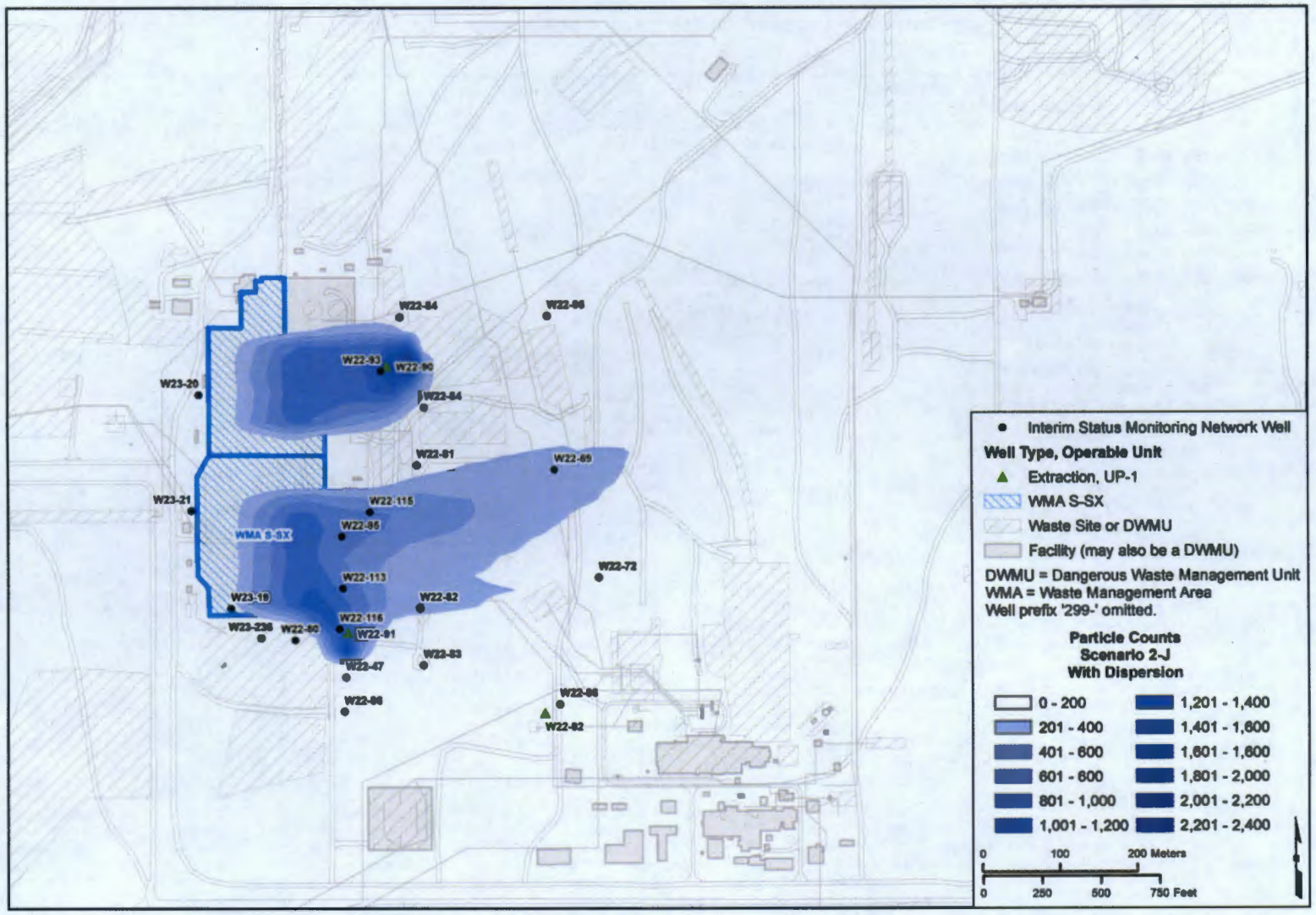

Figure A-28. Particle Count Scenario 2, Sub-scenario J with Dispersion

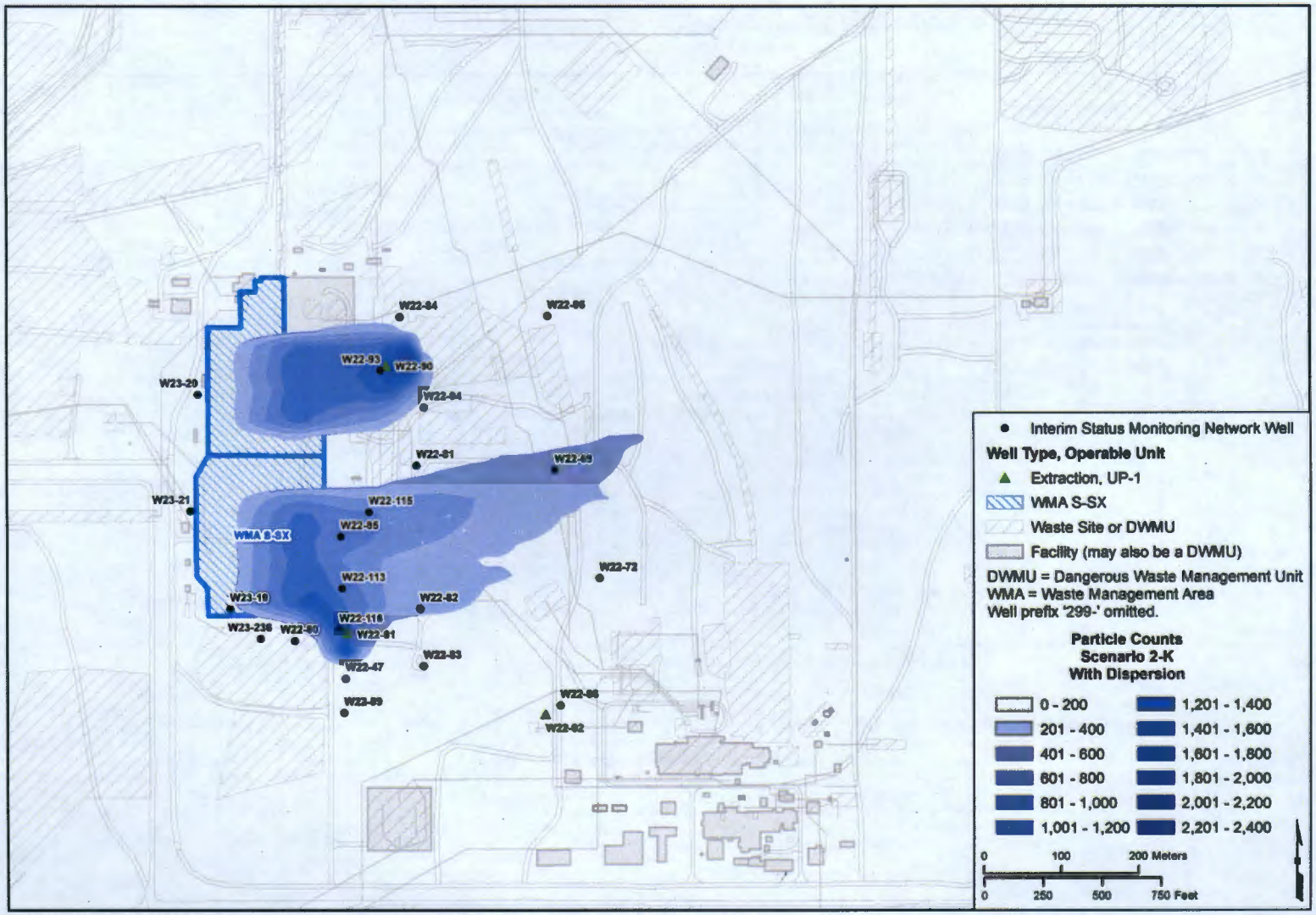

Figure A-29. Particle Count Scenario 2, Sub-scenario K with Dispersion

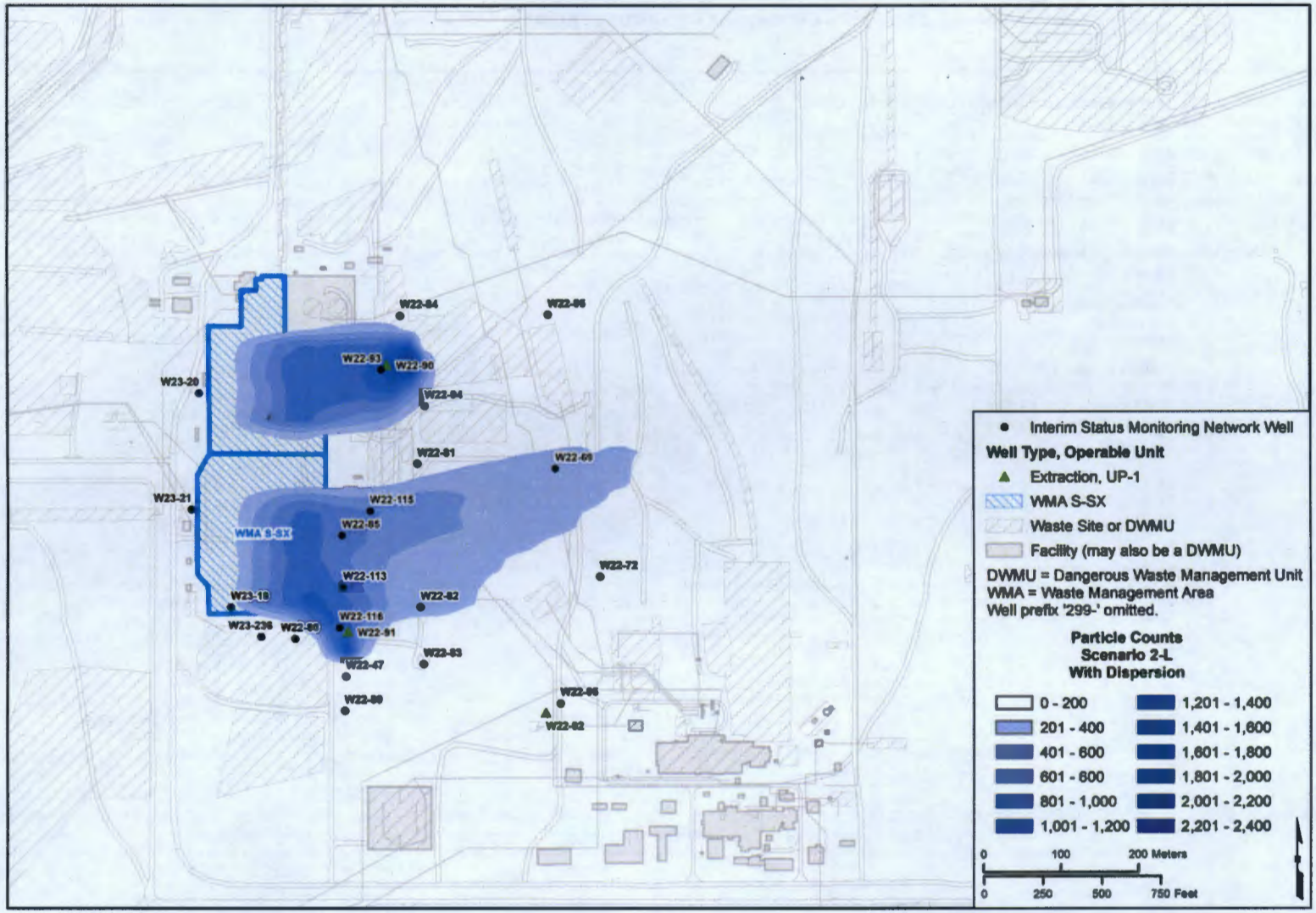

Figure A-30. Particle Count Scenario 2, Sub-scenario L with Dispersion

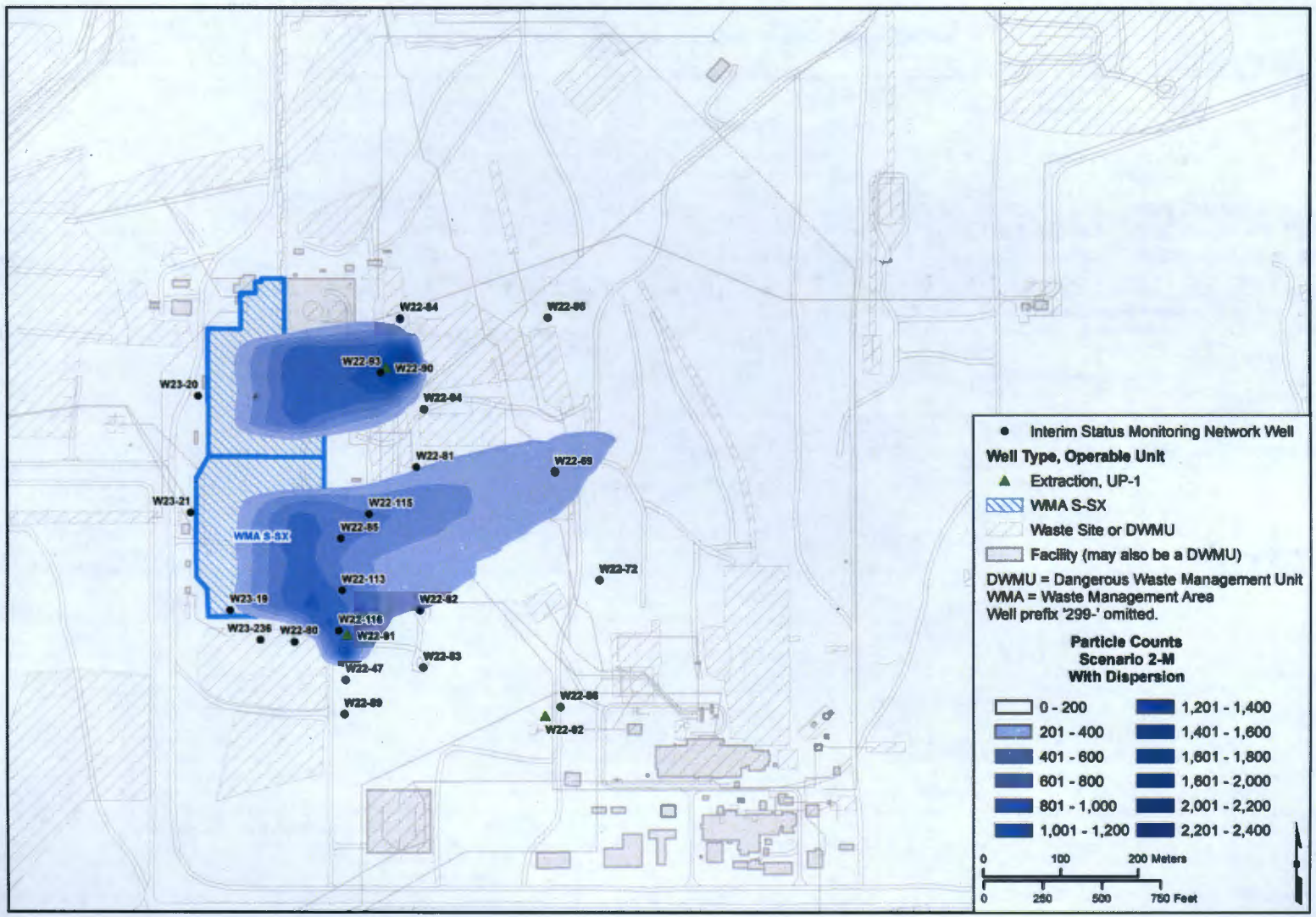

Figure A-31. Particle Count Scenario 2, Sub-scenario M with Dispersion

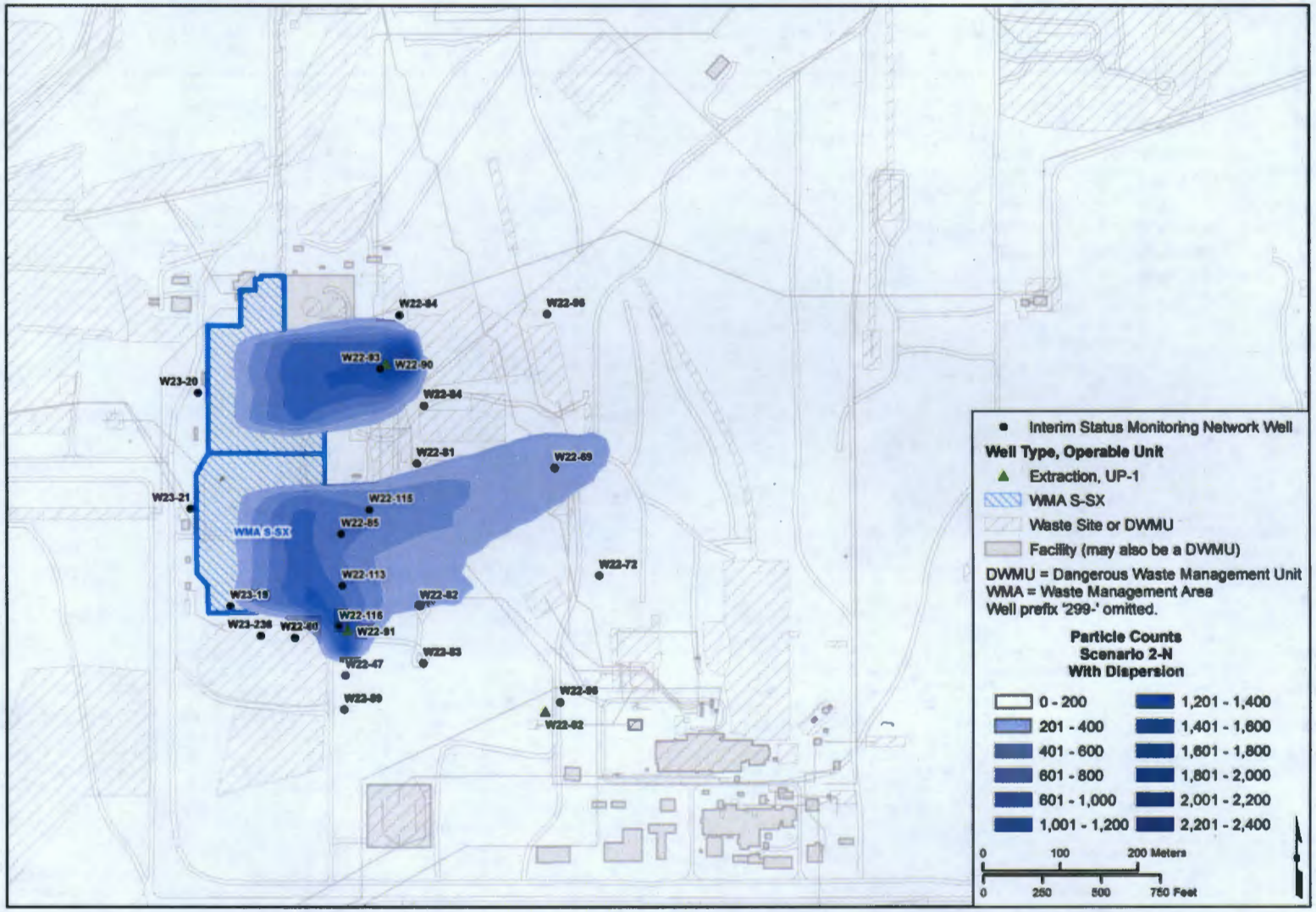

Figure A-32. Particle Count Scenario 2, Sub-scenario N with Dispersion

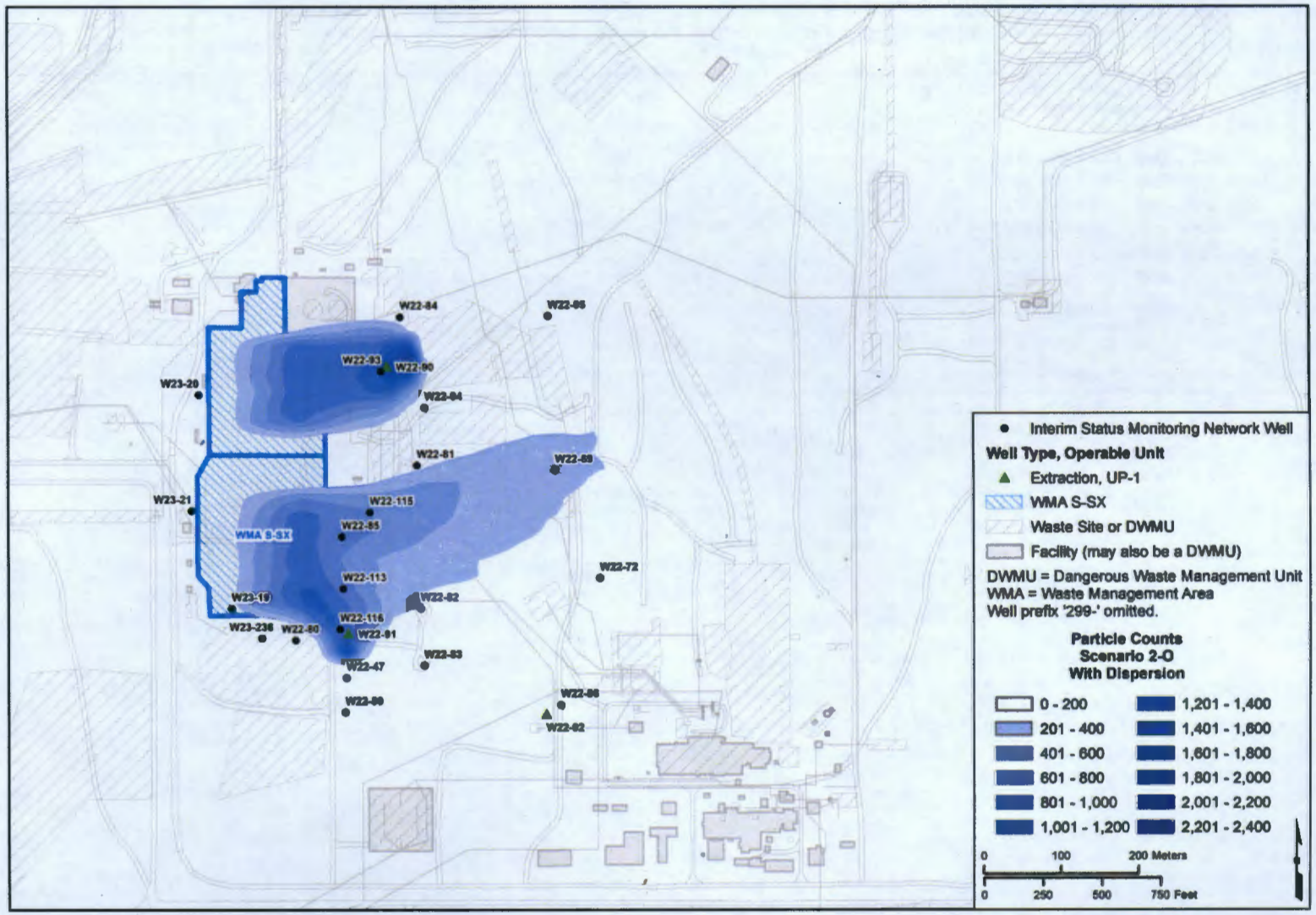

Figure A-33. Particle Count Scenario 2, Sub-scenario O with Dispersion

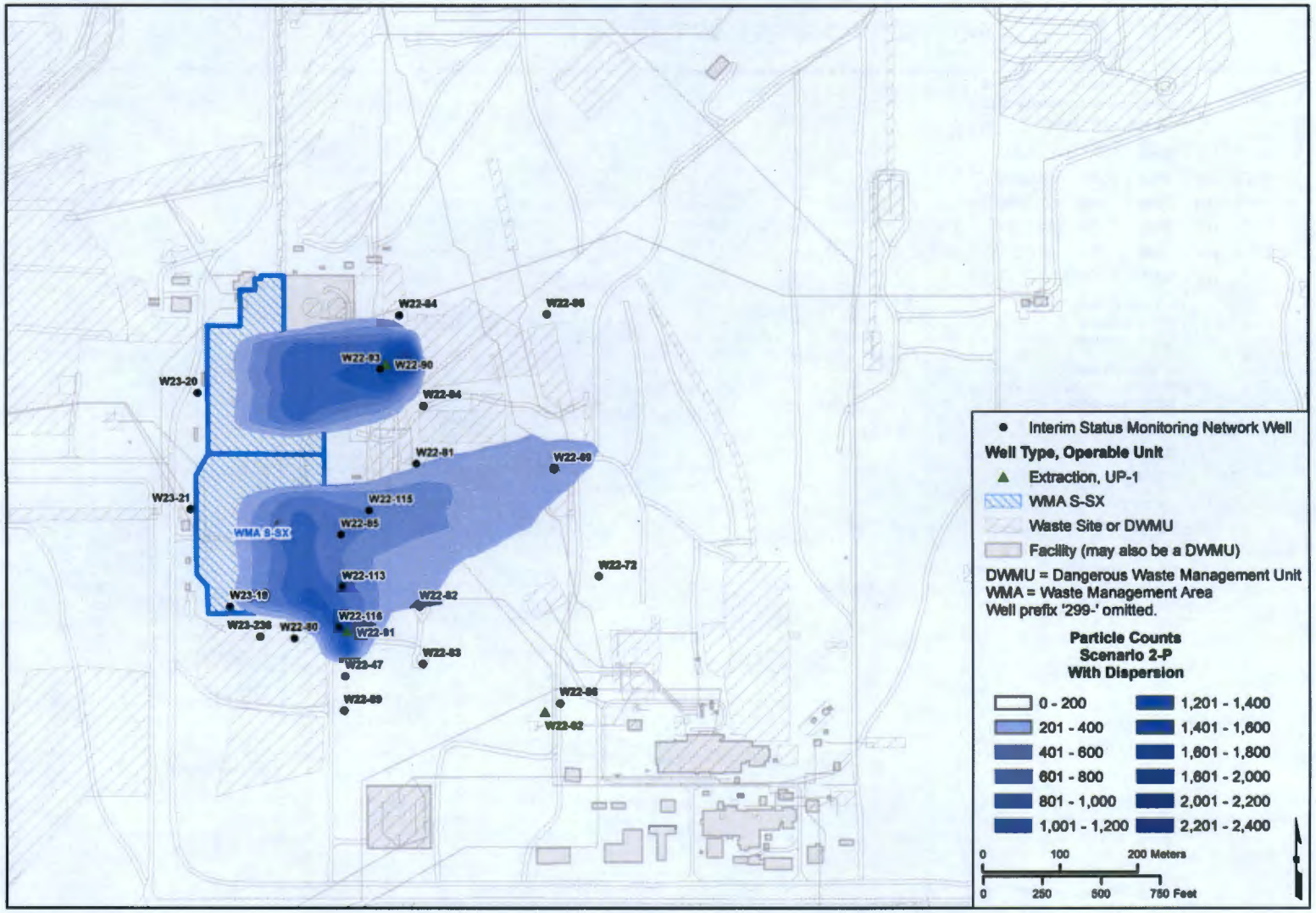

Figure A-34. Particle Count Scenario 2, Sub-scenario P with Dispersion

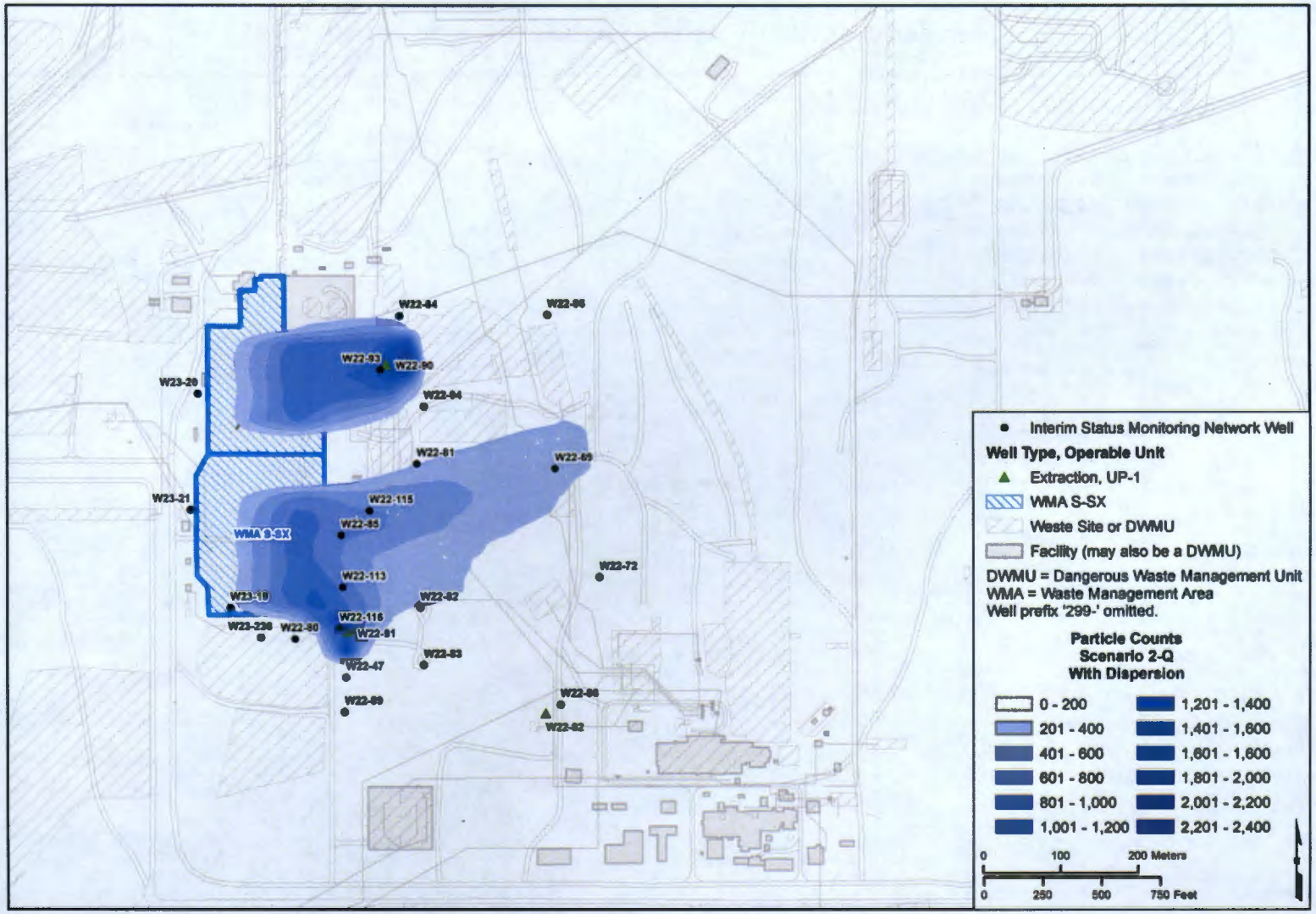

Figure A-35. Particle Count Scenario 2, Sub-scenario Q with Dispersion

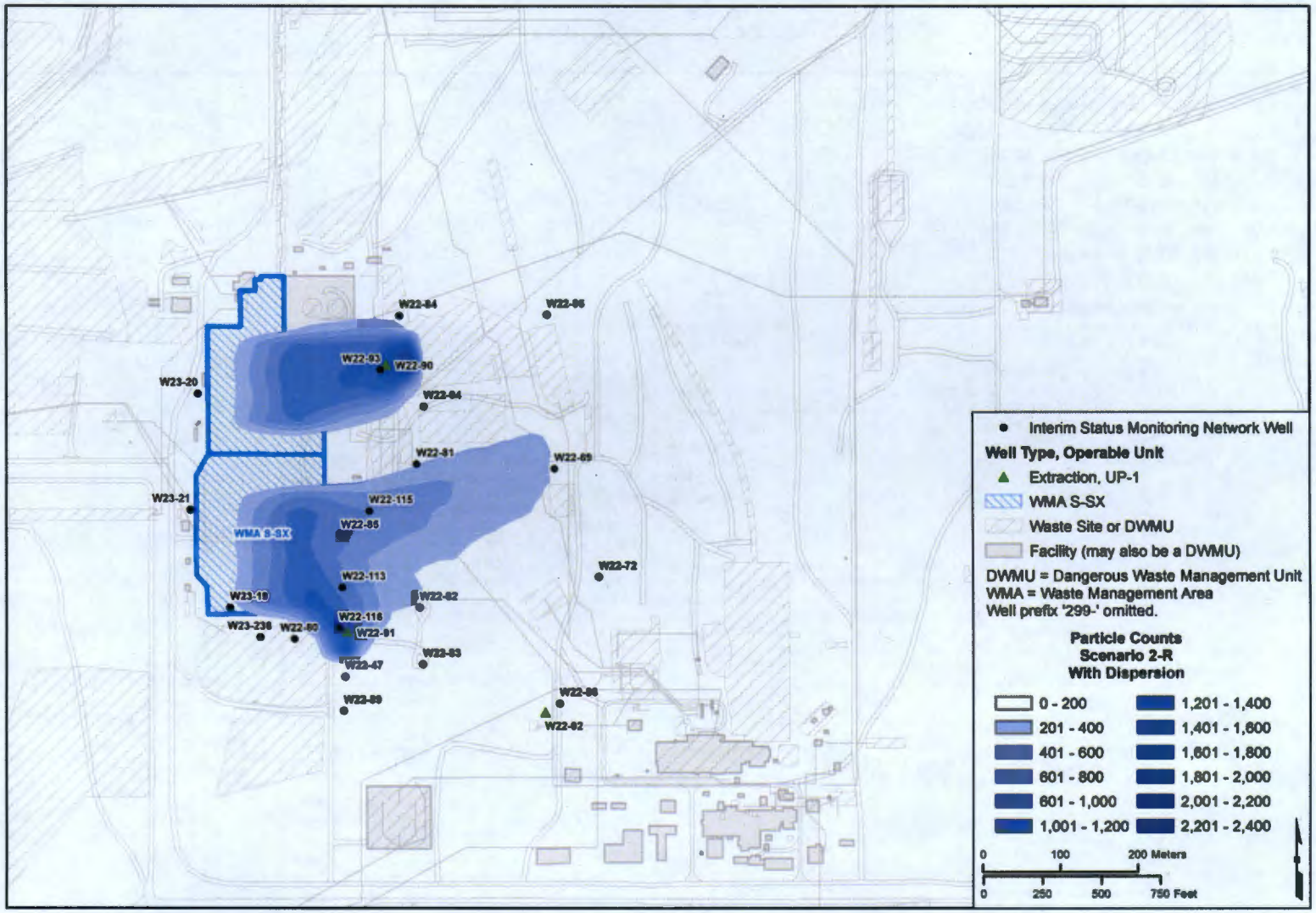

Figure A-36. Particle Count Scenario 2, Sub-scenario R with Dispersion

Appendix B

WMA S-SX Release Unit Plume Maps

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Figures

Figure B-1. Release Unit Plume Map Scenario 1, Sub-scenario A B-1
Figure B-2. Release Unit Plume Map Scenario 1, Sub-scenario B B-2
Figure B-3. Release Unit Plume Map Scenario 1, Sub-scenario C B-3
Figure B-4. Release Unit Plume Map Scenario 1, Sub-scenario D B-4
Figure B-5. Release Unit Plume Map Scenario 1, Sub-scenario E B-5
Figure B-6. Release Unit Plume Map Scenario 1, Sub-scenario F B-6
Figure B-7. Release Unit Plume Map Scenario 1, Sub-scenario G B-7
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Figure B-9. Release Unit Plume Map Scenario 1, Sub-scenario I B-9
Figure B-10. Release Unit Plume Map Scenario 1, Sub-scenario J B-10
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Figure B-12. Release Unit Plume Map Scenario 1, Sub-scenario L B-12
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Figure B-15. Release Unit Plume Map Scenario 1, Sub-scenario O B-15
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Figure B-19. Release Unit Plume Map Scenario 2, Sub-scenario A B-19
Figure B-20. Release Unit Plume Map Scenario 2, Sub-scenario B B-20
Figure B-21. Release Unit Plume Map Scenario 2, Sub-scenario C B-21
Figure B-22. Release Unit Plume Map Scenario 2, Sub-scenario D B-22
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Figure B-26. Release Unit Plume Map Scenario 2, Sub-scenario H B-26
Figure B-27. Release Unit Plume Map Scenario 2, Sub-scenario I B-27
Figure B-28. Release Unit Plume Map Scenario 2, Sub-scenario J B-28
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Figure B-31. Release Unit Plume Map Scenario 2, Sub-scenario M B-31
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Figure B-36. Release Unit Plume Map Scenario 2, Sub-scenario R B-36
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Terms

200 West Facilities	dangerous waste management units located in the 200 West Area of the Hanford Site Central Plateau
DWMU	dangerous waste management unit
WMA	waste management area

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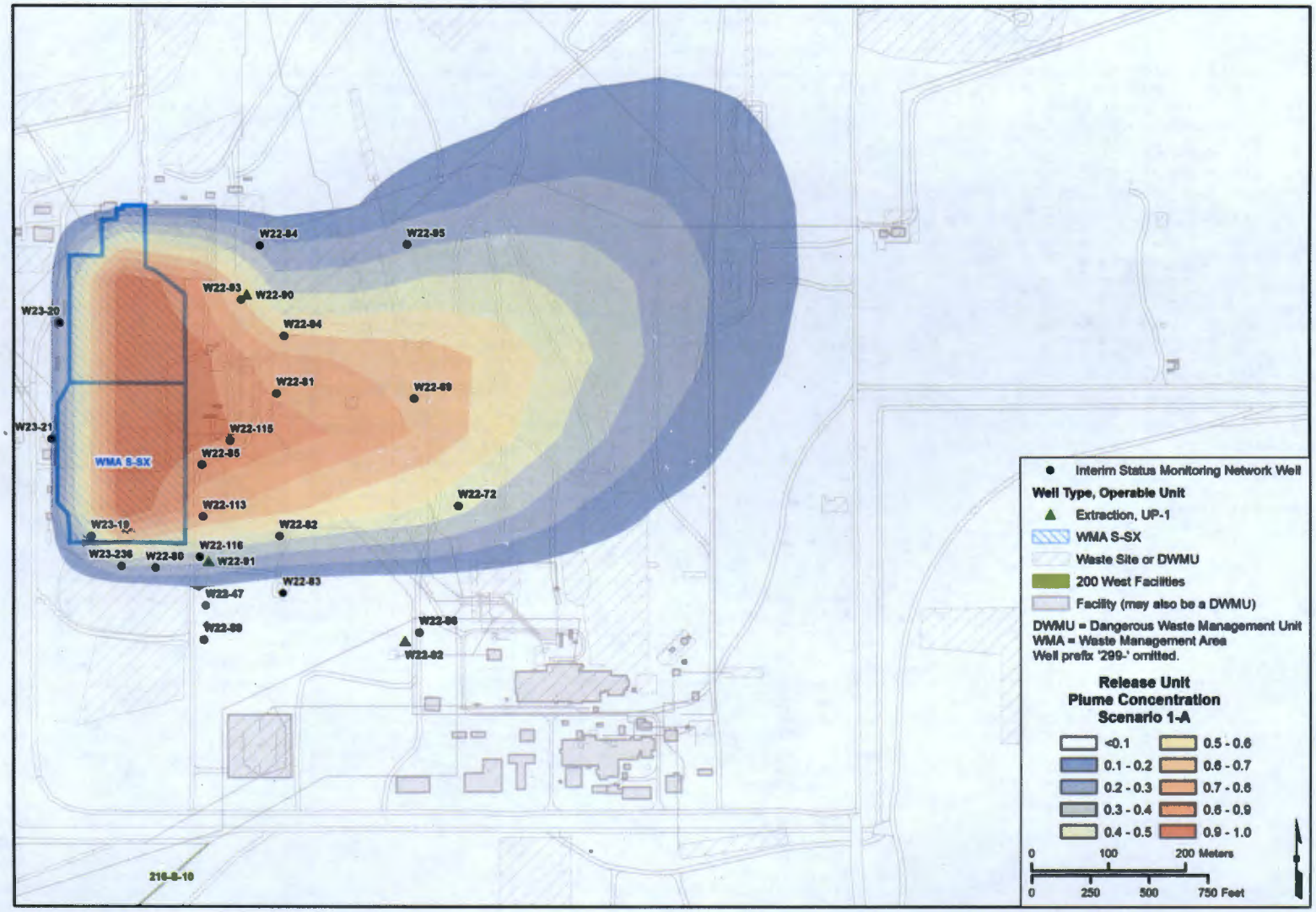


Figure B-1. Release Unit Plume Map Scenario 1, Sub-scenario A

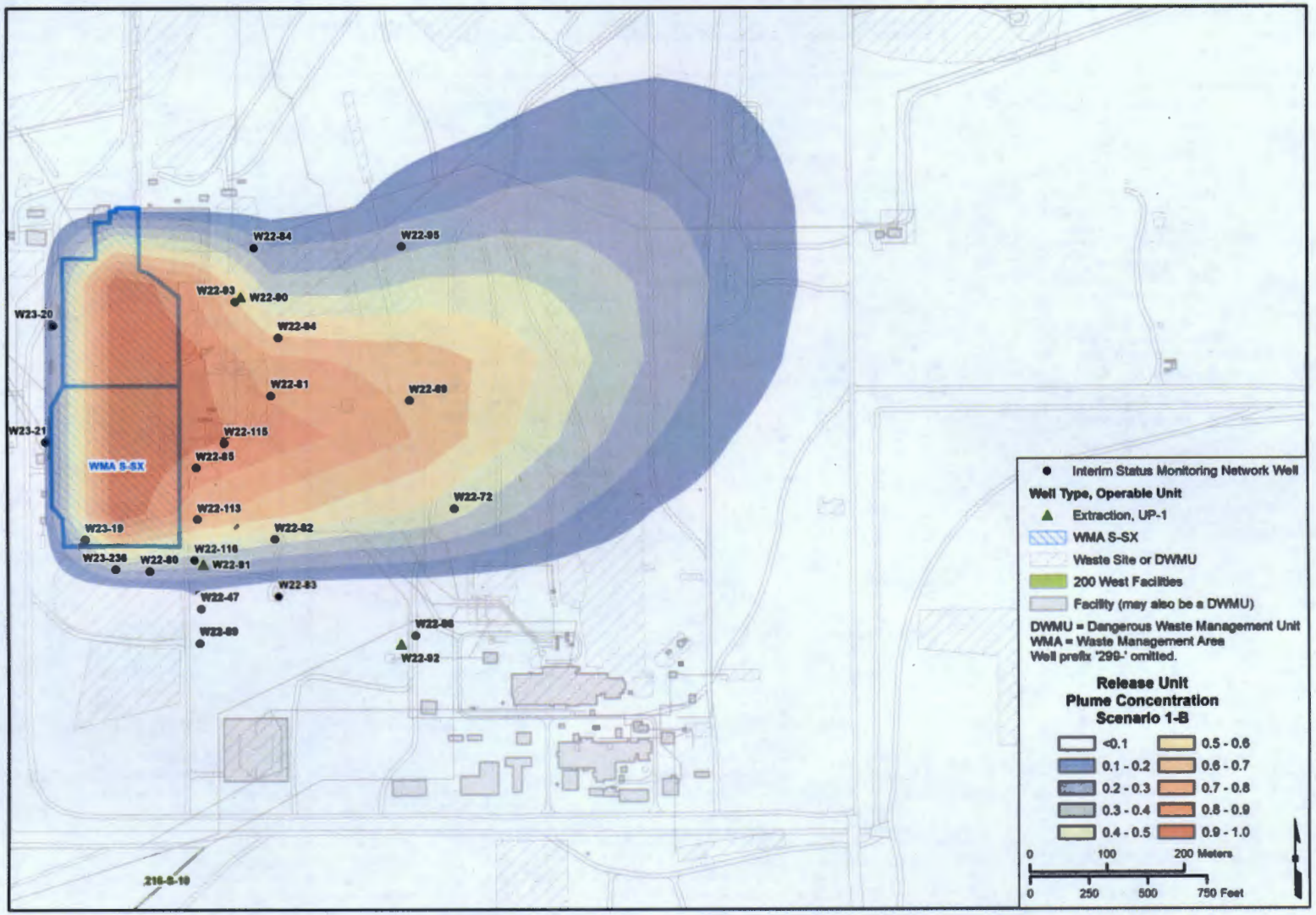
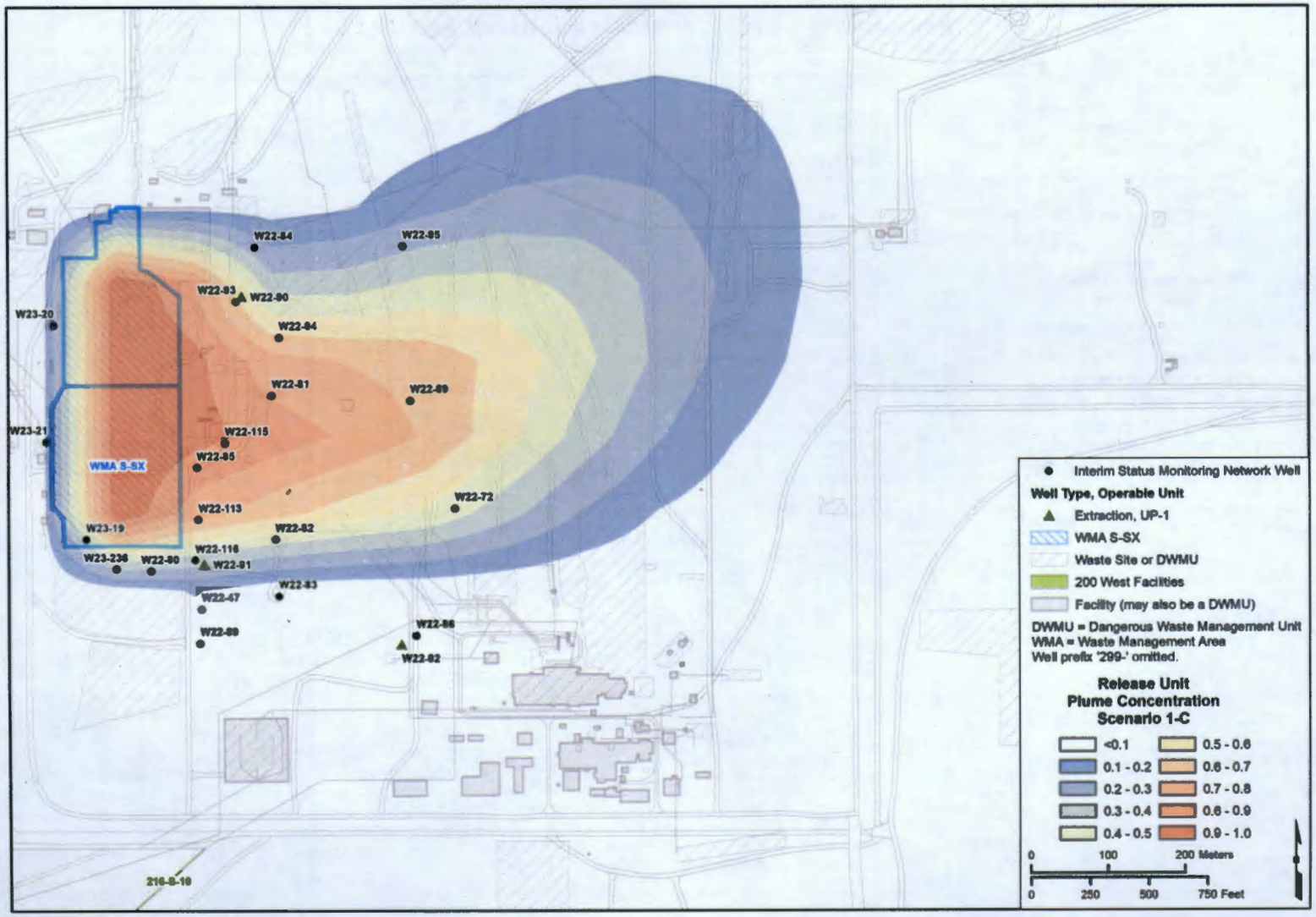


Figure B-2. Release Unit Plume Map Scenario 1, Sub-scenario B



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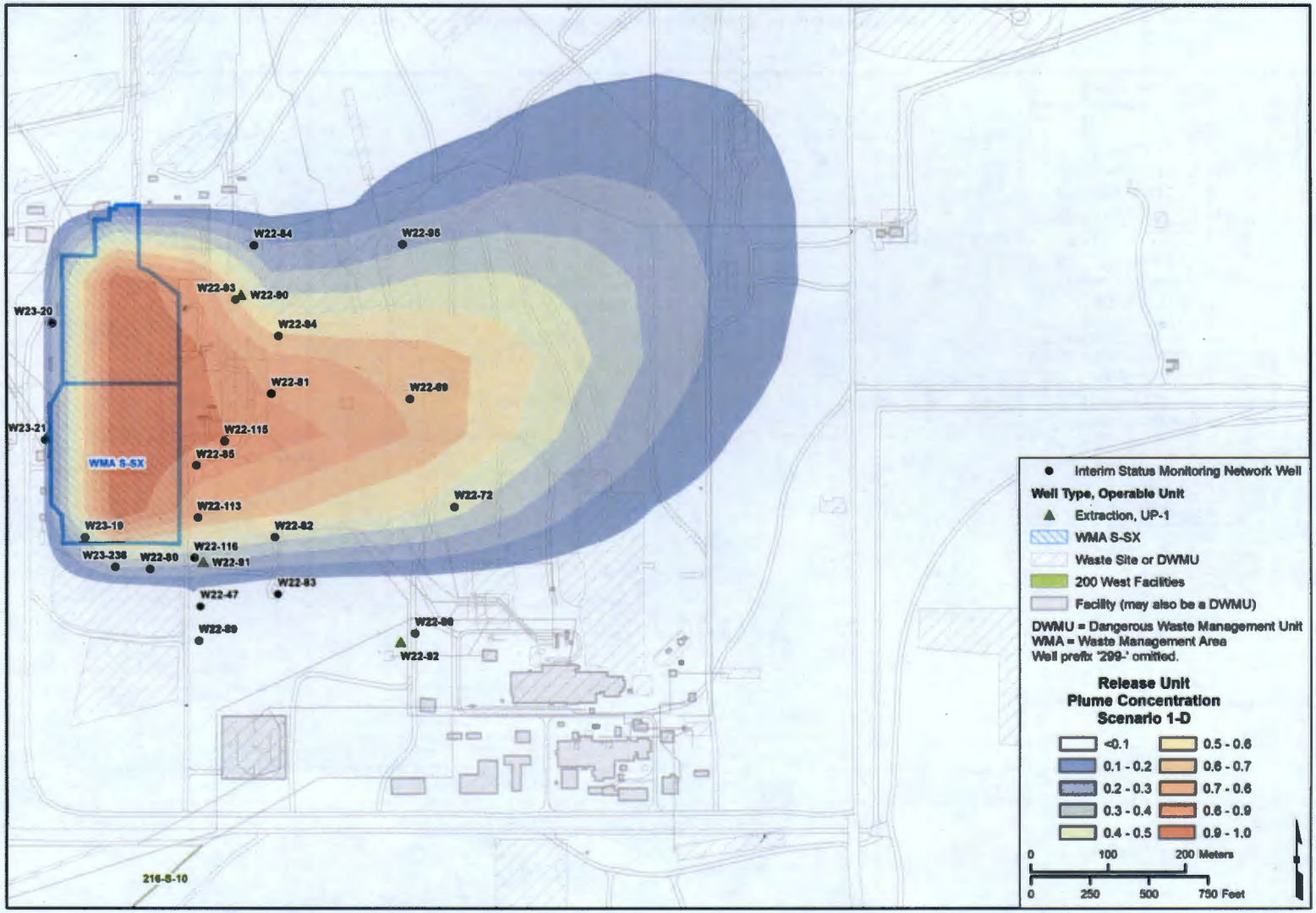

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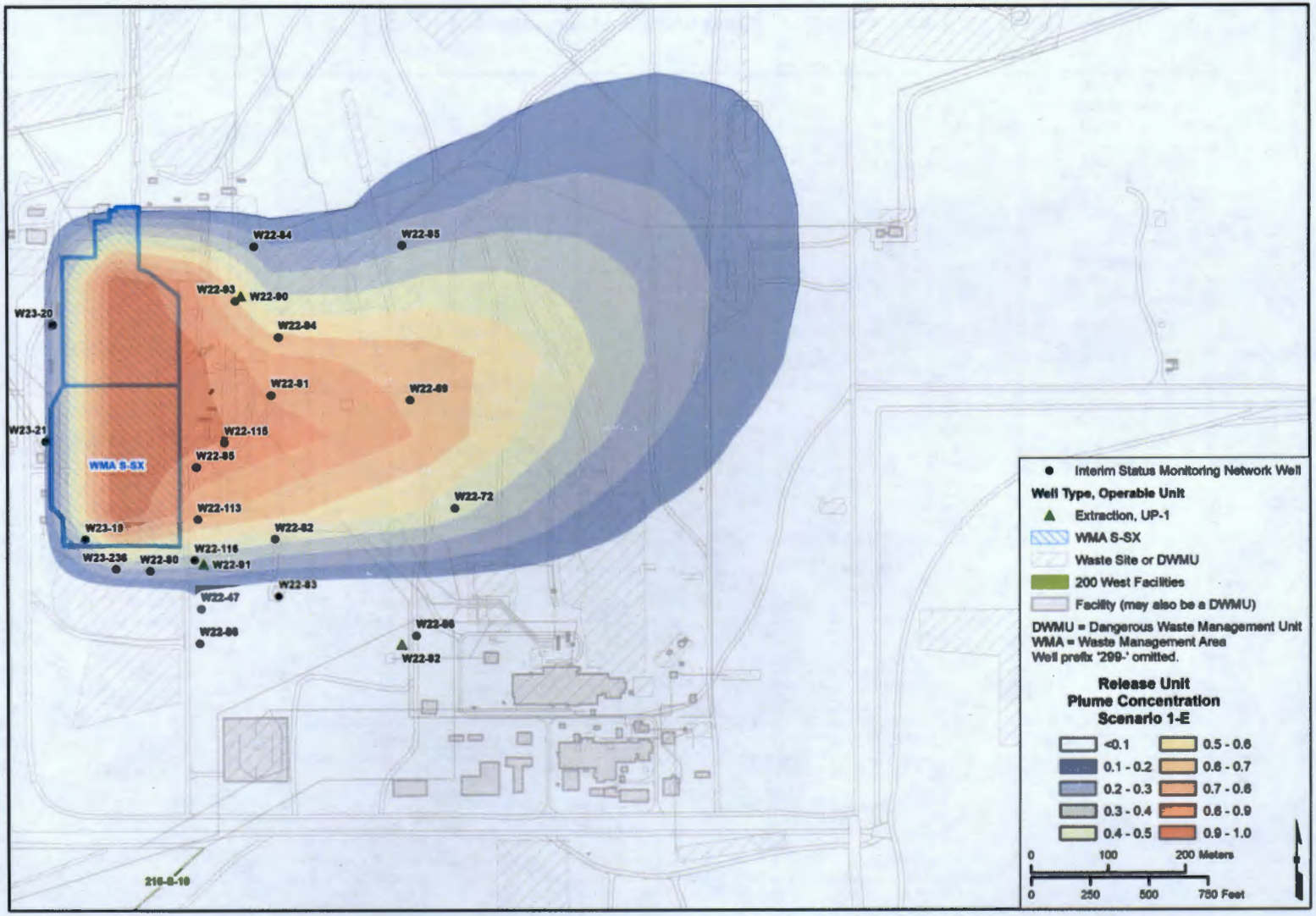
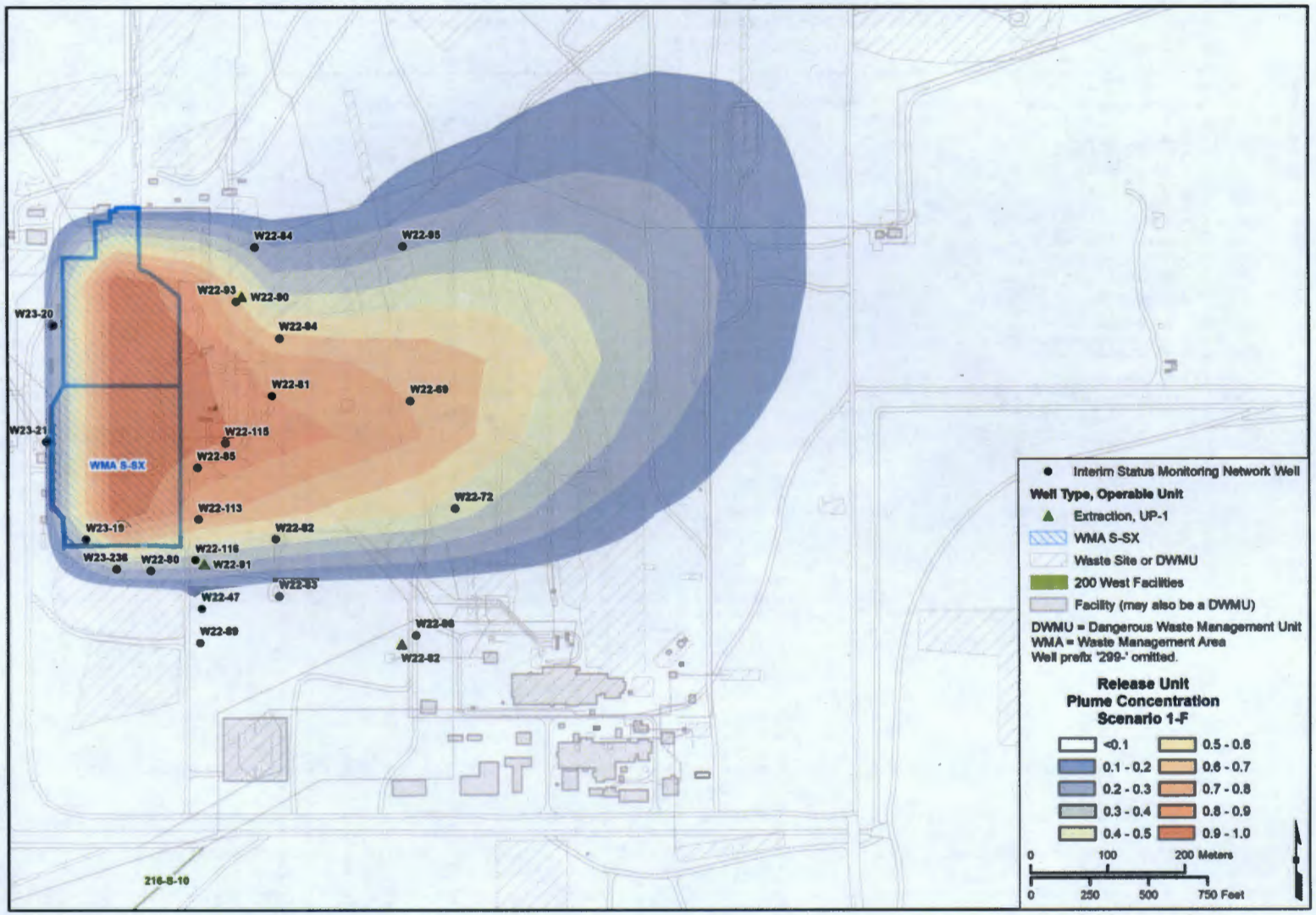


Figure B-5. Release Unit Plume Map Scenario 1, Sub-scenario E



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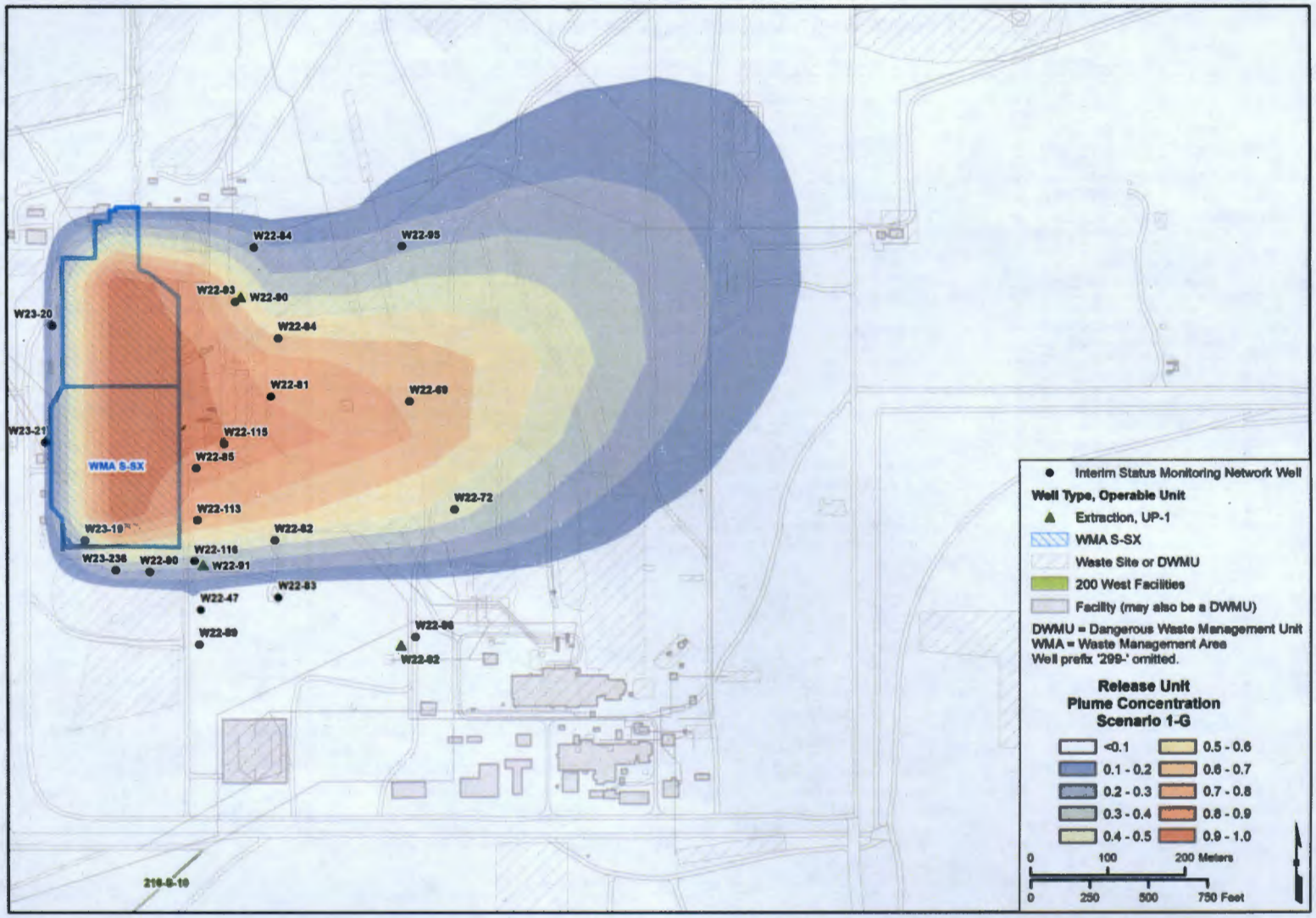

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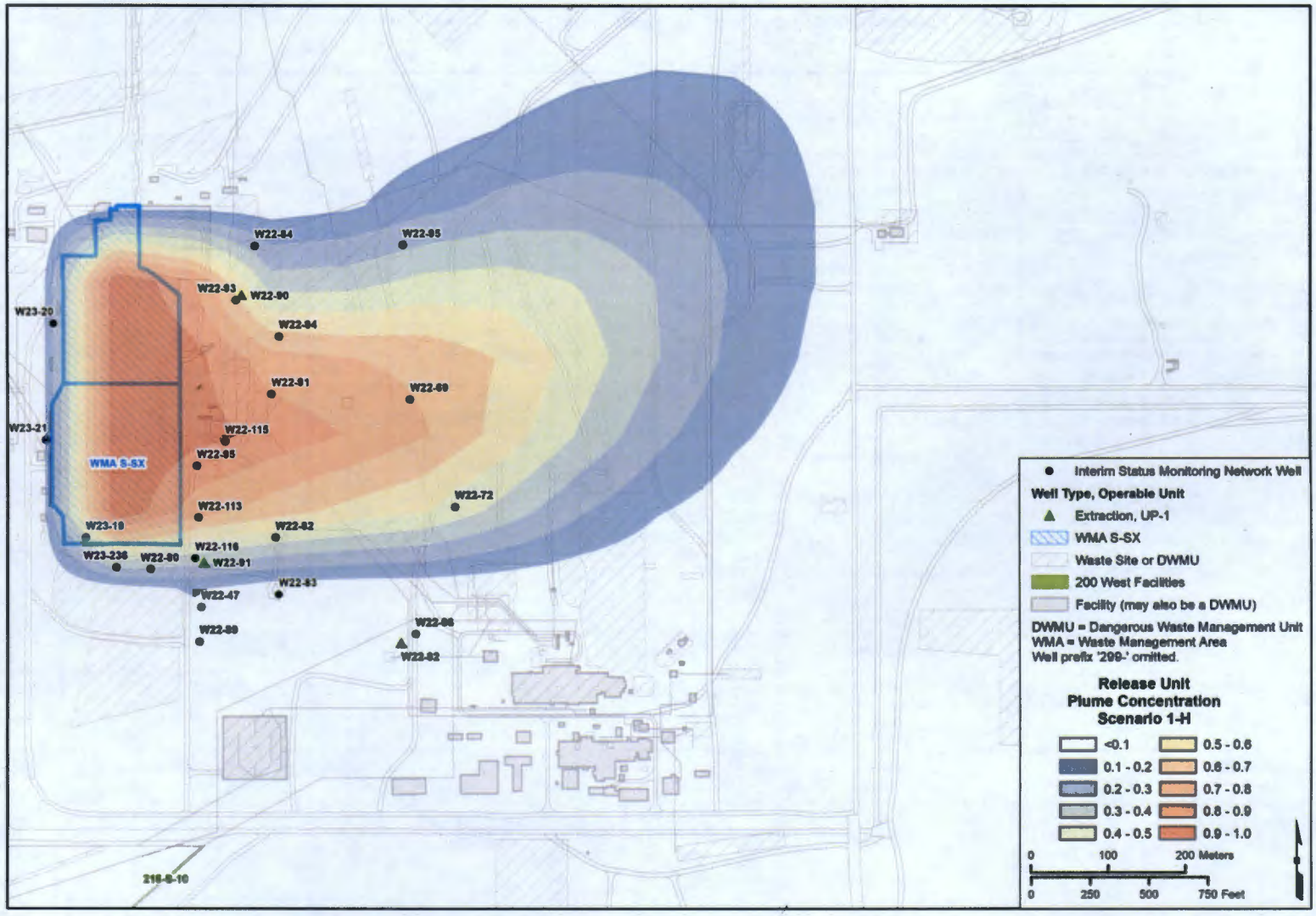


Figure B-8. Release Unit Plume Map Scenario 1, Sub-scenario H

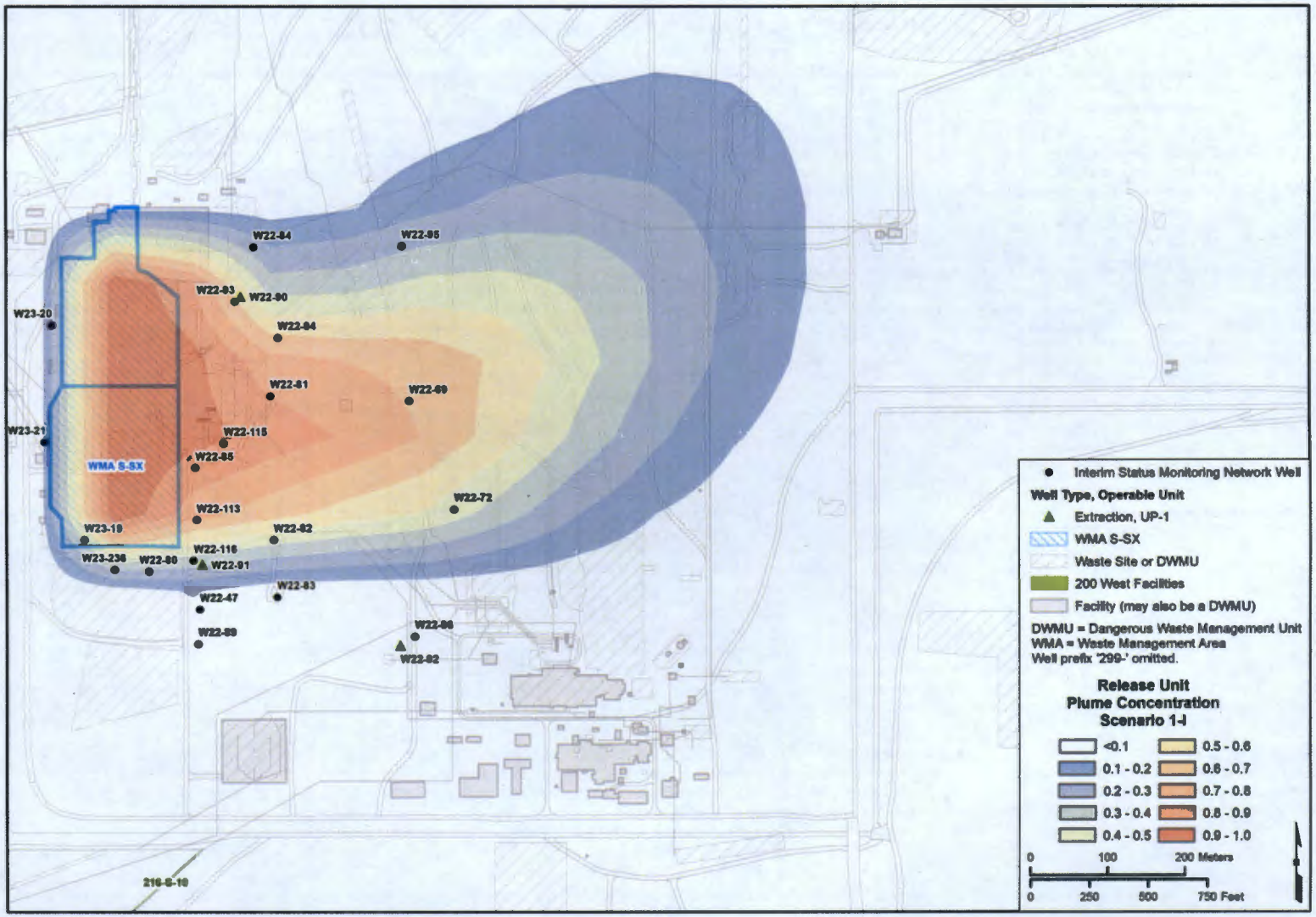


Figure B-9. Release Unit Plume Map Scenario 1, Sub-scenario I

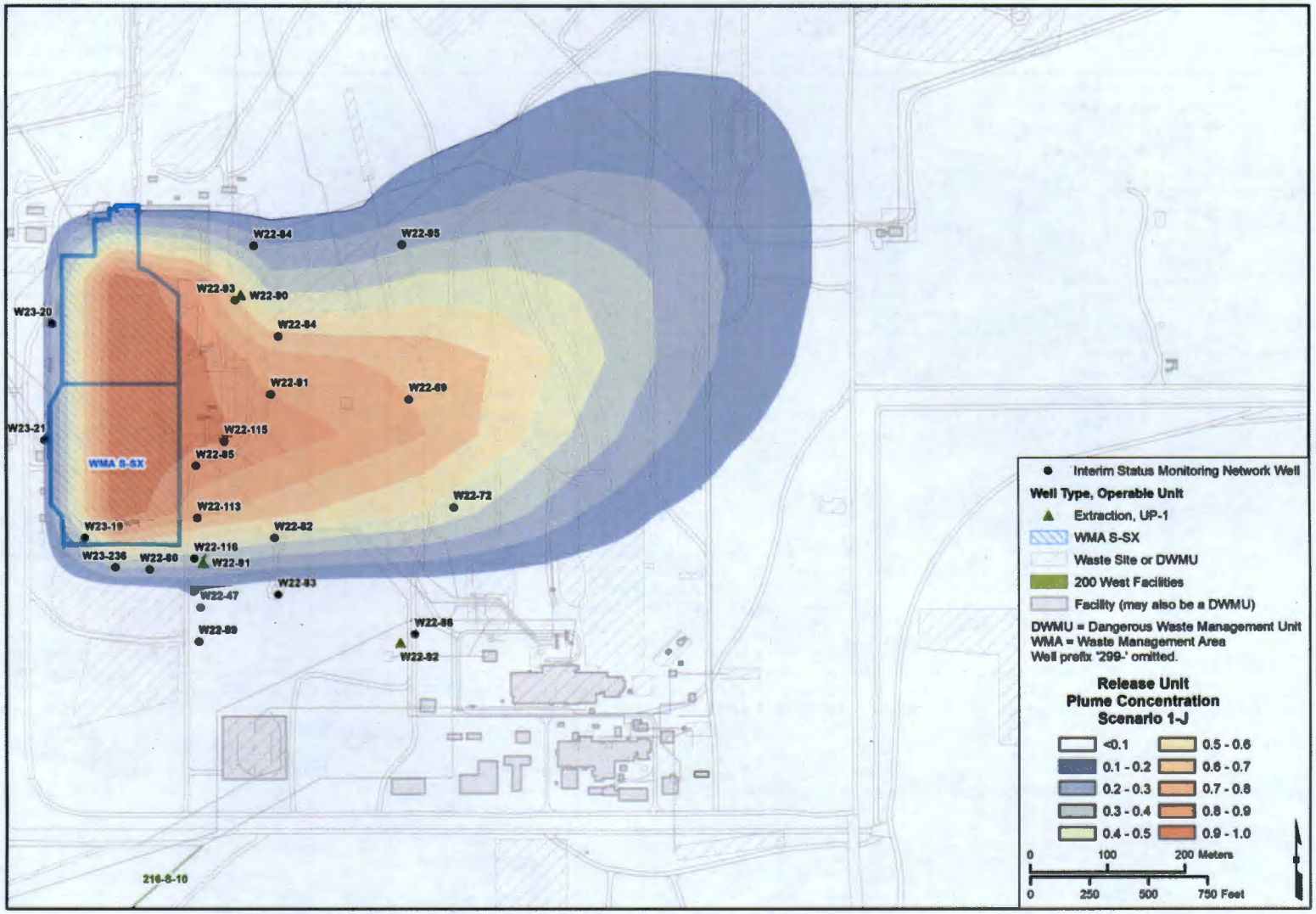


Figure B-10. Release Unit Plume Map Scenario 1, Sub-scenario J

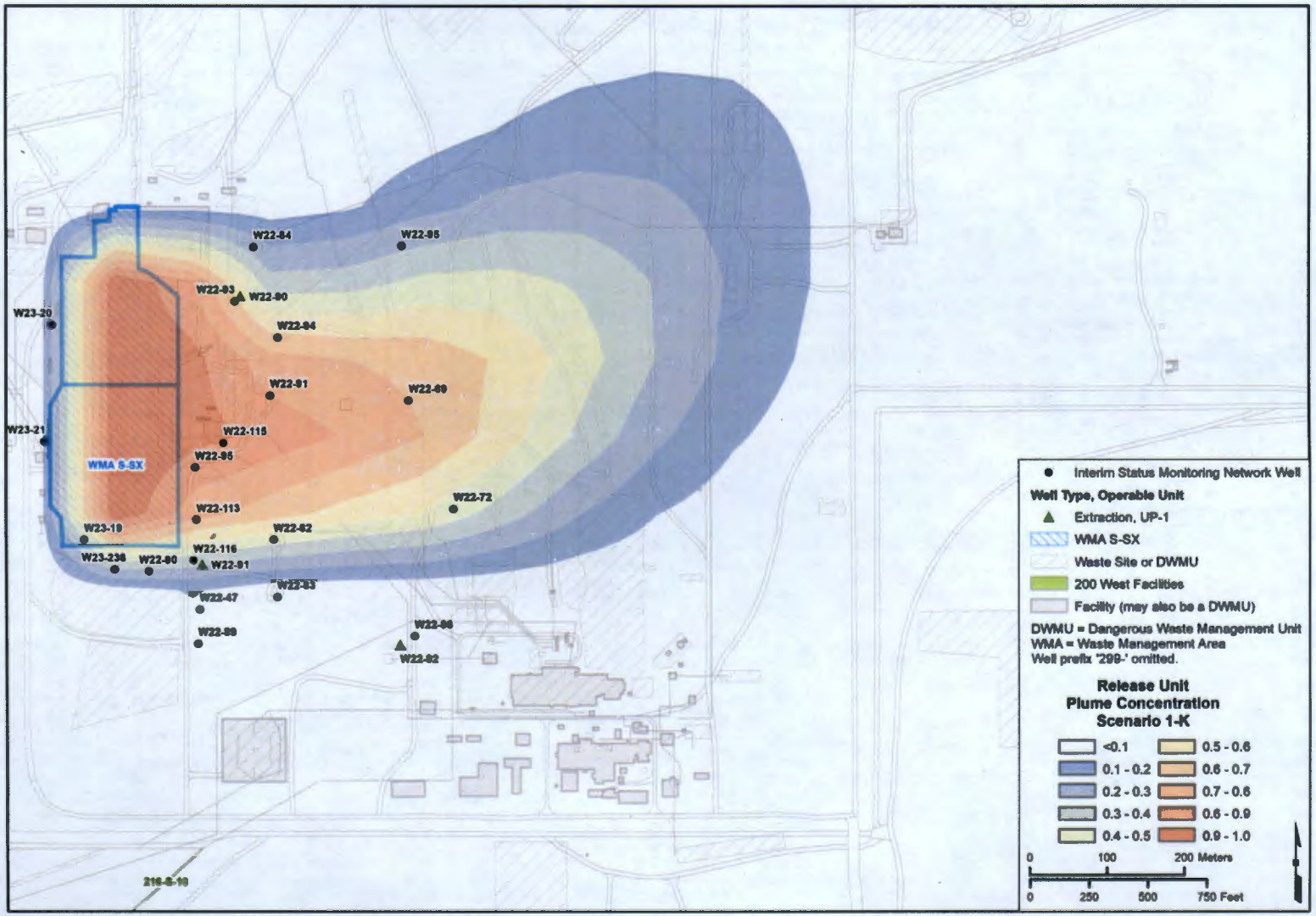
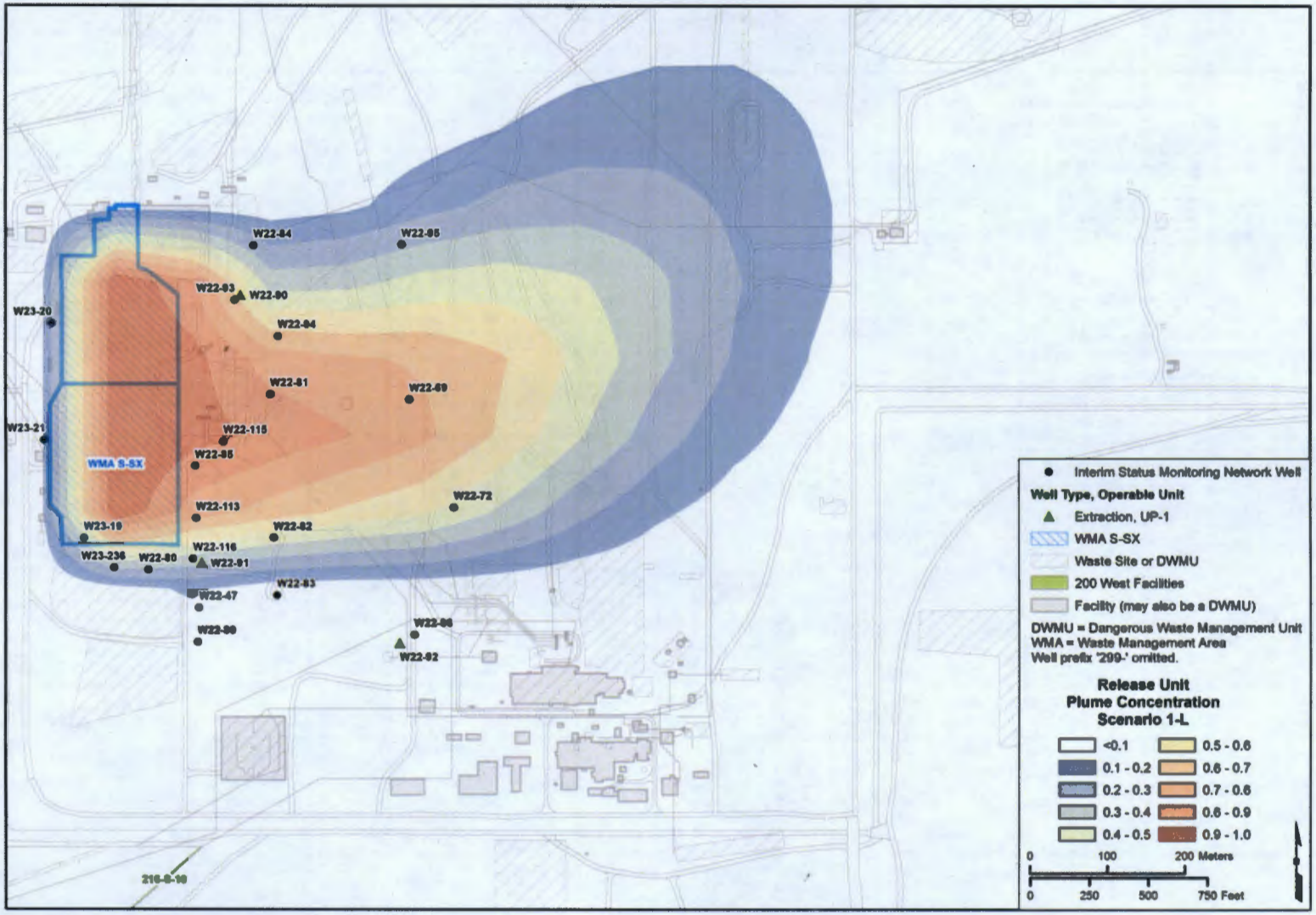


Figure B-11. Release Unit Plume Map Scenario 1, Sub-scenario K



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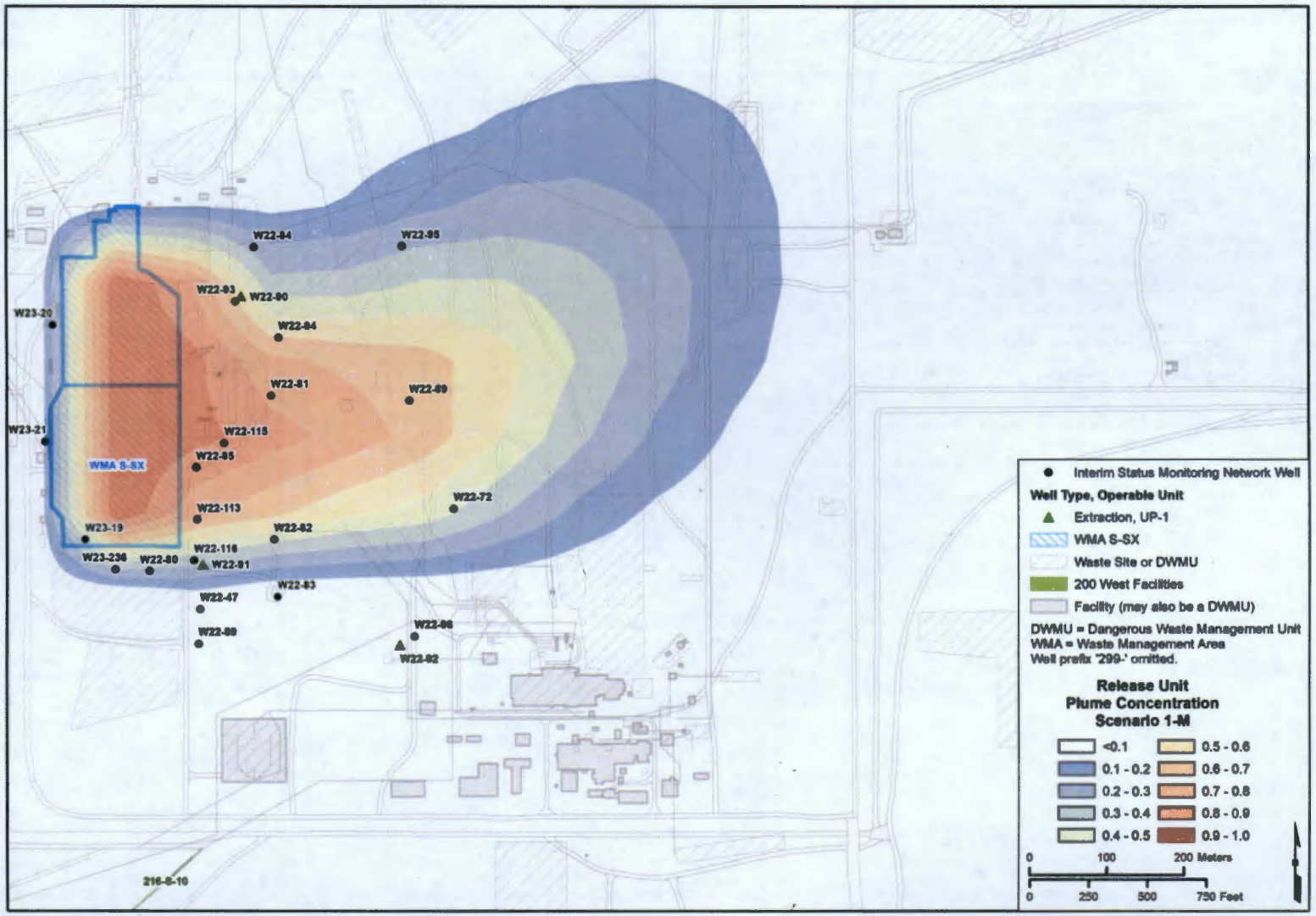

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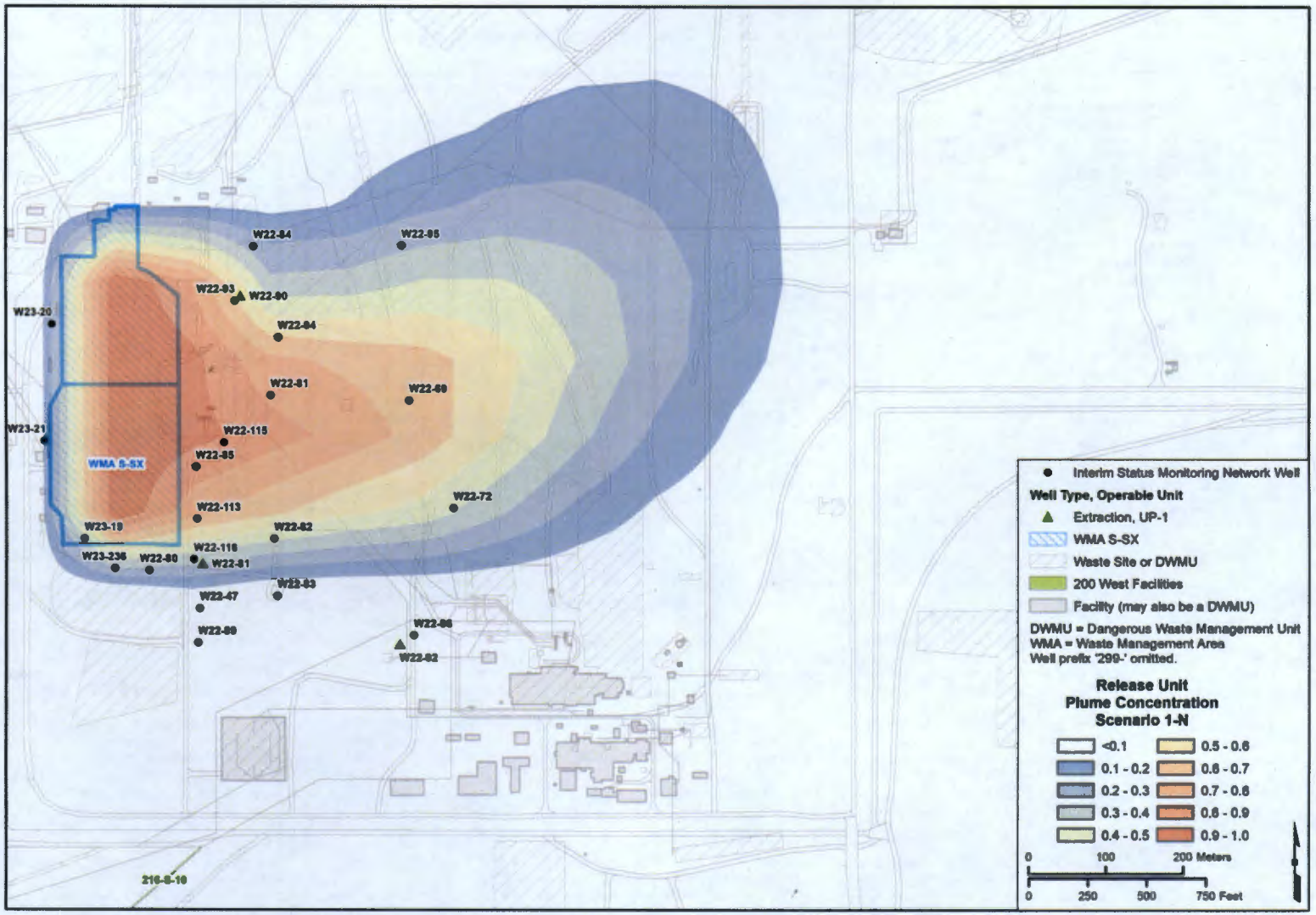

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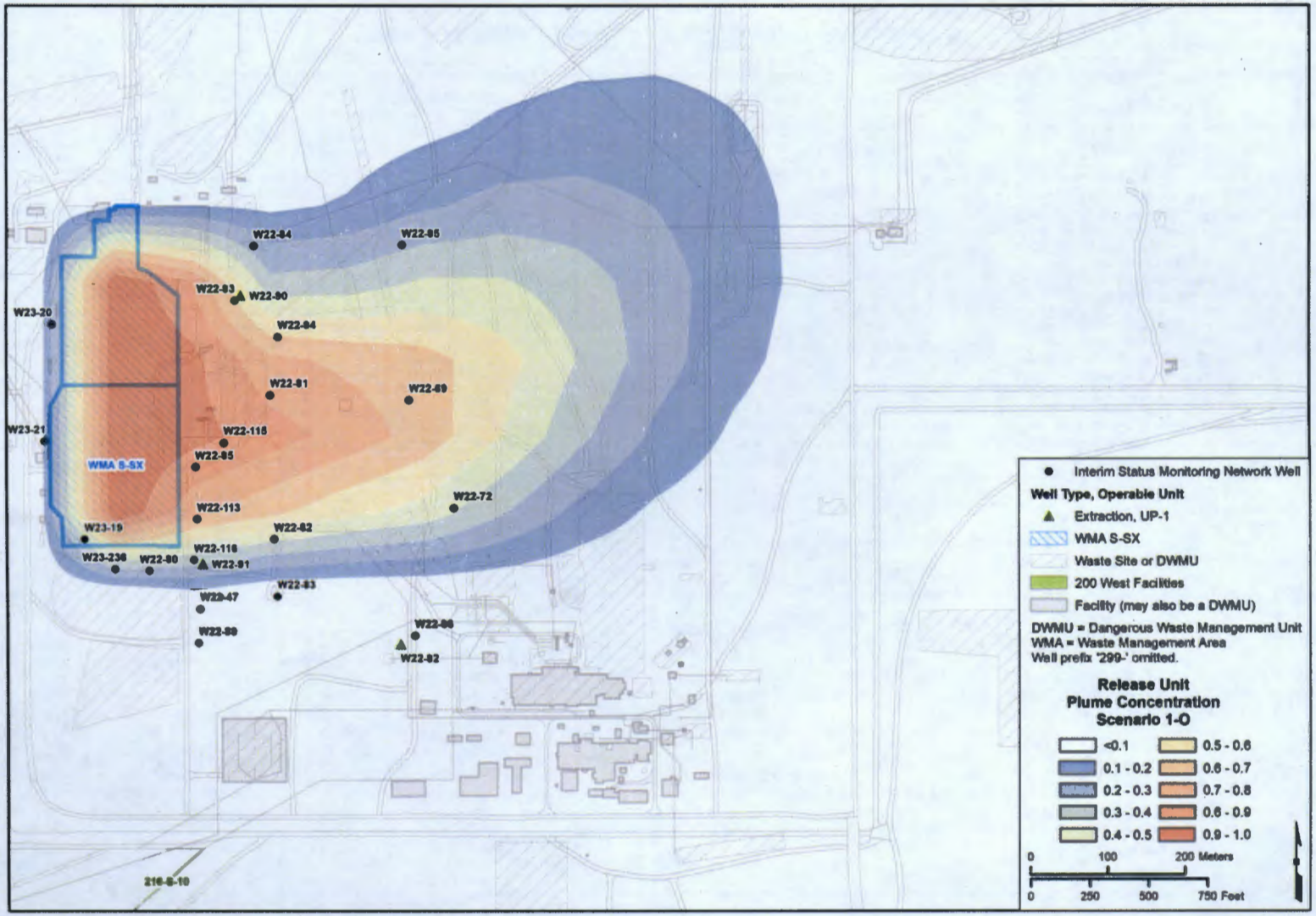

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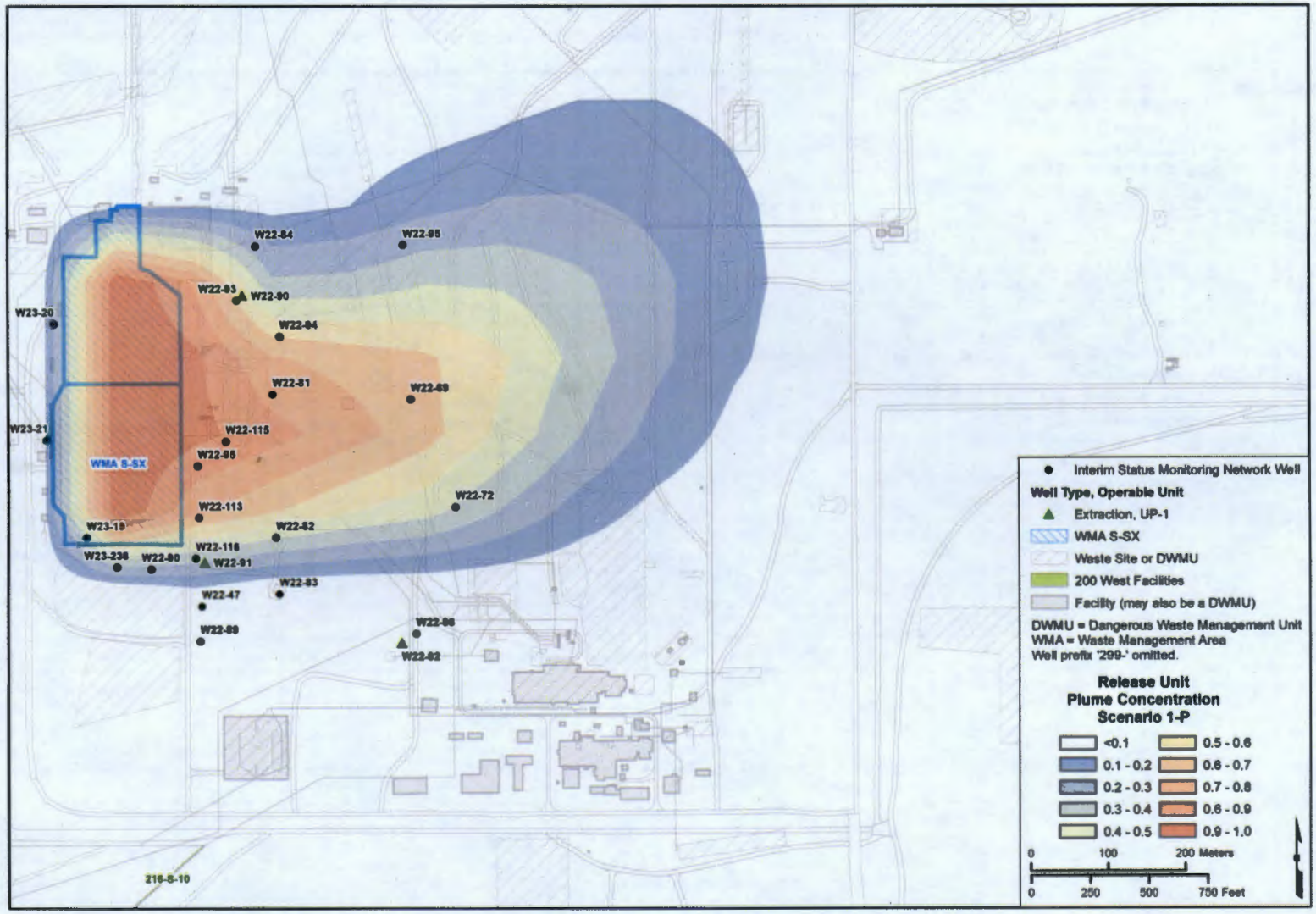

Figure B-16. Release Unit Plume Map Scenario 1, Sub-scenario P

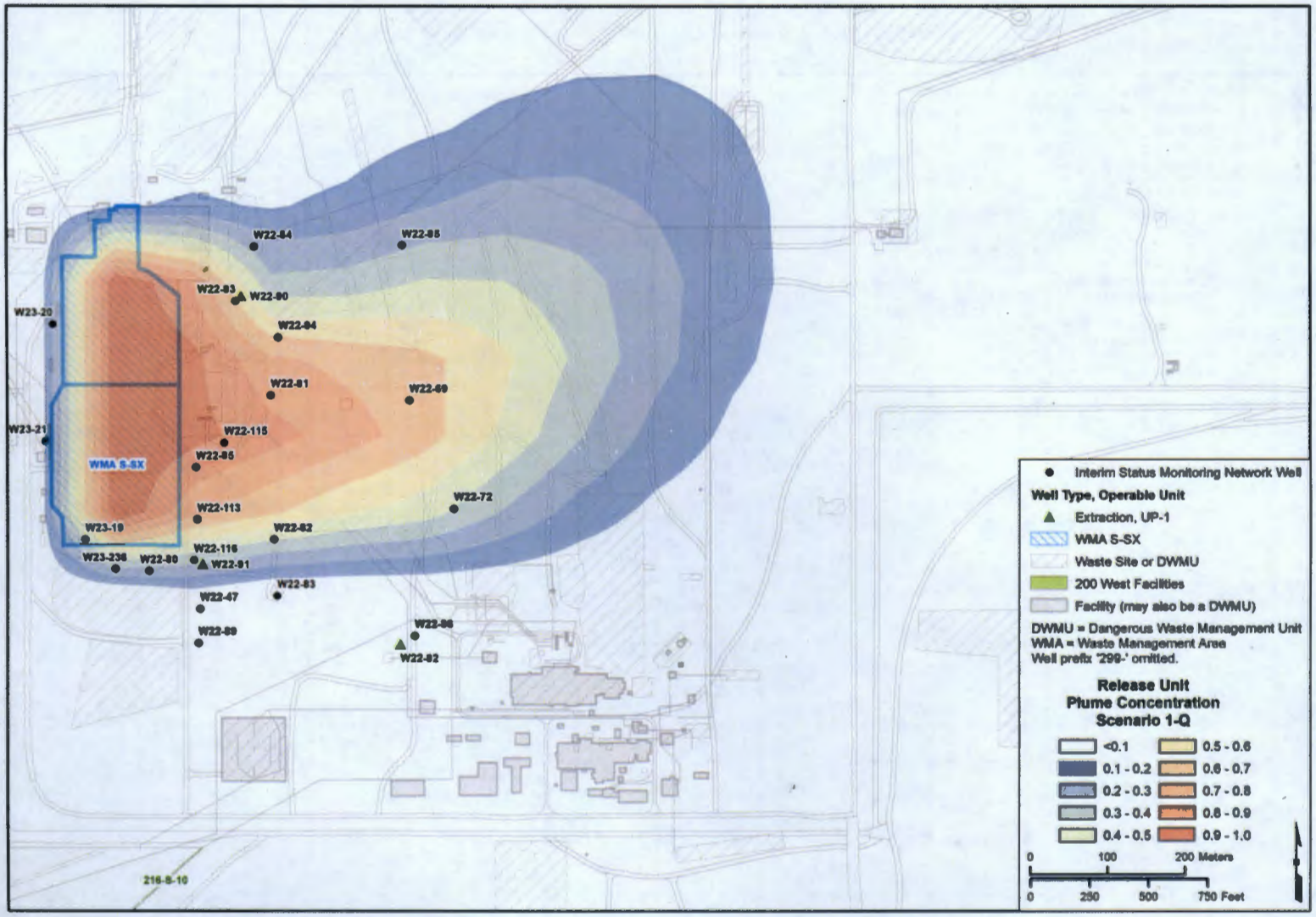

Figure B-17. Release Unit Plume Map Scenario 1, Sub-scenario Q

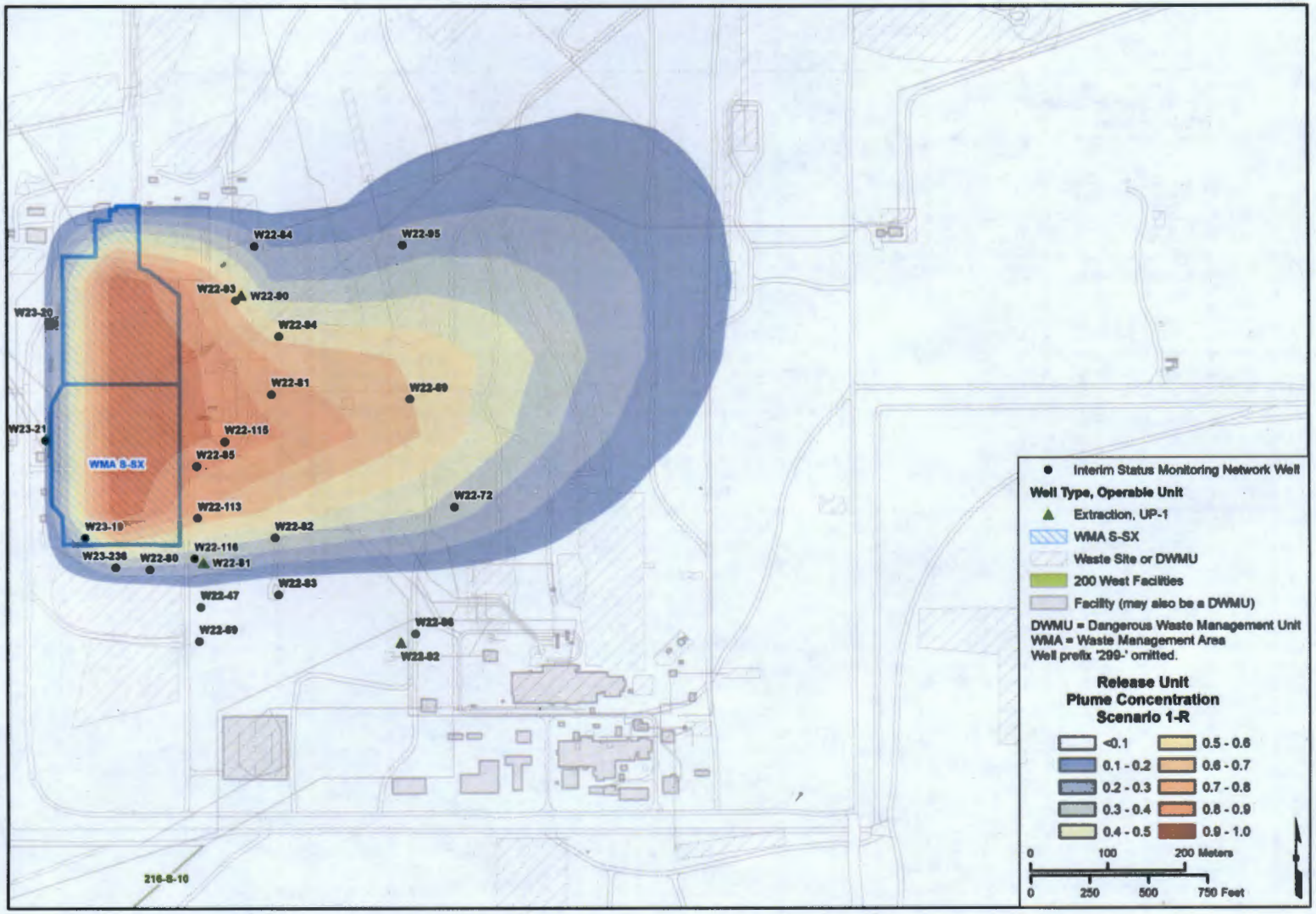

Figure B-18. Release Unit Plume Map Scenario 1, Sub-scenario R

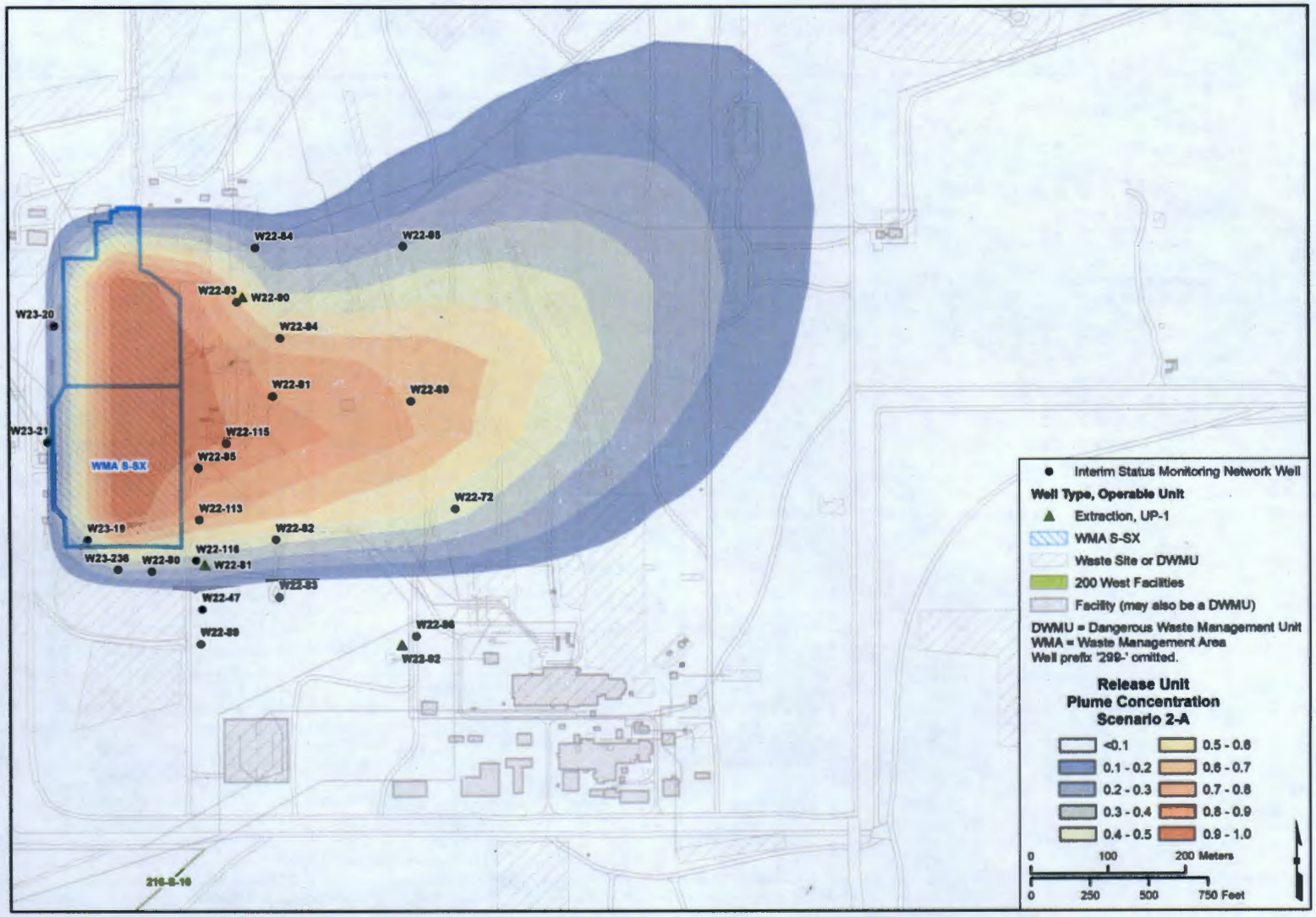

Figure B-19. Release Unit Plume Map Scenario 2, Sub-scenario A

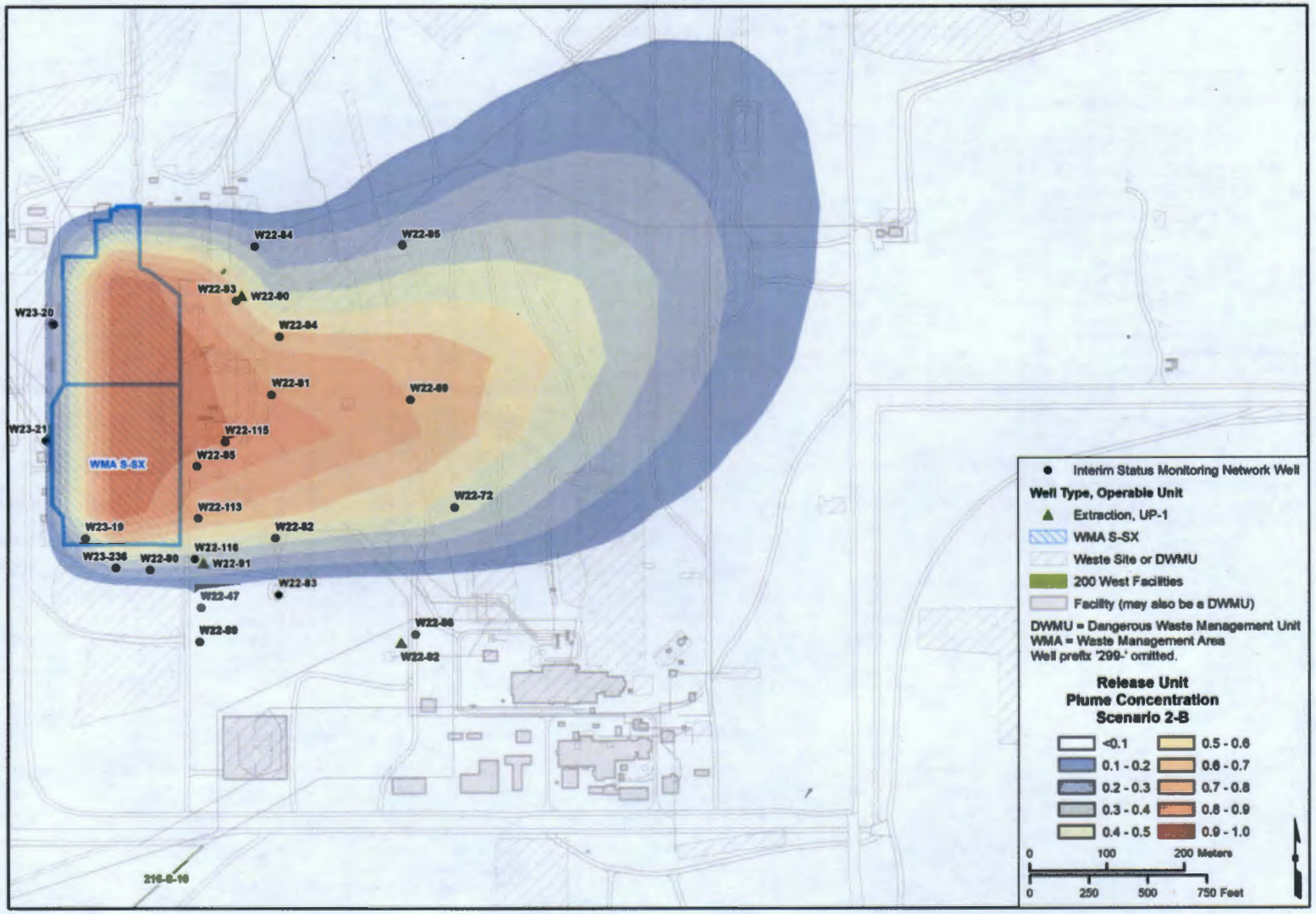

Figure B-20. Release Unit Plume Map Scenario 2, Sub-scenario B

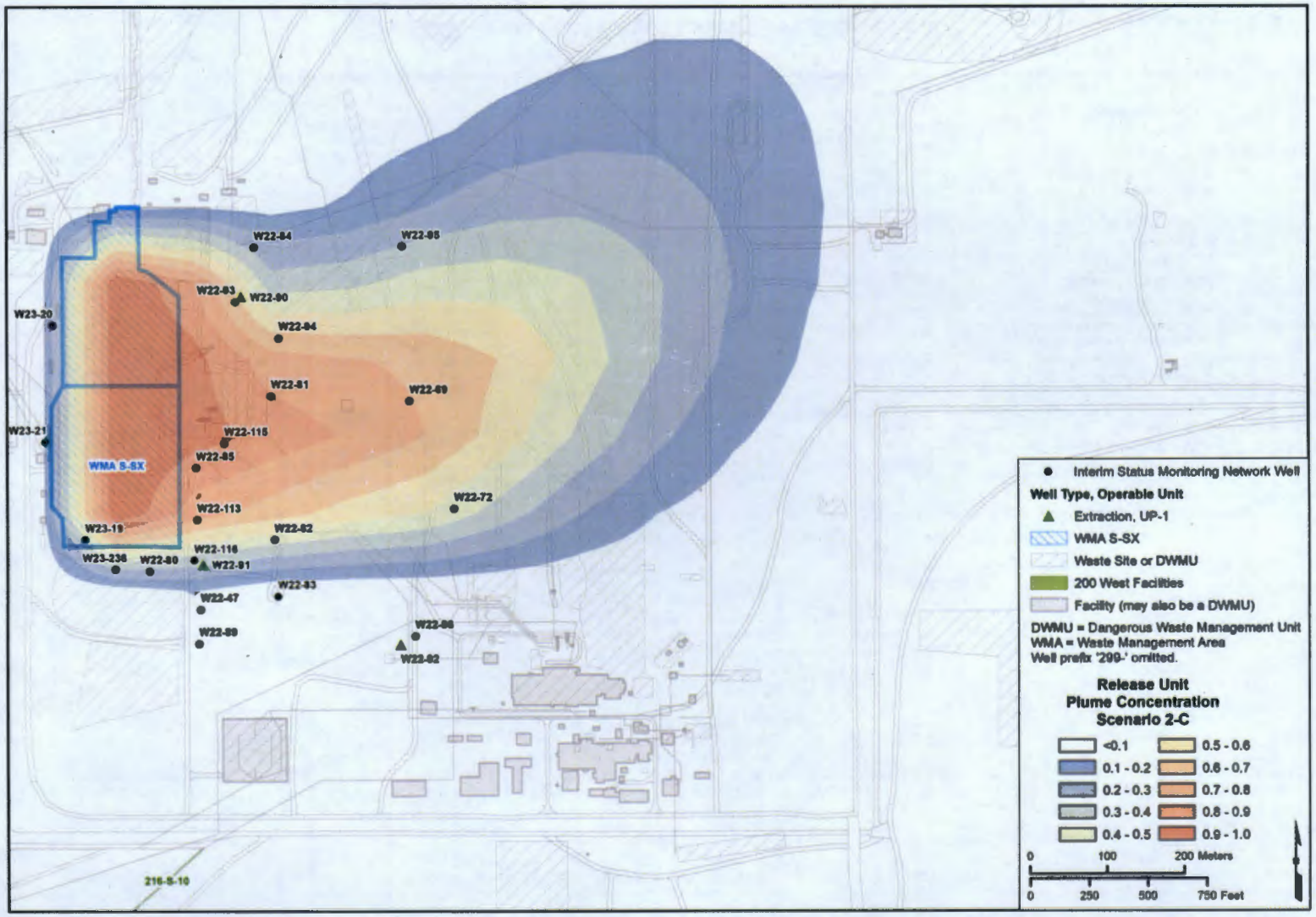

Figure B-21. Release Unit Plume Map Scenario 2, Sub-scenario C

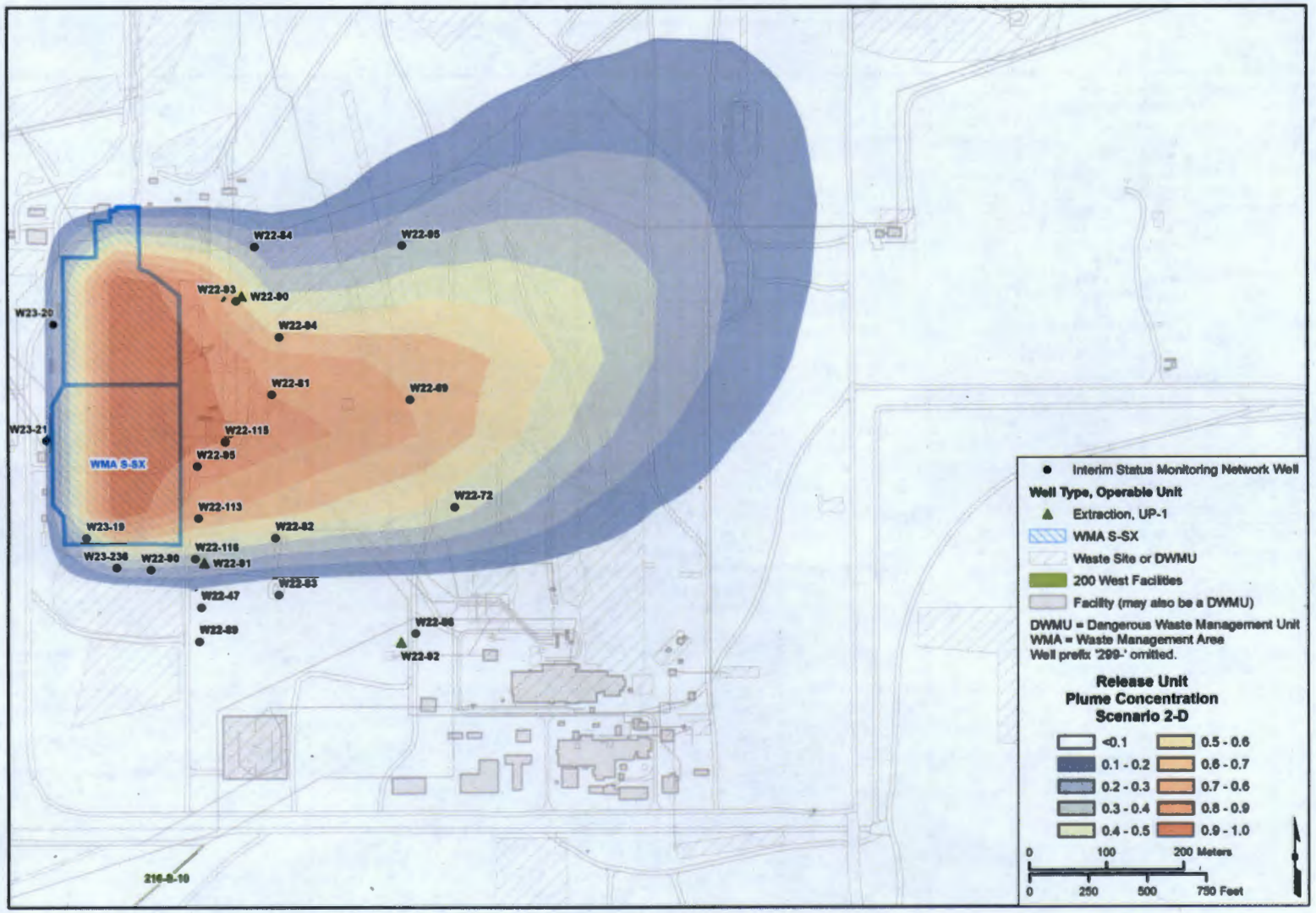

Figure B-22. Release Unit Plume Map Scenario 2, Sub-scenario D

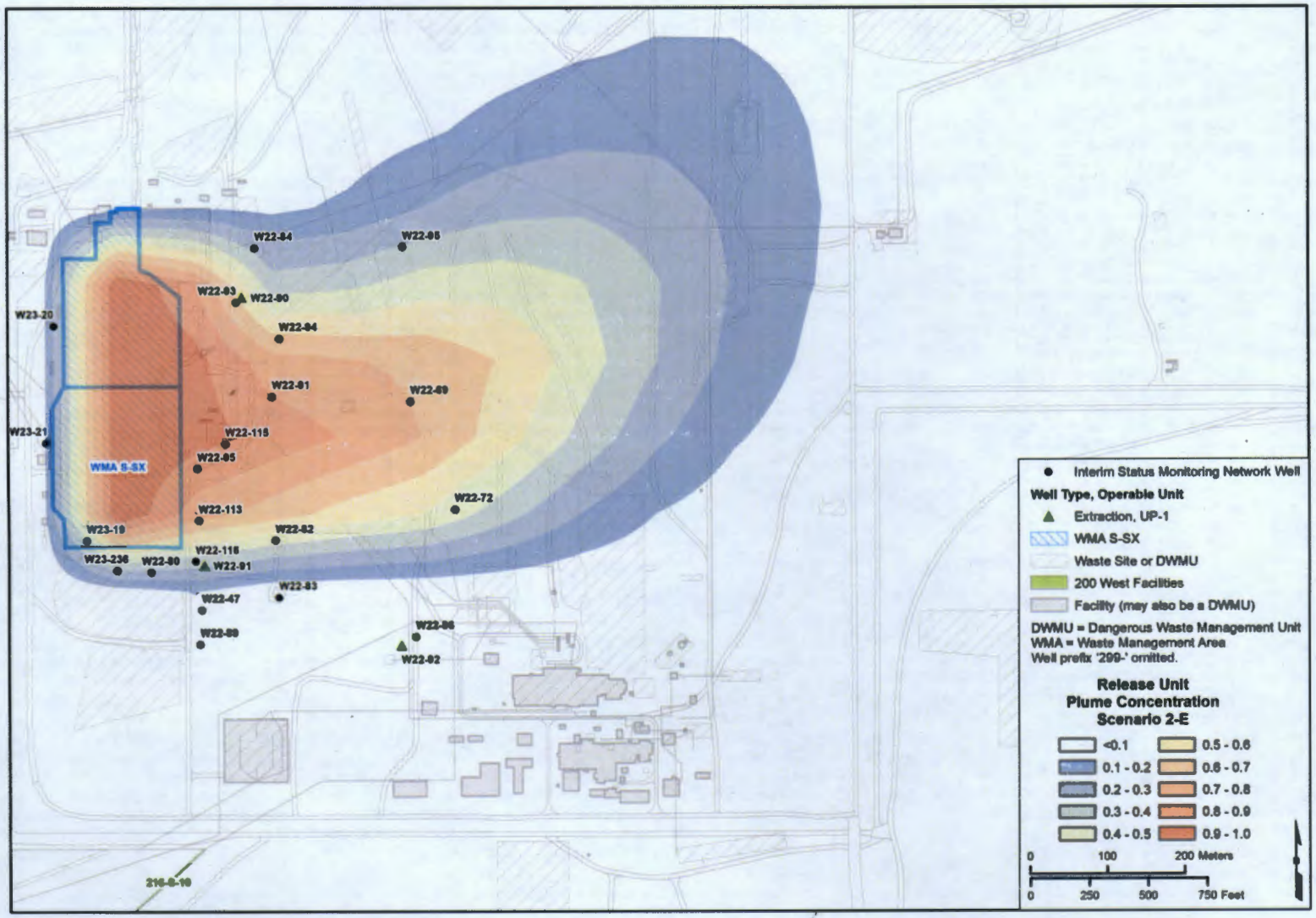

Figure B-23. Release Unit Plume Map Scenario 2, Sub-scenario E

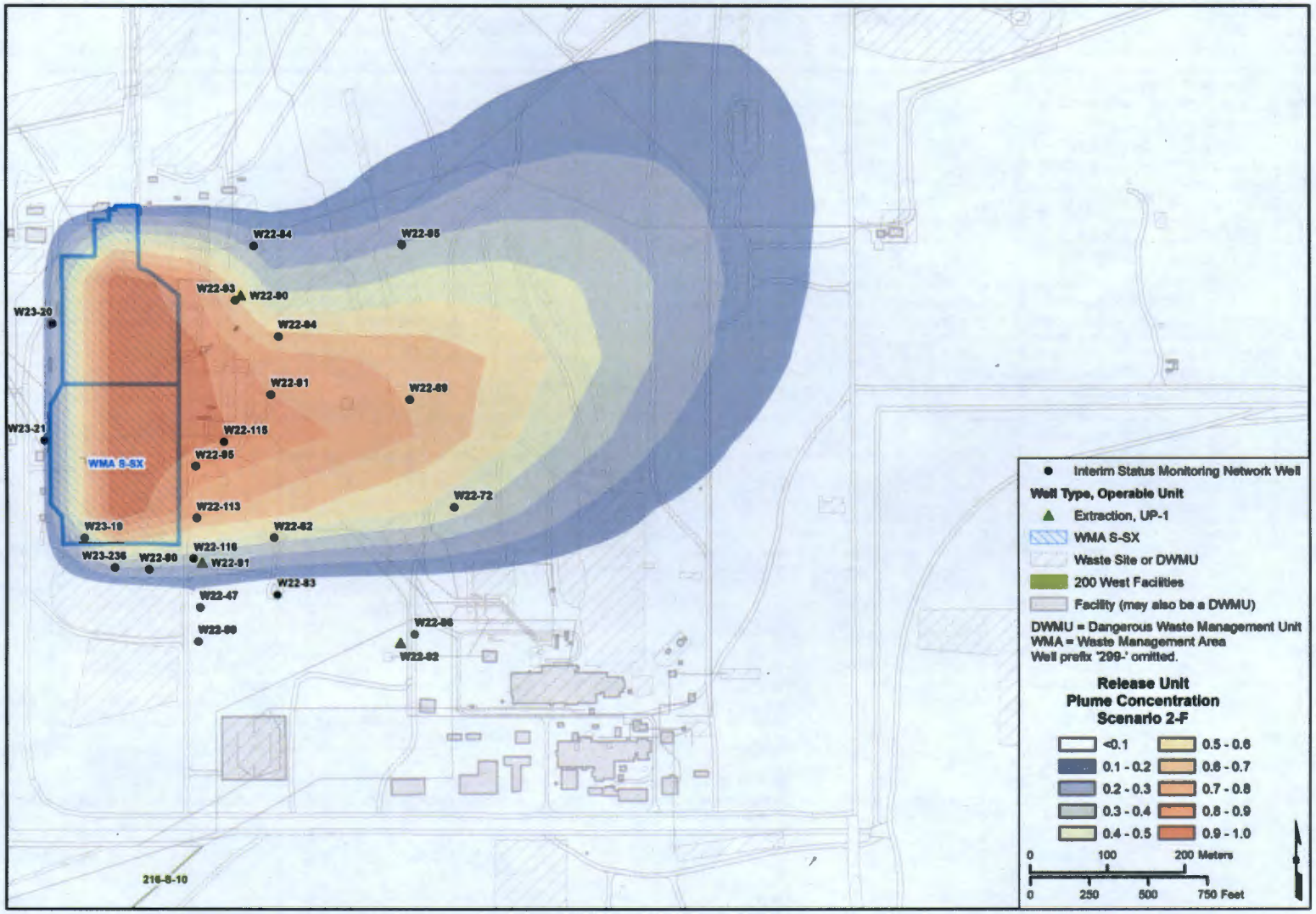

Figure B-24. Release Unit Plume Map Scenario 2, Sub-scenario F

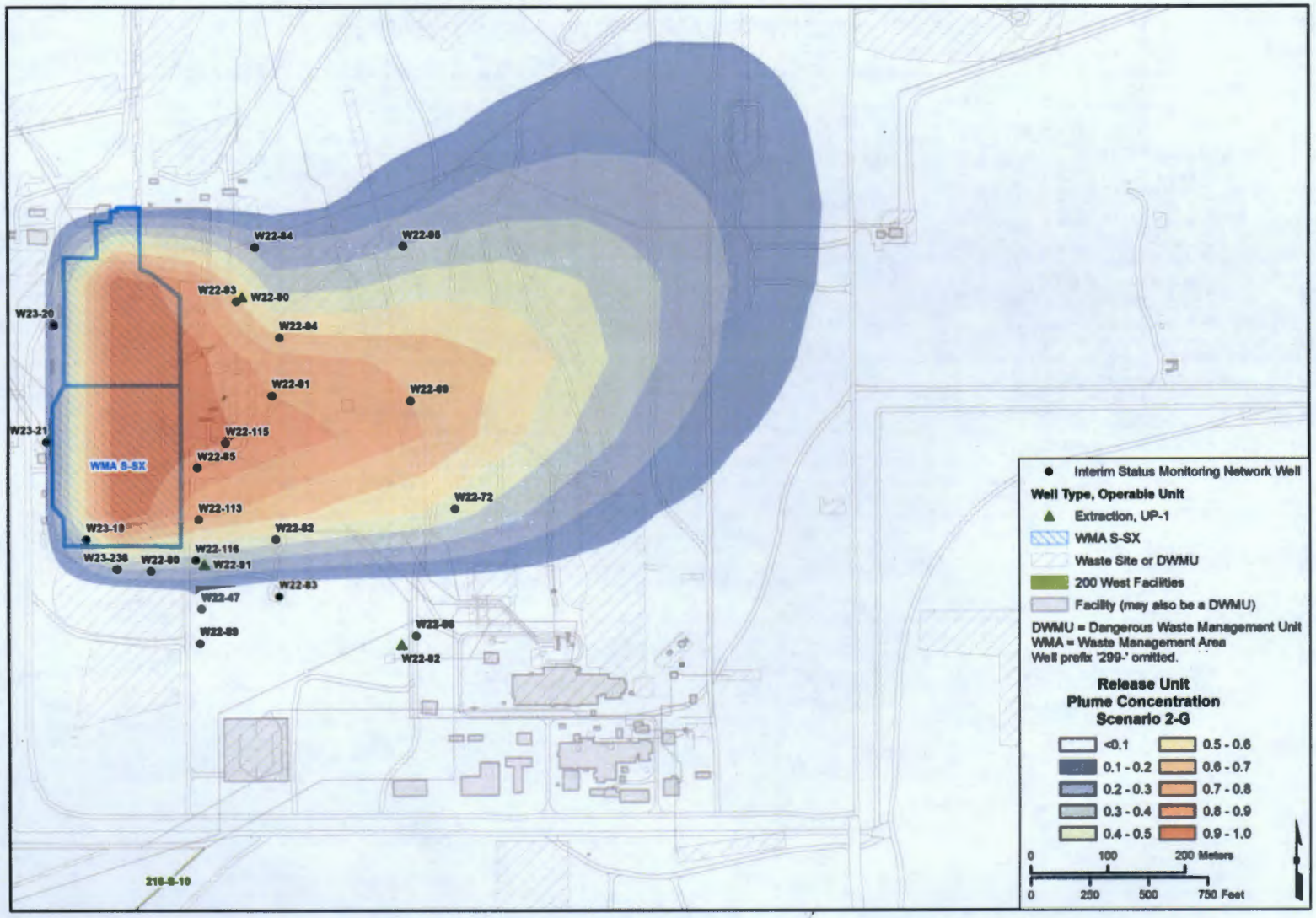

Figure B-25. Release Unit Plume Map Scenario 2, Sub-scenario G

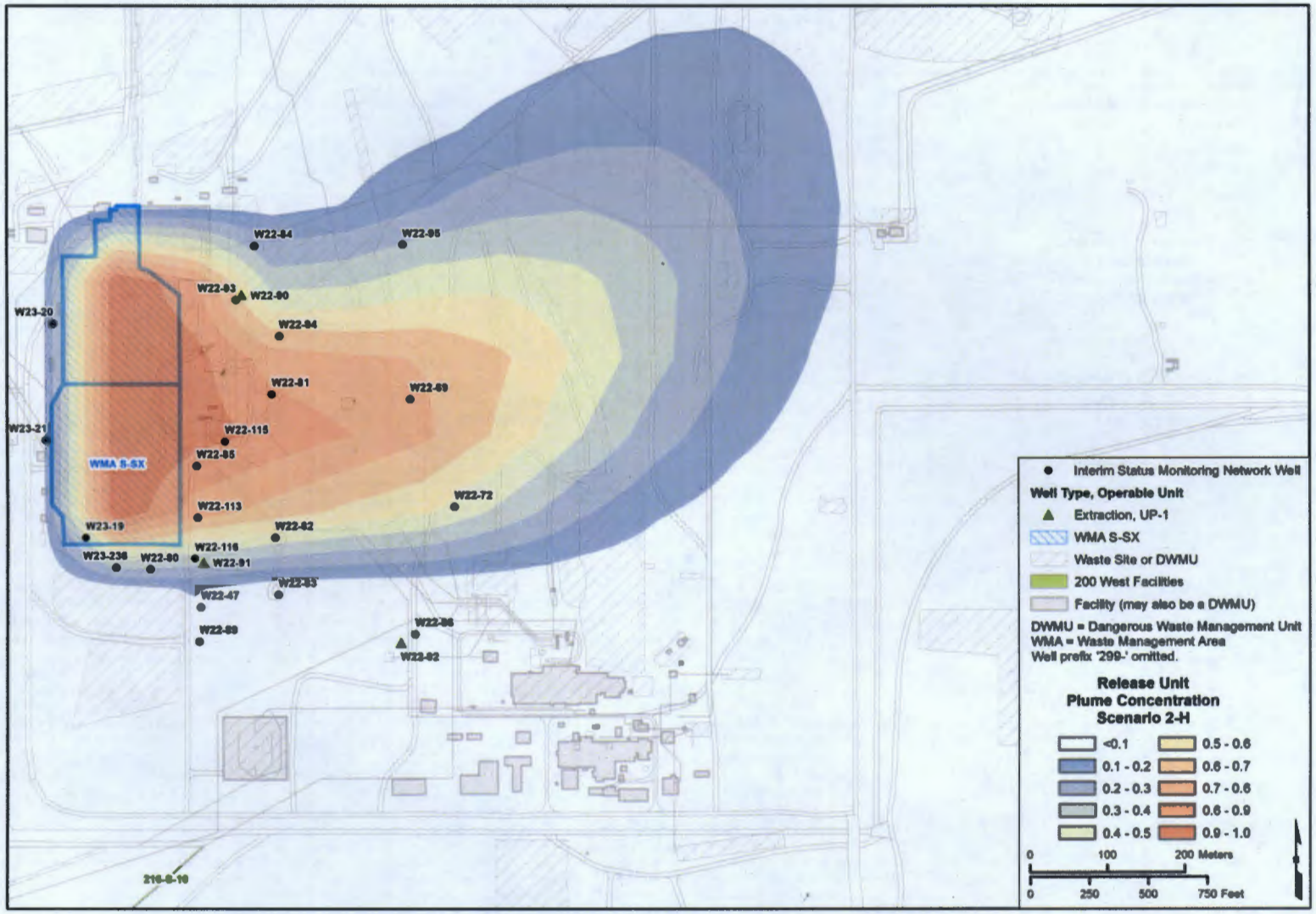

Figure B-26. Release Unit Plume Map Scenario 2, Sub-scenario H

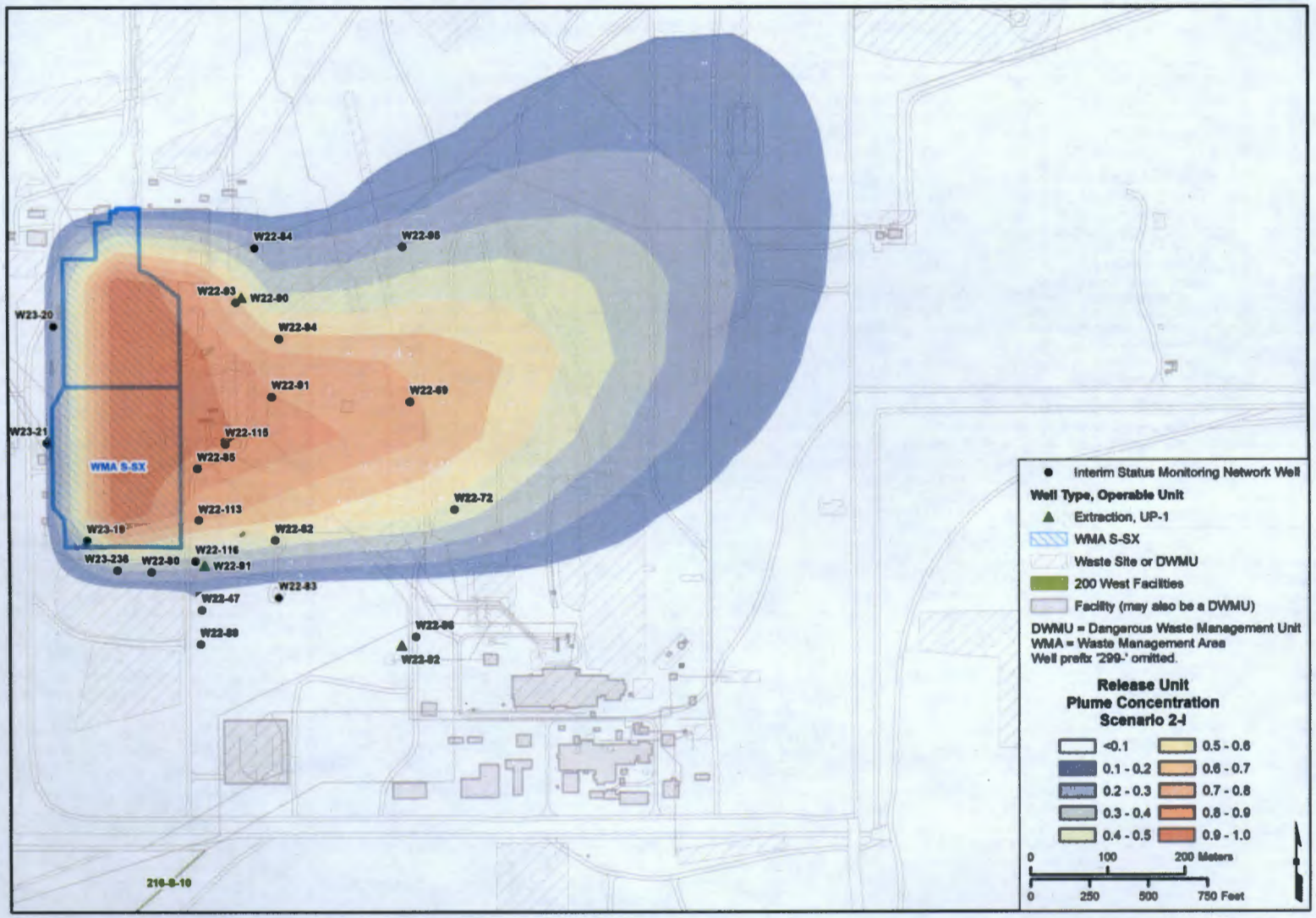

Figure B-27. Release Unit Plume Map Scenario 2, Sub-scenario I

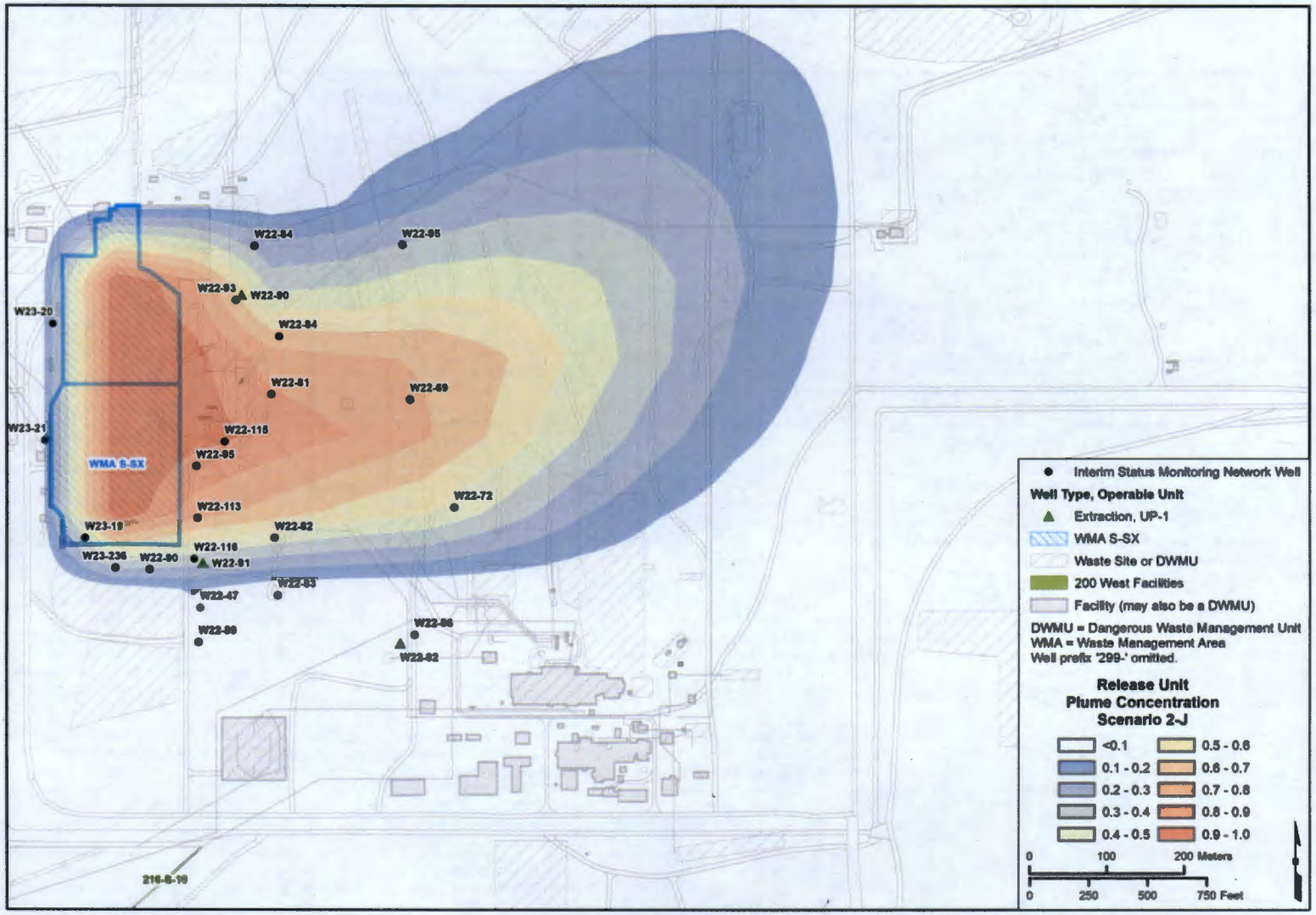

Figure B-28. Release Unit Plume Map Scenario 2, Sub-scenario J

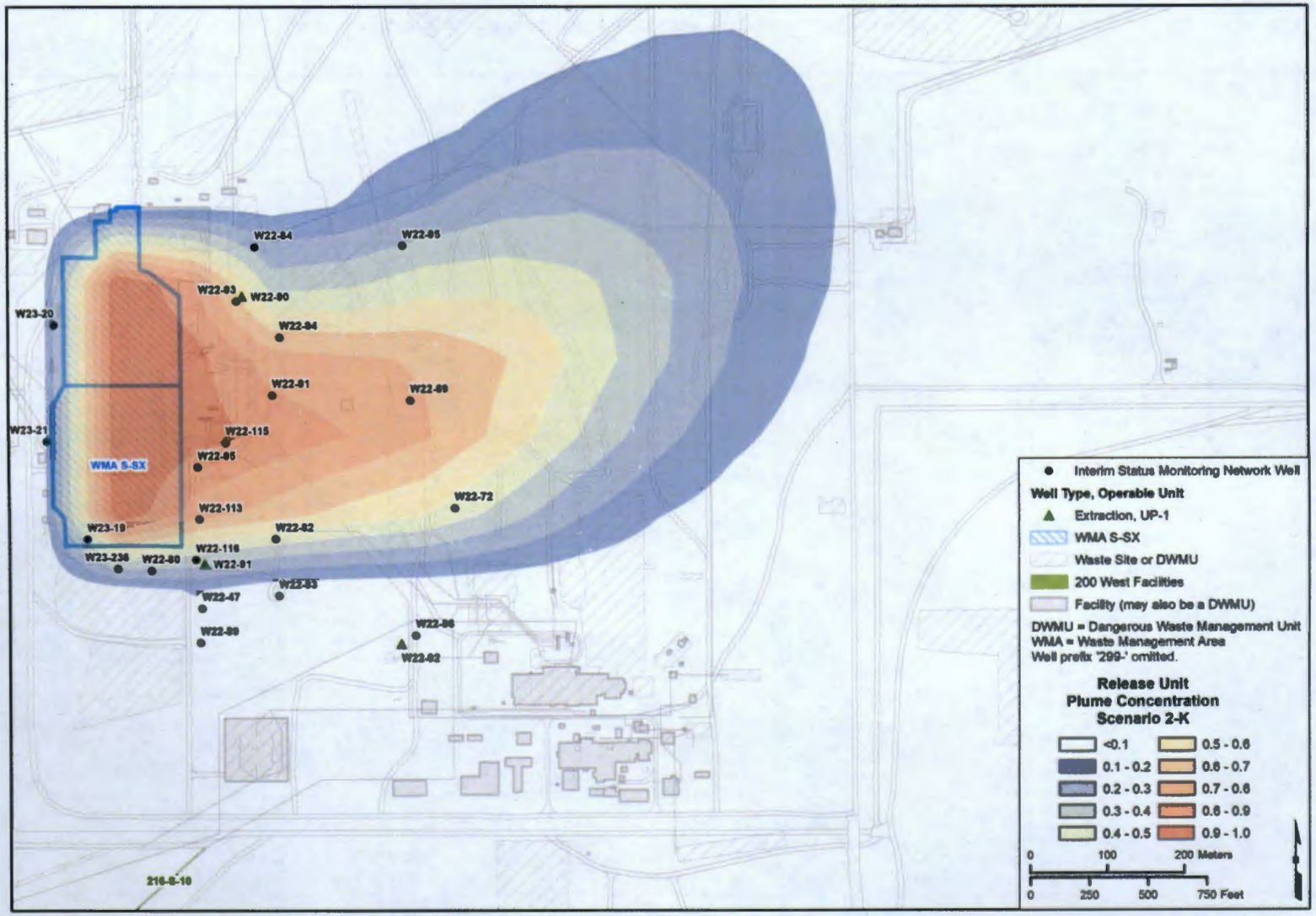

Figure B-29. Release Unit Plume Map Scenario 2, Sub-scenario K

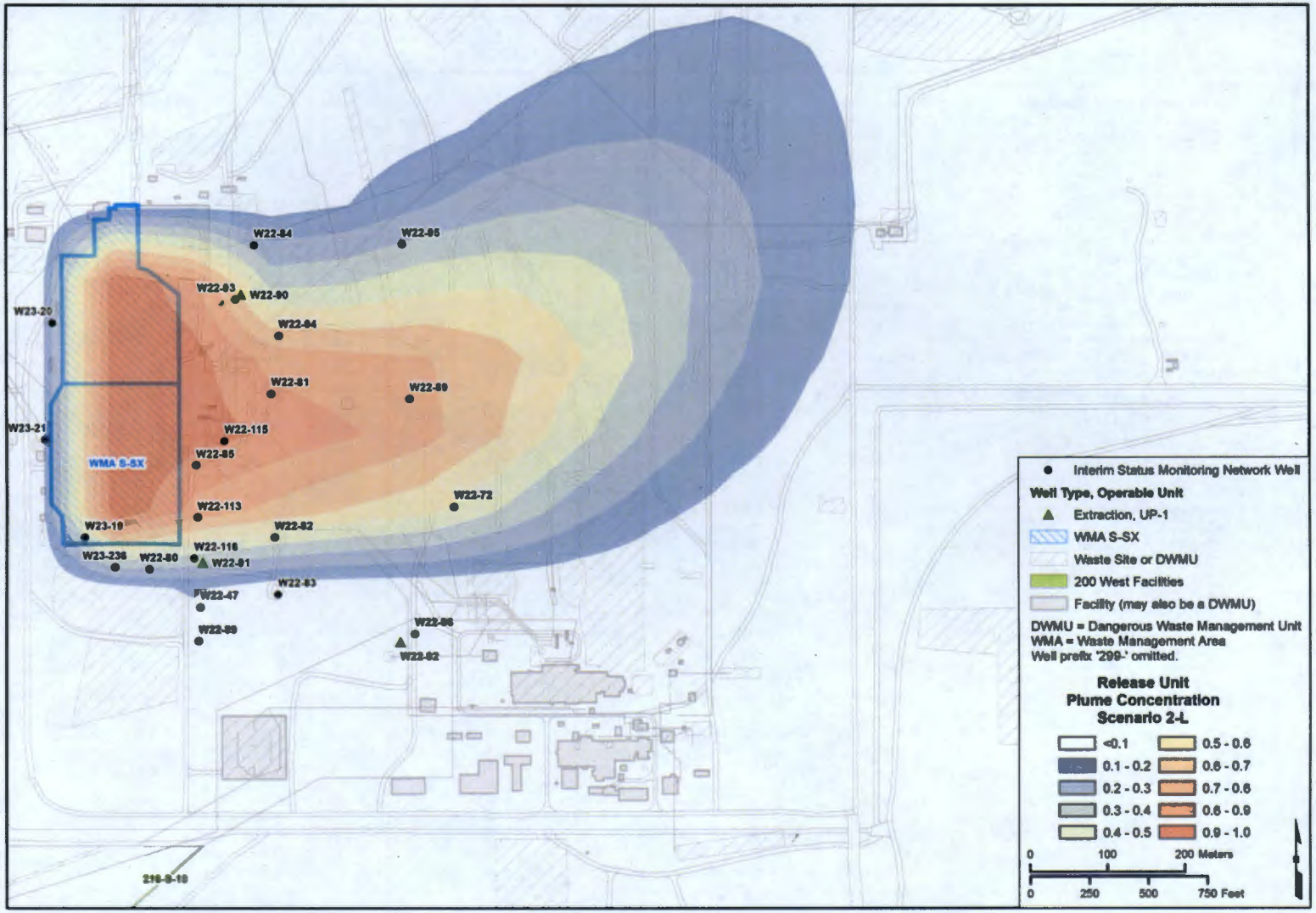

Figure B-30. Release Unit Plume Map Scenario 2, Sub-scenario L

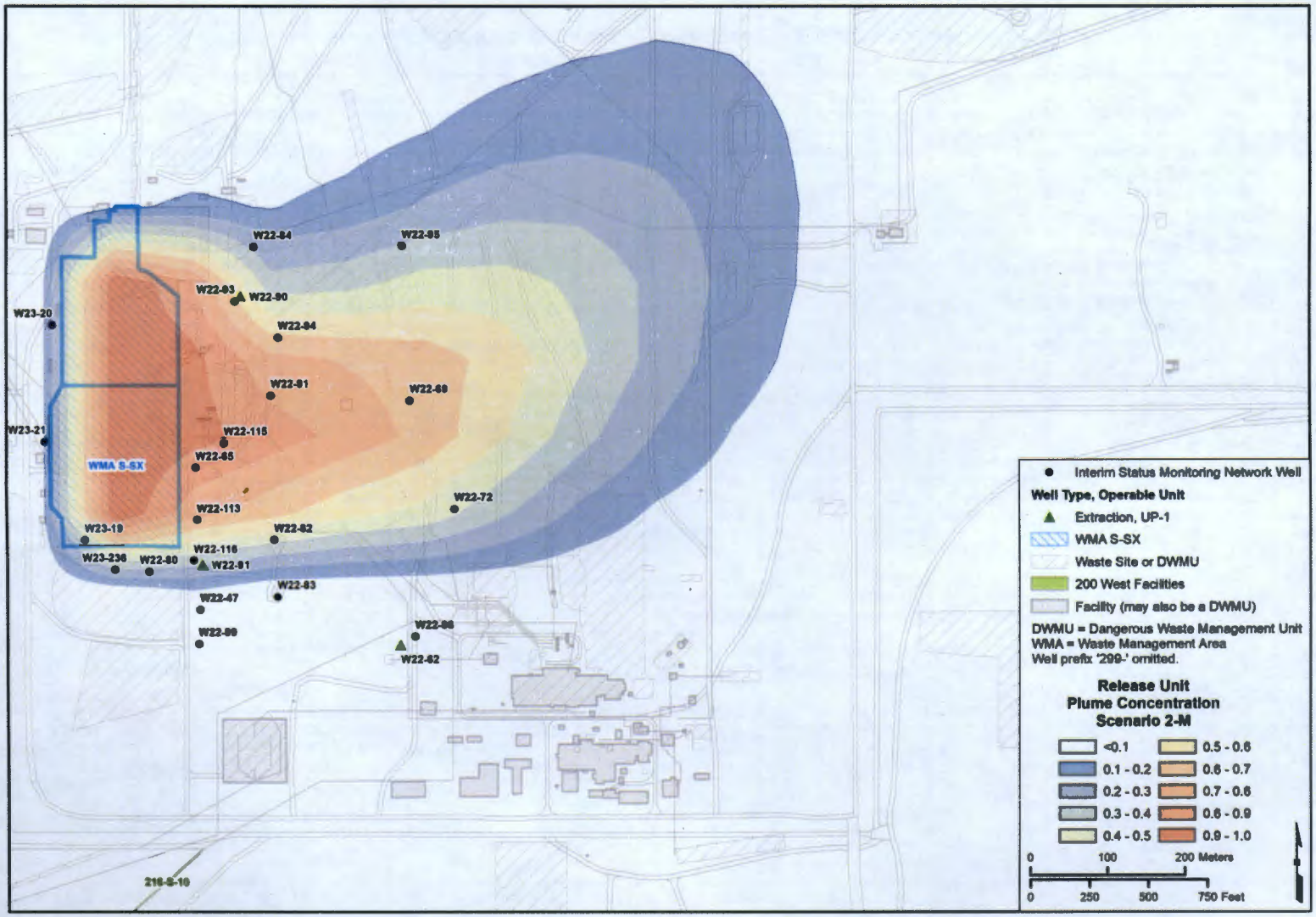

Figure B-31. Release Unit Plume Map Scenario 2, Sub-scenario M

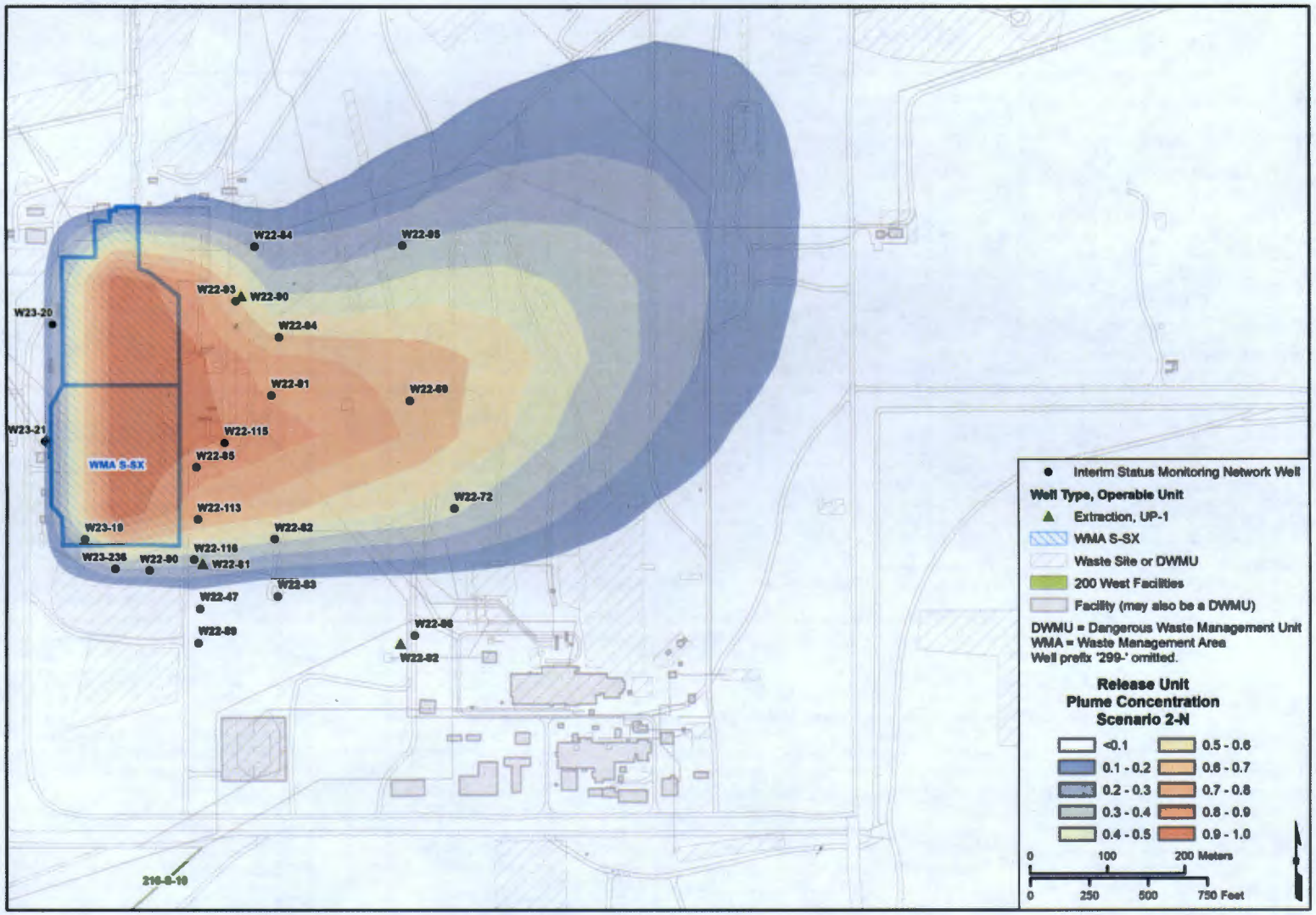

Figure B-32. Release Unit Plume Map Scenario 2, Sub-scenario N

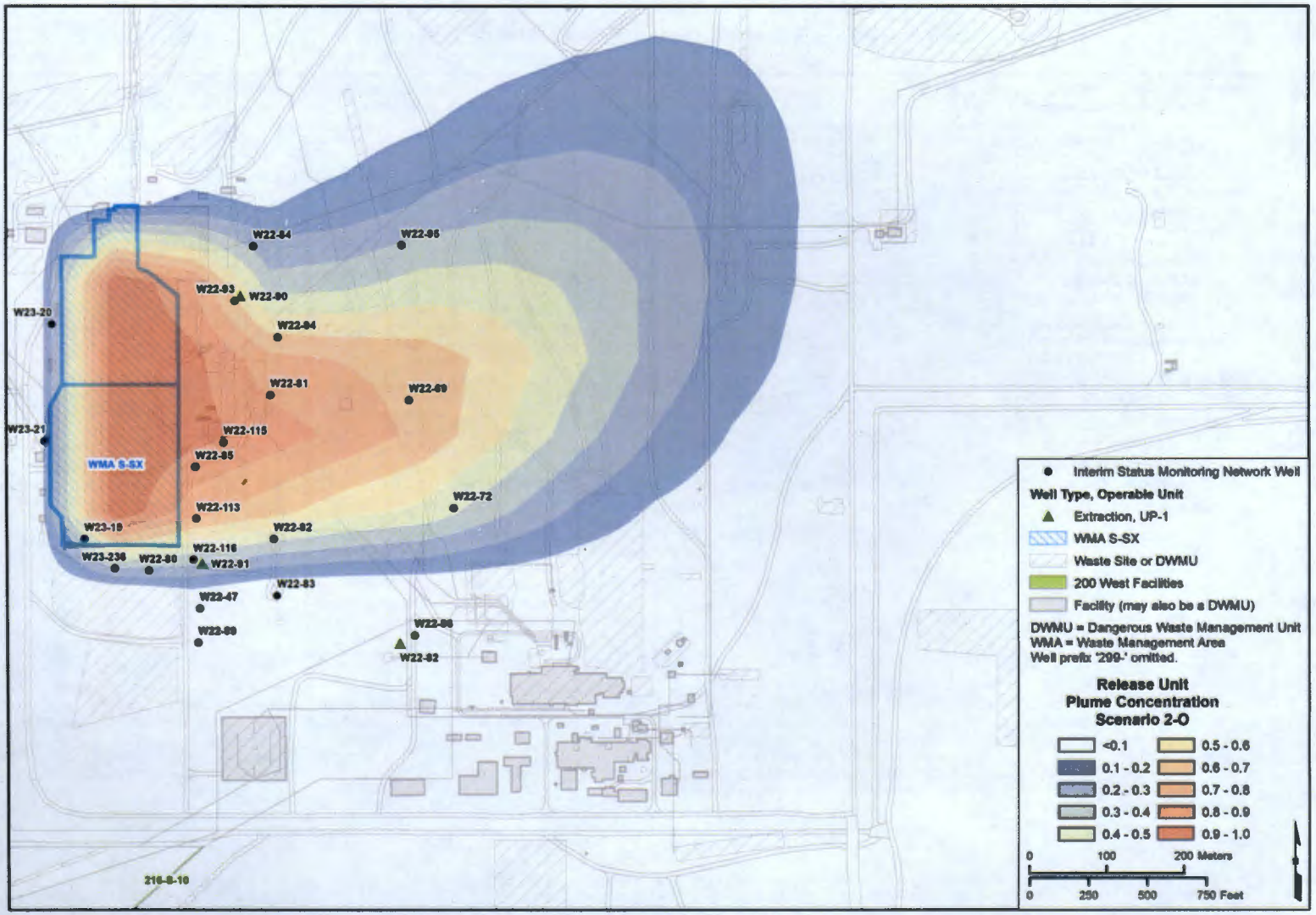

Figure B-33. Release Unit Plume Map Scenario 2, Sub-scenario O

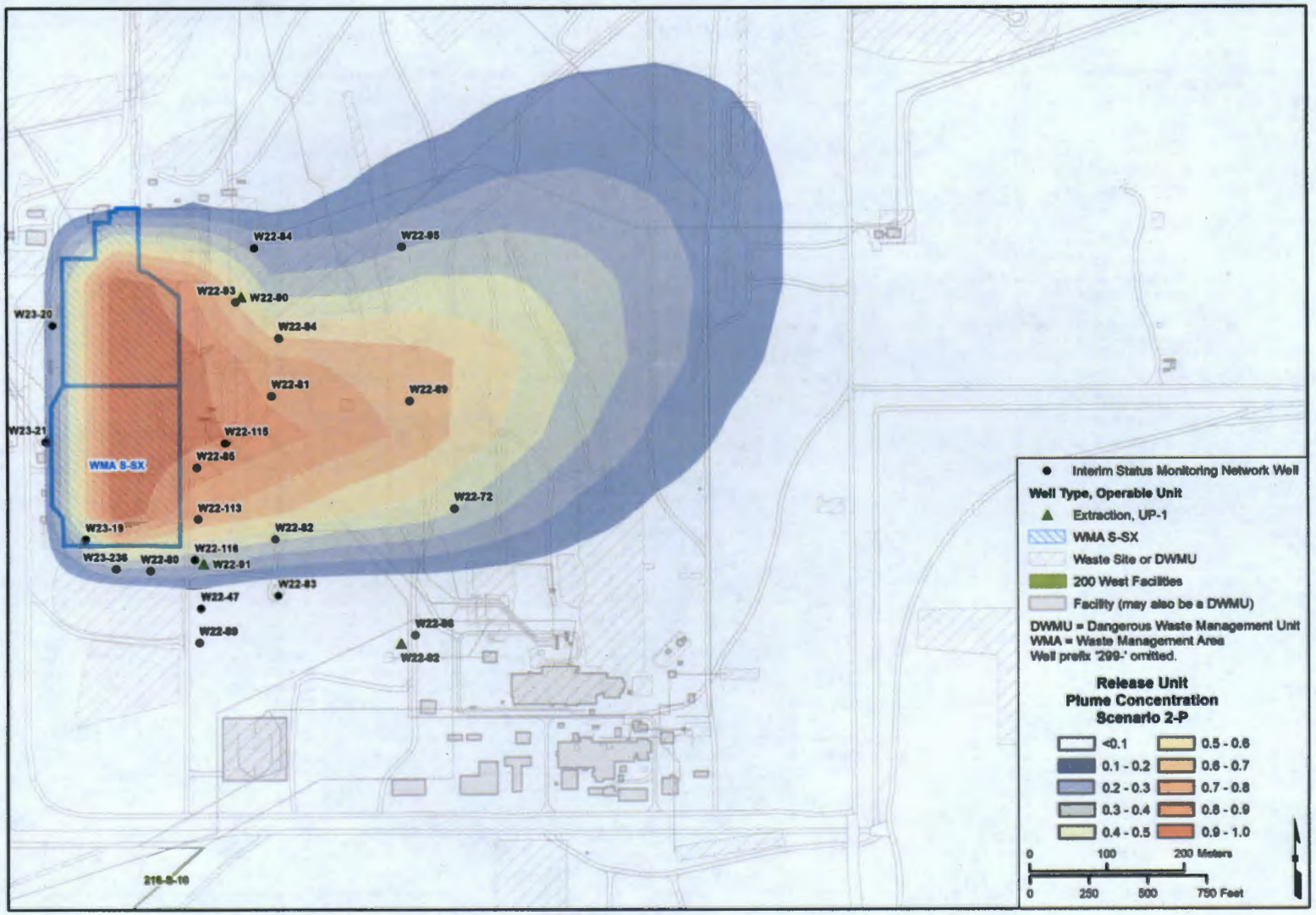

Figure B-34. Release Unit Plume Map Scenario 2, Sub-scenario P

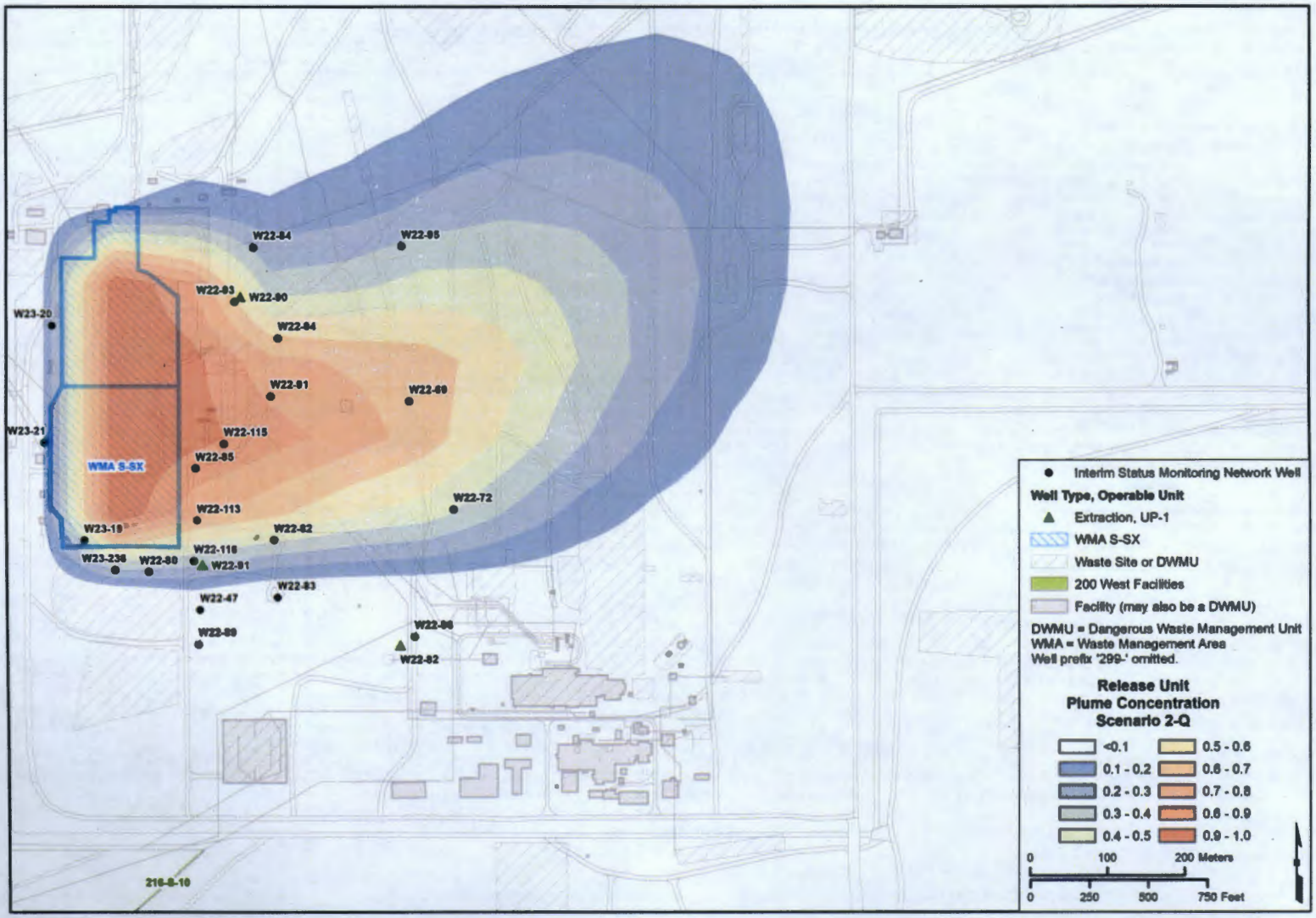

Figure B-35. Release Unit Plume Map Scenario 2, Sub-scenario Q

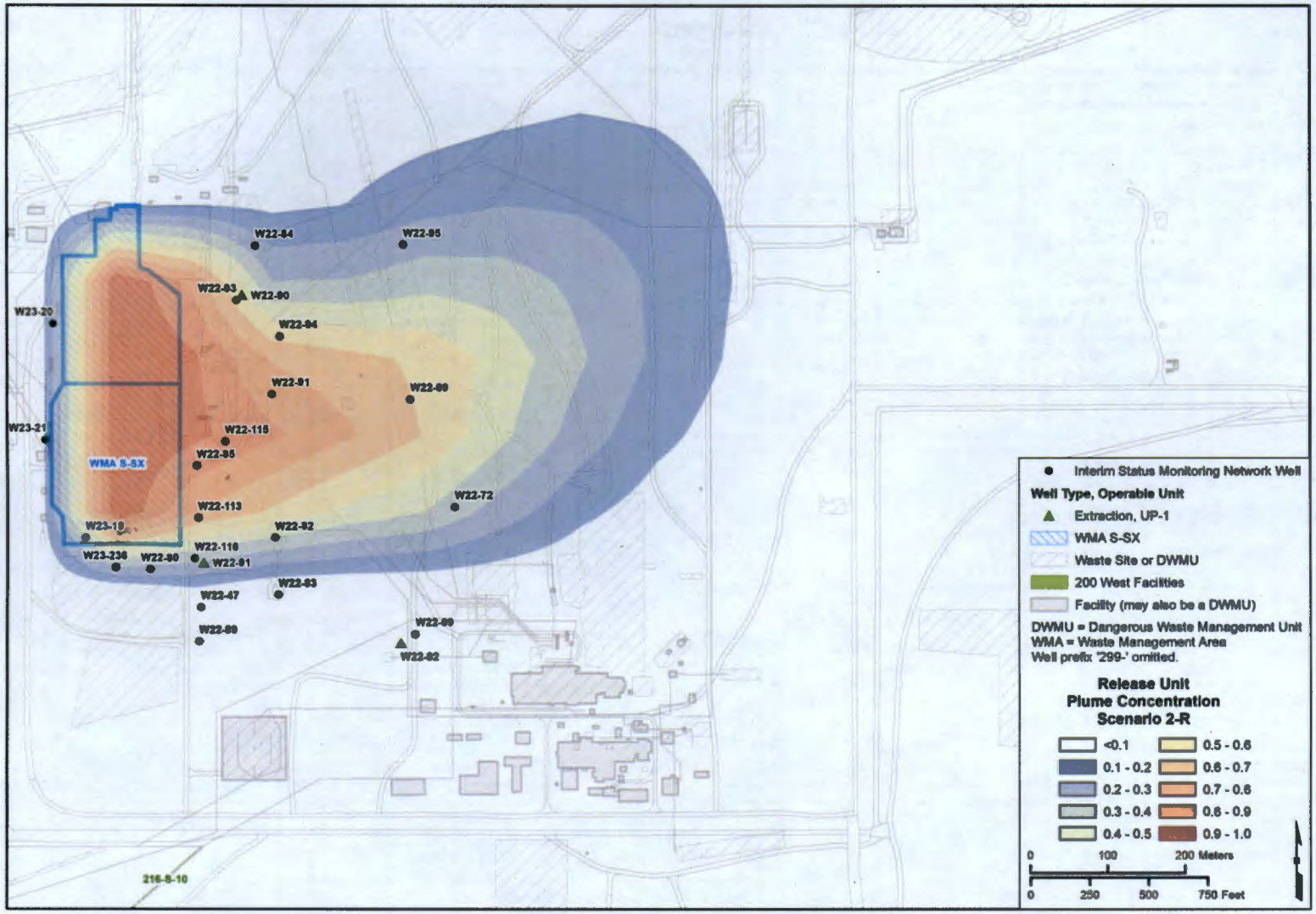

Figure B-36. Release Unit Plume Map Scenario 2, Sub-scenario R

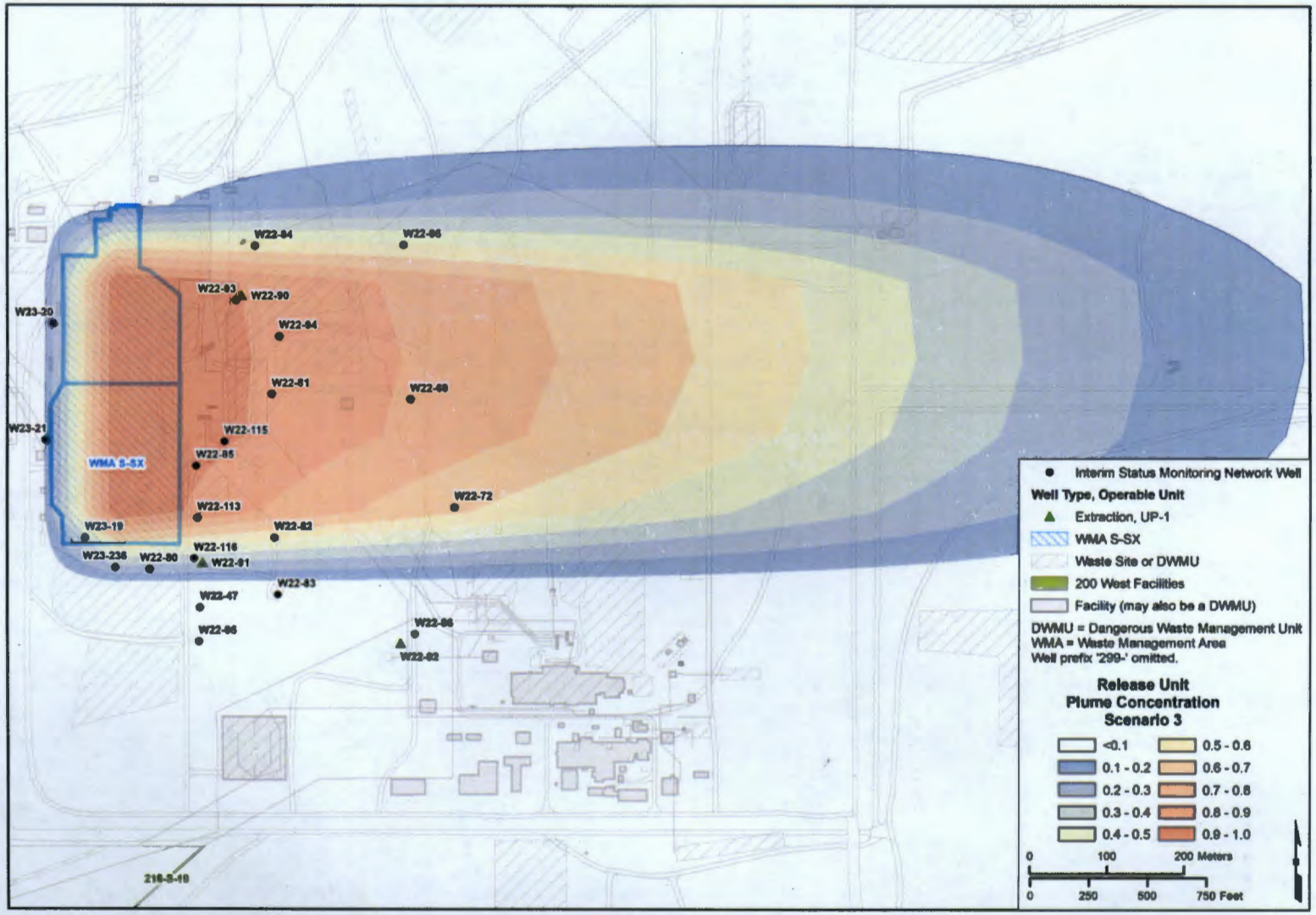

Figure B-37. Release Unit Plume Map Scenario 3

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