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Revision 0

CENTRAL PLATEAU GROUNDWATER TRACER STUDY PHASE I REPORT

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

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

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Terms

CPGWM	Central Plateau Groundwater Model
EDA	Environmental Dashboard Application
HEIS	Hanford Environmental Information System
NRDWL	Nonradioactive Dangerous Waste Landfill
SWL	Solid Waste Landfill

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1 Introduction

The U.S. Department of Energy, Richland Operations Office is performing a study of groundwater movement in the Hanford Site Central Plateau area using the approaches described in SGW-60511, *Central Plateau Groundwater Tracer Study Work Plan*. This report summarizes the results of the Phase I study that used existing groundwater observations and measurements from two general locations in the Central Plateau. The Phase I activities were intended to be exploratory and to evaluate the utility of existing historical groundwater data to support assessment of groundwater flow behavior.

The first Phase I study location is the vicinity of the Solid Waste Landfill/Nonradioactive Dangerous Waste Landfill (SWL/NRDWL) where a sequence of fluorescent dye tracer studies were conducted in 1956 and 1957 (HW-60601, *Aquifer Characteristics and Ground-Water Movement at Hanford*). These studies identified discrete arrival peaks of the emplaced fluorescein tracer at downgradient observation wells indicating very rapid groundwater movement; the peak arrival times for the two historical dye studies were about 30 days and 130 days at distances of 2.8 km (1.8 mi) and 3.9 km (2.4 mi), respectively. Historical groundwater movement in this location was evaluated using three-point gradient solutions in addition to use of the Central Plateau Groundwater Model (CPGWM) to compare simulated results to estimated groundwater velocity and flow direction during the historical test. The model was found to not reproduce the apparent travel time indicated in the historic study.

The second Phase I study location is the vicinity between the 200 West Area and 200 East Area where a plume of elevated tritium activity concentration evolved following historical discharges of wastewater in the 200 West Area beginning in the 1950s. Downgradient monitoring wells in this study area exhibited discrete tritium activity concentration transients. Historical groundwater movement in this area was evaluated using the CPGWM along with three-point gradient solutions and comparison to interpolated groundwater plume geometry. The model was found to reliably describe apparent groundwater flow directions; migration timing of tritium from the identified source areas and the resultant estimated downgradient activity concentrations were found to vary substantially, depending on the source release scenario applied. Variations in specified aquifer hydraulic properties (e.g., mobile porosity) may also contribute to the variability in groundwater velocity.

2 Scope and Objectives

The scope of the Phase I study was confined geographically to two general locations (i.e., the SWL/NRDWL vicinity and the area downgradient from the southern portion of 200 West Area between 216-U-10 Pond and 200 East Area). The Phase I study scope was constrained temporally in the SWL/NRDWL vicinity to the period from 1956 through 1958; this time period includes performance of historical fluorescein dye tracer emplacement studies in the area. The Phase I study was constrained temporally in the 200 West vicinity to a longer period of 1952 (when discharges started to the identified source areas) to 2016. Contaminant analysis was limited to tritium.

The objective of the Phase I study was to assimilate historical data for water levels and measured tracer concentrations, perform selected analytical solutions to identify hydraulic gradient direction and magnitude and compare the observed conditions to the results of transport simulations using the CPGWM.

The scope was completed and objectives of the Phase I study were met.

3 Assembly and Reduction of Existing Data

The following approaches to data analysis were applied as part of the Phase I study:

- Data assembly
  - Groundwater elevations
  - Fluorescein dye in vicinity of SWL/NRDWL
  - Tritium in groundwater in vicinity of the 200 West Area
- Data correlation to monitoring locations
- Evaluation of screened and/or perforated intervals in the identified monitoring wells
- Derivation and mapping of hydraulic gradient magnitude and direction using three-point solutions at selected locations in the study area
- Derivation of the fluorescent dye tracer source term concentration at the SWL/NRDWL location
- Derivation of estimated tritium source term contribution to groundwater at selected source locations in 200 West Area
- Simulation of groundwater flow directions and estimated transport of tracer in groundwater using the CPGWM
  - Transport of dye tracer in vicinity of SWL/NRDWL following historical tracer emplacement at known locations under selected sets of transport parameters
  - Forward particle tracking from selected tritium source locations in the 200 West Area
  - Transport of tritium in groundwater for selected source release cases in the 200 West Area
- Comparison of historically observed concentrations to simulation results of the CPGWM

Because the types of data, situation in which data were collected, and the volume of measurements and observations collected vary substantially between the two Phase I study areas, the methods of data assembly and reduction are presented separately for each of the study areas in the following subsections.

3.1 Data Assembly and Reduction for Historical Dye Tracer Study

An overview of the data reduction and analysis methods used for the historical dye tracer study in the vicinity of SWL/NRDWL is presented below.

3.1.1 Data Assembly for SWL/NRDWL Vicinity

Groundwater tracer concentration data for the SWL/NRDWL vicinity were assembled from a historical technical report (HW-60601). Because the tracer test data from the 1950s exist only as graphical depiction in a published document, the data values were transcribed to a Microsoft® Excel® spreadsheet and plotted for use in subsequent evaluations (Figure 1). Although the observed dye concentrations in groundwater at observation wells were relatively low (e.g., less than 20 μg/L at maximum), the peaks exhibited clear multi-point antecedent trends with discrete maxima. It should be noted that there remains uncertainty regarding the potential for appearance of additional tracer transient peaks after the end of the monitoring period (i.e., after 230 days) given the long travel distances.

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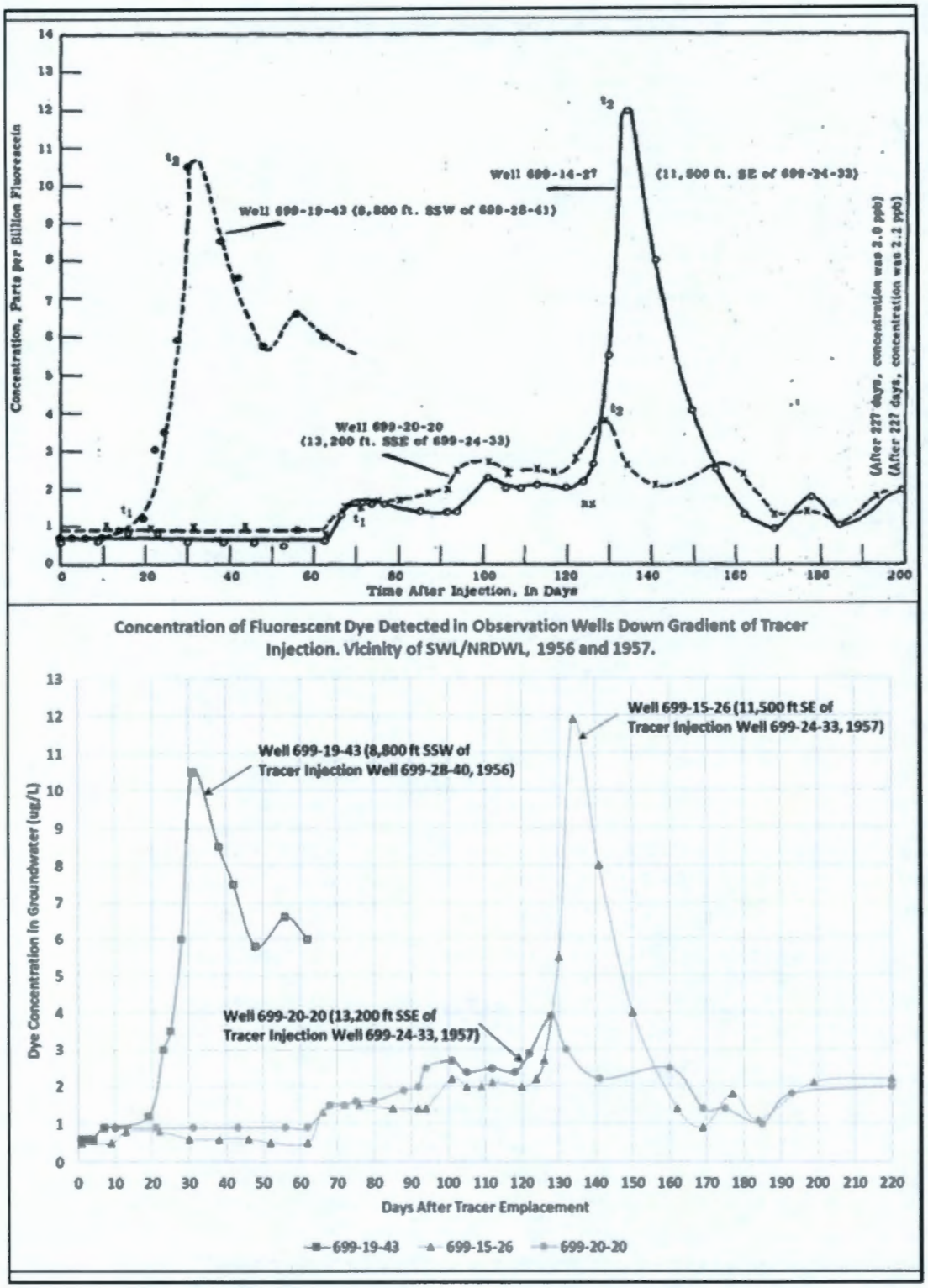

Figure 1. Fluorescein Dye Concentration Data (Top from Original Report, Bottom from Transcription)

Groundwater elevation data were extracted from the Hanford Environmental Information System (HEIS) for each of the wells of interest.

3.1.2 Data Correlation to Monitoring Locations

Data correlation for this study area was limited to confirming that the wells identified for the historical study were correctly identified and located. Well 699-28-41, the tracer dye injection well for the 1956 tracer study, was subsequently renamed 699-28-40 and retains that well name currently. Well location coordinates were extracted from the HEIS database. The relative location of the wells of interest for the historical dye tracer study analysis are shown in Figure 2, along with the observed historical tracer breakthrough response curves.

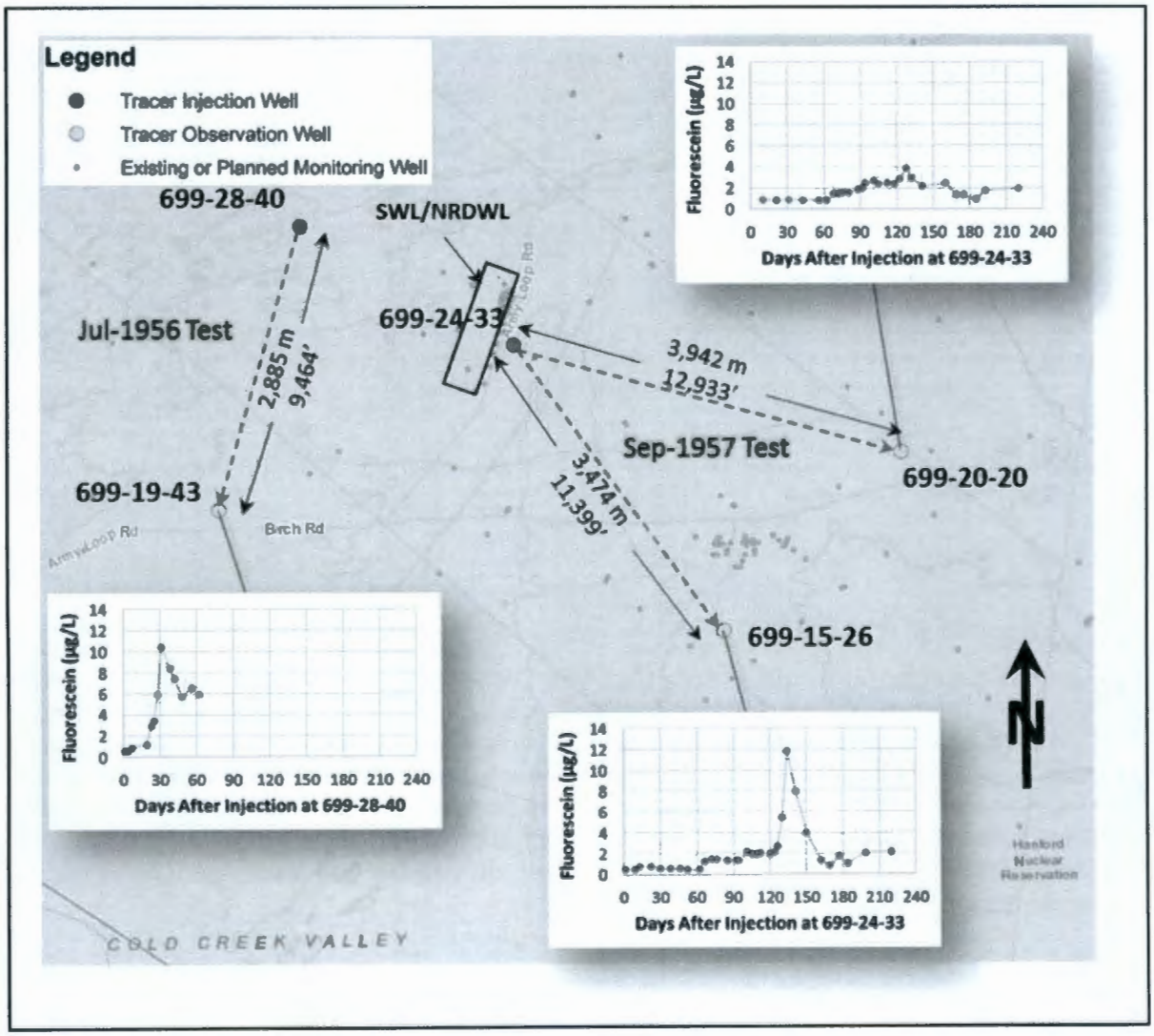

Figure 2. Location of Dye Injection and Observation Wells in Vicinity of SWL/NRDWL for Analysis of Historical Tracer Dye Study

3.1.3 Evaluation of Screened and Perforated Intervals

Well construction records from the Environmental Dashboard Application (EDA) (i.e., drilling logs, borehole logs, and well construction as-built diagrams) were reviewed to verify that the wells in the dye study area were perforated at similar, or overlapping, elevation intervals and could, therefore, be expected to provide comparable observations of aquifer conditions. After the review, the wells were found to be suitable for use. A summary of well construction information for the wells is shown in Table 1.

Table 1. Construction Features of Selected Wells in Vicinity of SWL/NRDWL.

Well Name	Approximate Depth to Groundwater in the Mid-1950s (m | ft bgs)	Perforated Interval (m | ft bgs)	Perforated Interval Thickness (m | ft)
699-31-31	41.5 | 136	41.1 to 61.0 | 135 to 200	19.8 | 65
699-24-46	60.4 | 198	57.9 to 204.2 | 190 to 670	146.3 | 480
699-28-40	**49.7 | 163**	**45.7 to 140.8 | 150 to 462**	**95.1 | 312**
699-19-43	47.5 | 156	39.3 to 56.4 | 129 to 185	17.1 | 56
699-24-33	**39.3 | 129**	**39.3 to 43.9 | 129 to 144**	**4.6 | 15**
699-15-26	40.2 | 132	36.6 to 45.7 | 120 to 150	9.1 | 30
699-20-20	34.4 | 113	35.1 to 39.6 | 115 to 130	4.6 | 15

Well names in bold are the tracer injection wells.

bgs = below ground surface

3.1.4 Derivation of Hydraulic Gradient Magnitude and Direction

Gradient magnitude and direction for selected aquifer zones within the study area were derived using a three-point solution technique and historical groundwater elevation measurements extracted from HEIS. The derivation of three-point solutions for this area is included in the attached Excel spreadsheet identified as Appendix A. The azimuthal direction and magnitude of the gradient were generated for sets of three wells, called triplets. The map locations of well triplets selected for this analysis and their derived gradient azimuth (i.e., degrees clockwise from north) and magnitude are shown in Figure 3. The derived hydraulic gradient azimuths and magnitudes are shown on individual axes for clarity in Figures 4 and 5 for these triplets.

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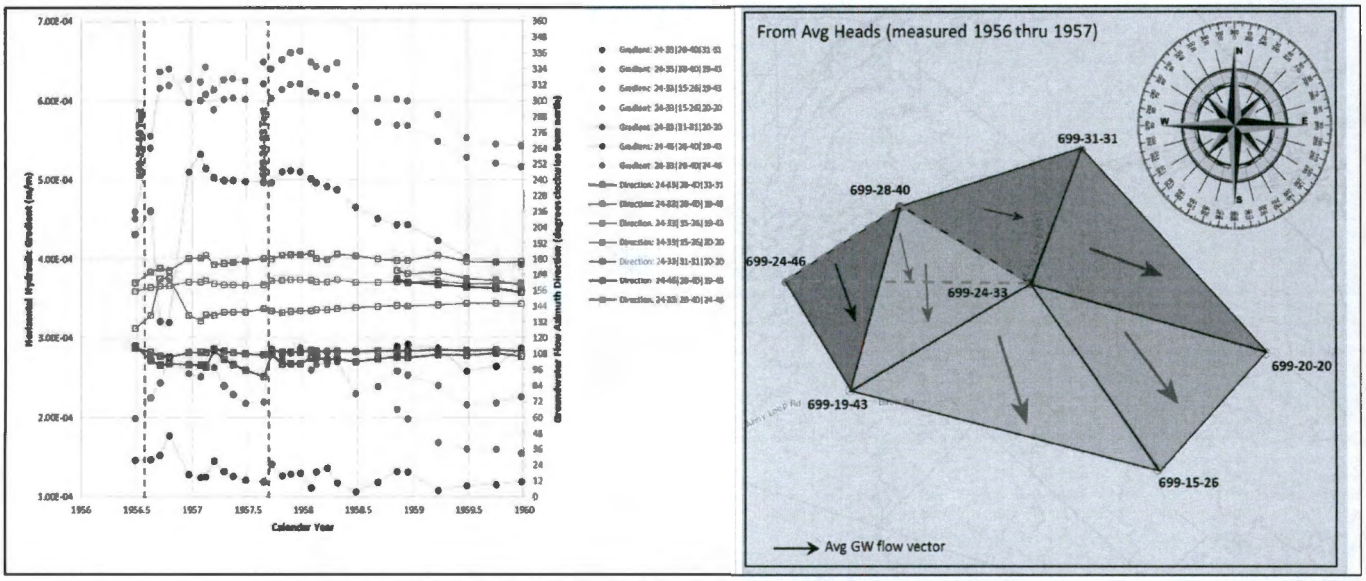

Figure 3. Time Series of Derived Groundwater Gradient Direction and Magnitude for Selected Well Triplets in Vicinity of SWL/NRDWL and Map Illustrating Flow Direction in 1956-1957

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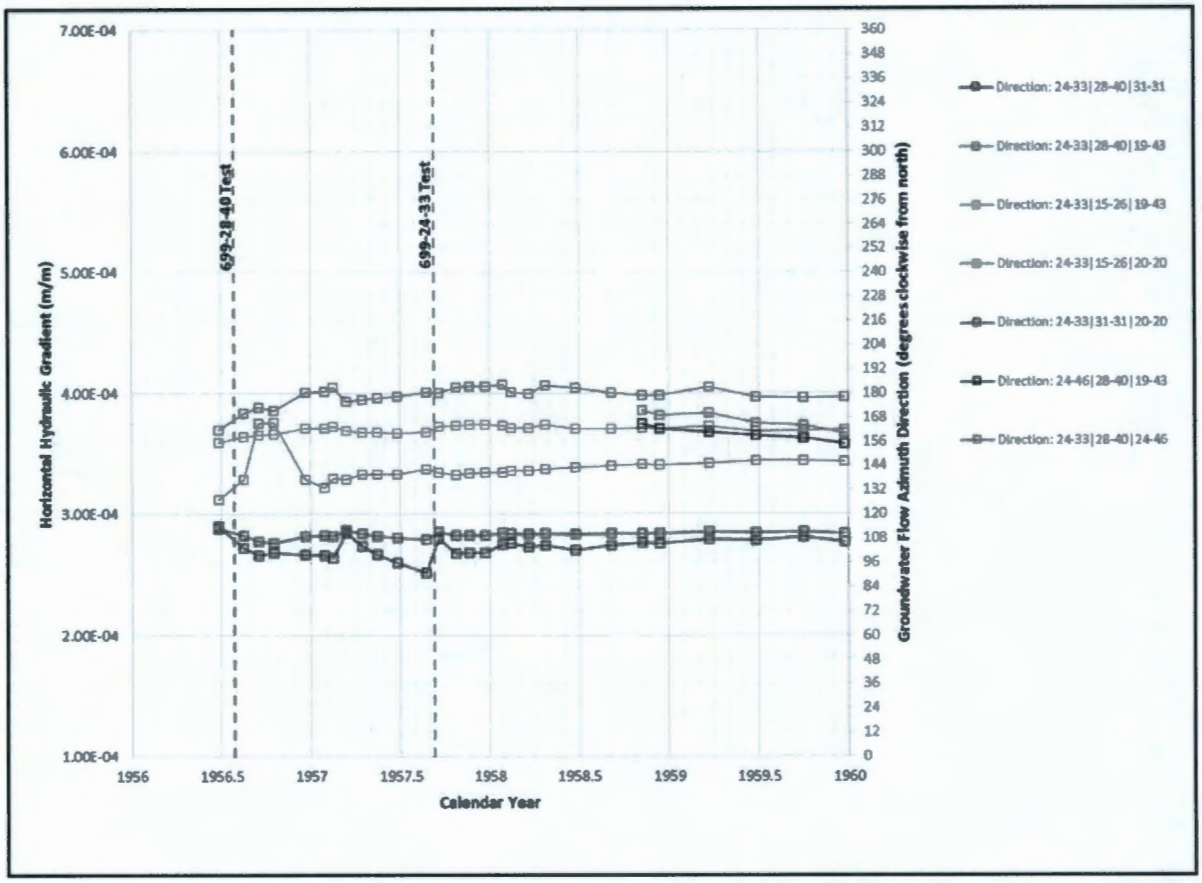

Figure 4. Time Series of Derived Hydraulic Gradient Azimuth Directions for Selected Well Triplets in Vicinity of SWL/NRDWL During the Historical Dye Tracer Studies

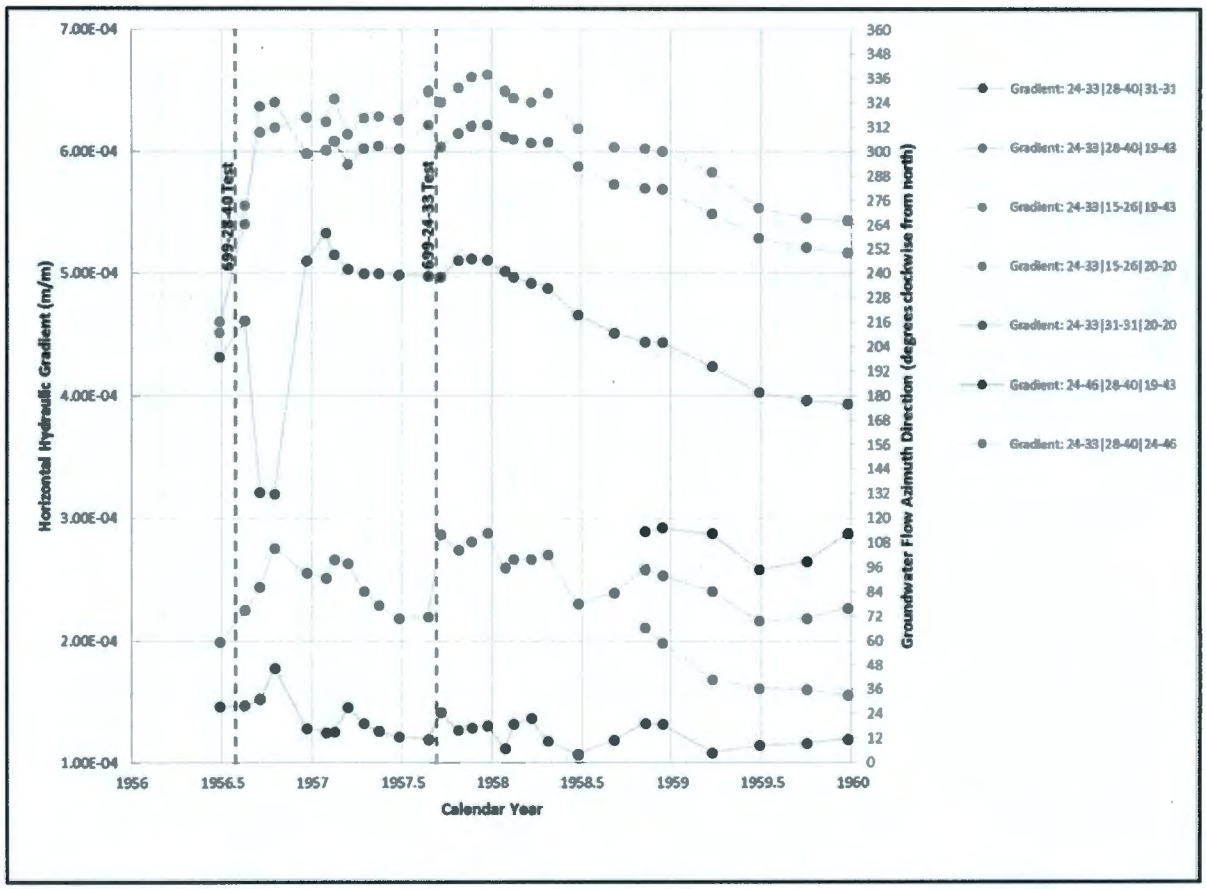

Figure 5. Time Series of Derived Hydraulic Gradient Magnitude for Selected Well Triplets in Vicinity of SWL/NRDWL During the Historical Dye Tracer Studies

3.1.5 Derivation of Initial Dye Tracer Concentration

The reference document for the historical tracer study (HW-60601) does not provide a detailed description of the actual tracer material used in the study. The tracer emplacement is described only as placement of "100 pounds of dye powder [described as sodium fluorescein] mixed into 100 gallons of water." The duration of the dye placement is not described either; however, it is assumed for the purposes of this evaluation to have been over a short duration (estimated on the order of minutes). Two initial dye solution concentrations were derived, ranging from a solution concentration of 60 million µg/L for an assumed 50 wt% dye powder to 120 million µg/L for an assumed 100 wt% dye powder. Both of these estimates would have resulted in concentrated, dense solution.

3.2 Data Assembly and Reduction for 200 West Area Vicinity Tritium Plume

An overview of the data reduction and analysis methods used for the historical tritium migration study in the vicinity of the 200 West Area is presented below. The data assembly included historically measured groundwater tritium activity concentration in selected monitoring wells, historical groundwater elevation measurements in selected monitoring wells, and estimates of source inventories from waste sites identified as contributors to tritium in groundwater in the 200 West Area.

3.2.1 Data Assembly for 200 West Vicinity

Historical tritium activity concentration data and groundwater elevation measurements for the selected wells within and downgradient from the 200 West Area were extracted from the HEIS database in spreadsheet format for further reduction and use. The following wells were identified as downgradient wells that exhibit distinct tritium activity concentration transient changes that indicate migration of tritium downgradient from the sources:

- 699-35-70
- 699-35-66A
- 699-32-62
- 699-36-61A

The following wells were selected as near-source well locations exhibiting high historical tritium activity concentration:

- 299-W19-2 (located adjacent to 216-U-8 Crib)
- 299-W22-14 (located adjacent to 216-S-7 Crib)

Figure 6 illustrates time series of tritium activity concentration in selected monitoring wells and their relative locations in the study area.

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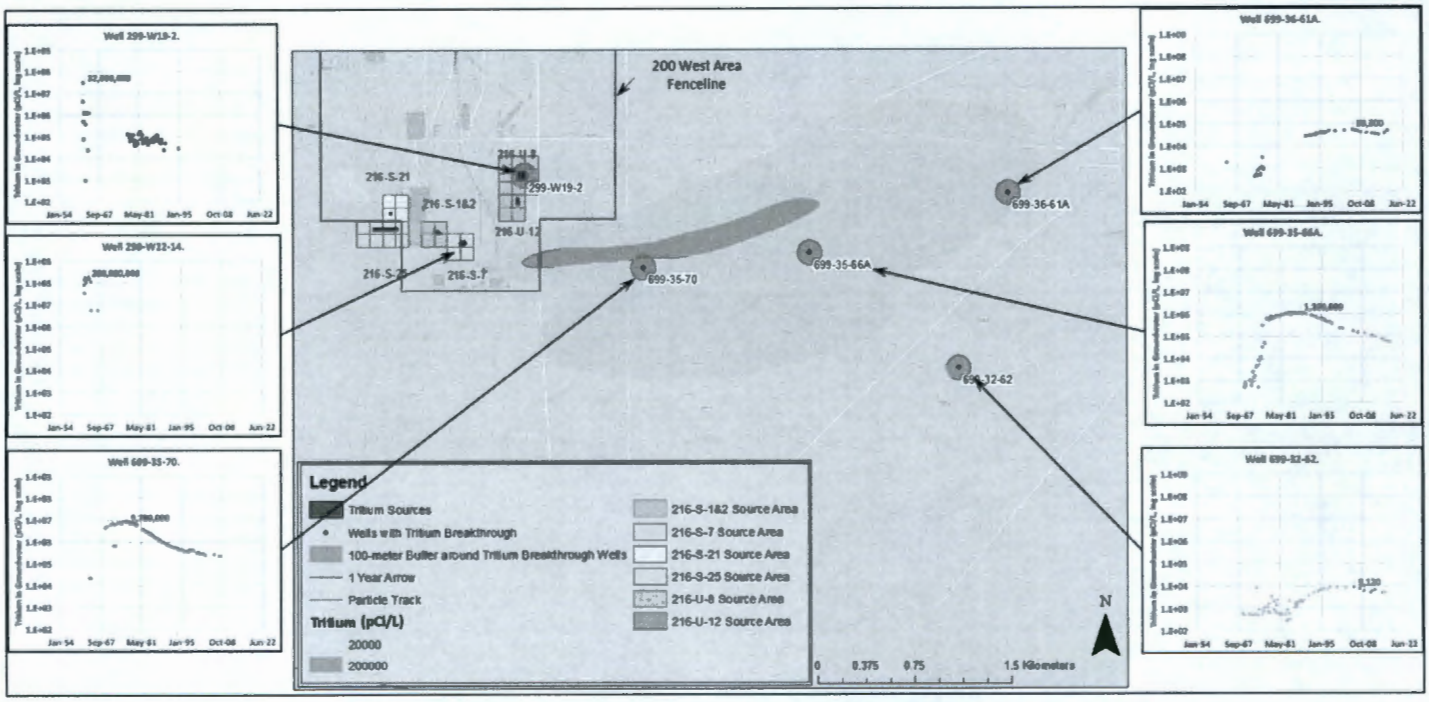

Figure 6. Tritium Activity Concentration Time Series in Selected Monitoring Wells Illustrating Changes in Tritium Activity Concentration Spatially and Temporarily

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3.2.2 Data Correlation to Monitoring Locations

Monitoring well location coordinates were downloaded from the HEIS database via the EDA.

3.2.3 Evaluation of Screened and Perforated Intervals

Well construction records accessed in EDA (i.e., drilling logs, borehole logs, and well construction as-built diagrams) were reviewed to identify that the wells of interest were perforated at similar, or overlapping, elevation intervals and could, therefore, be expected to provide comparable observations of aquifer conditions. A summary of well construction of the selected wells for the 200 West Area tritium evaluation is shown in Table 2.

Table 2. Summary of Selected Well Construction Features in 200 West Area.

Well Name	Approximate Depth to Groundwater in the Mid-1980s (m | ft bgs)	Perforated Interval (m | ft bgs)	Perforated Interval Thickness (m | ft)
299-W19-2	69.7 | 228.6	70.1 to 82.6 | 230 to 271	12.5 | 41
699-32-62	84.5 | 277.2	90.5 to 122.8 | 297 to 403	32.3 | 106
699-32-70B	64.2 | 210.6	63.1 to 100.6 | 207 to 330	37.5 | 123
699-35-66A	86.7 | 284.4	79.2 to 126.5 | 260 to 415	47.3 | 155
699-35-70	72.7 | 238.5	71.0 to 77.1 | 233 to 253	6.1 | 20
699-35-78A	56.1 | 184.1	54.9 to 85.0 | 180 to 279	30.1 | 99
699-36-61A	103.4 | 339.2	100.6 to 118.6 | 330 to 389	18.0 | 59
699-38-65	98.0 | 351.5	67.1 to 120.4| 220 to 395	53.3 | 175
699-38-70	77.2 | 253.3	77.7 to 115.8 | 255 to 380	38.1 | 125
699-40-62	104.0 | 341.2	102.1 to 112.5 | 335 to 369	10.4 | 34
699-44-64	97.0 | 318.2	96.3 to 109.7 | 316 to 360	13.4 | 44

bgs = below ground surface

3.2.4 Derivation of Hydraulic Gradient Magnitude and Direction

Gradient magnitude and direction for selected well triplets within the study area were derived using a three-point solution technique and historical groundwater elevation measurements extracted from the HEIS database. The derivation of three-point solutions for this area is included in the attached Excel spreadsheet identified as Appendix B. The azimuthal direction and magnitude of the hydraulic gradient were generated for sets of triplets. The map locations of well triplets selected for this analysis, and their derived hydraulic gradient azimuth and magnitude are shown in Figure 7. The derived hydraulic gradient azimuths and magnitudes are shown on individual axes in Figures 8 and 9 for these triplets

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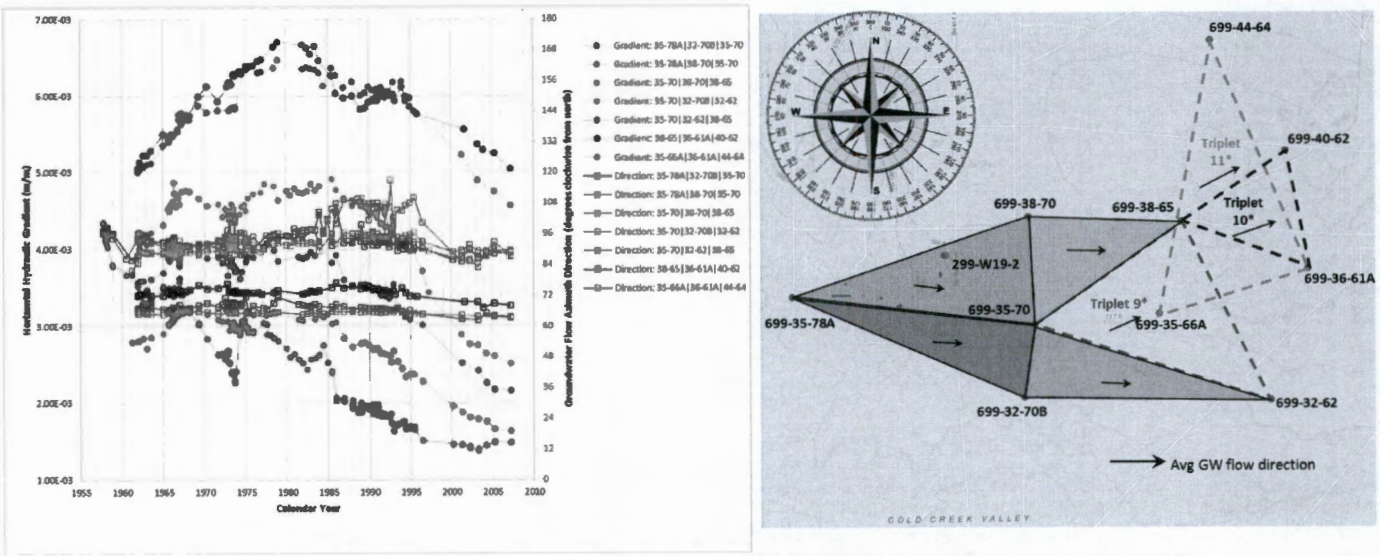

Figure 7. Time Series of Derived Groundwater Gradient Direction and Magnitude for Selected Well Triplets in Vicinity of 200 West Area and Map Illustrating Flow Direction in 1955-2010

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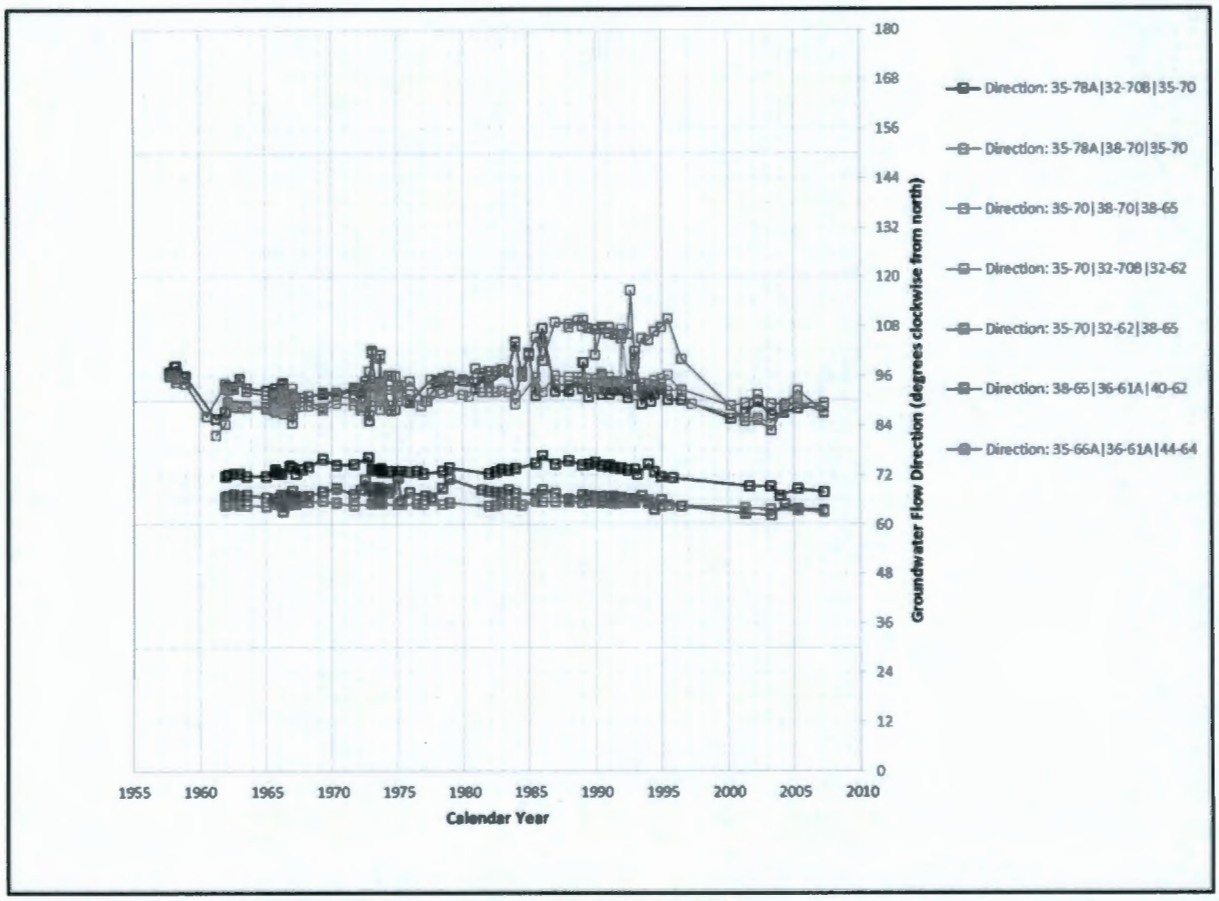

Figure 8. Time Series of Derived Hydraulic Gradient Azimuth Directions for Selected Well Triplets in Vicinity of the 200 West Area 1955 to 2010

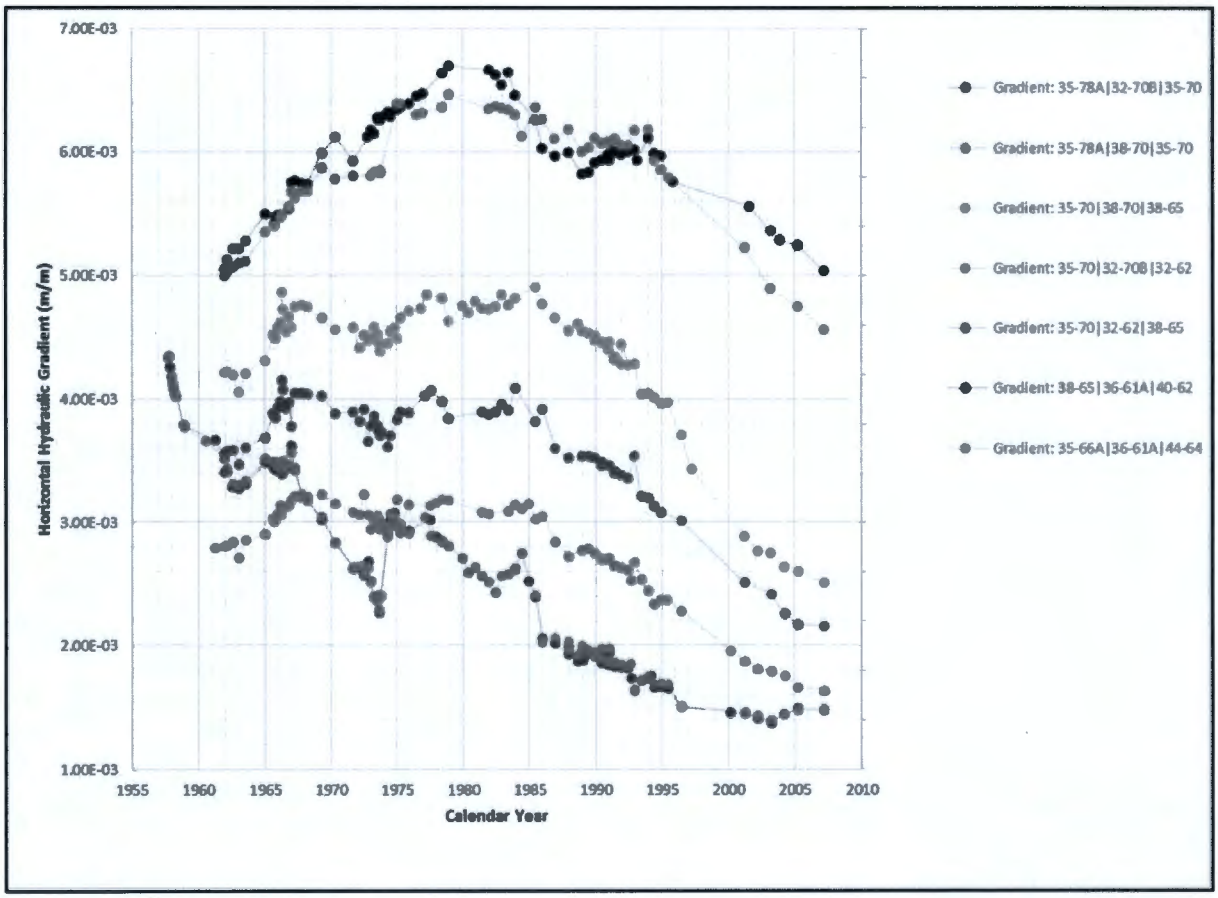

Figure 9. Time Series of Derived Hydraulic Gradient Magnitude for Selected Well Triplets in Vicinity of the 200 West Area 1955 to 2010

3.2.5 Derivation of Tritium Source Releases

In order to apply the CPGWM to simulate the movement of tritium in groundwater, an estimate of the flux of tritium entering the aquifer from the overlying vadose zone was prepared. Derivation of a source term for tritium release to groundwater in the 200 Area is a key element of the analysis of tritium transport to the downgradient monitoring wells. The tritium source term derivation is described in ECF-HANFORD-18-0021, *Central Plateau Phase I Groundwater Tracer Study Simulations*. First, the known major tritium release sites (shown in Table 3) were identified by evaluating the derived discharge inventories using the Hanford Soil Inventory Model (RPP-26744, *Hanford Soil Inventory, Rev. 1*).

Historical tritium groundwater monitoring data in the HEIS database from wells located nearby source sites shown in Table 3 confirms the presence of elevated tritium activity concentrations in groundwater near these sites (Table 4).

Table 3. 200 West Tritium Source Identification

Waste Site	Years Active	Total Curies of Tritium Released
216-S1&2	1952 – 1956	35,200
216-S-7	1956 – 1965	81,300
216-S-21	1954 – 1969	22,800
216-S-25	1973 – 1980, 1985	14,100
216-U-8	1952 – 1960	60,100
216-U-12	1960 – 1972, 1981 – 1988	20,200

Reference: RPP-26744, *Hanford Soil Inventory, Rev. 1.*

Tritium values reported in RPP-26744 are decayed to 01/01/2001; the values in this table were "undecayed" to the release year.

Table 4. Maximum Tritium Activity Concentration Observed in Wells Near Tritium Source Sites

Waste Site	Maximum [^{3}H] in Groundwater (pCi/L)	Well Exhibiting Maximum	Year of Maximum
216-U-8	3.2×10^{7}	299-W19-2	1962
216-S-1/S-2	1.0×10^{7}	299-W22-1	1962
216-S-7	2.0×10^{8}	299-W22-14	1963
216-S-9	2.0×10^{8}	299-W22-26	1966
216-S-21	1.1×10^{8}	299-W23-4	1964
216-S-25	9.0×10^{6}	299-W23-10	1976

Secondly, two approaches to the release of tritium from waste site inventories to groundwater were considered. The first involved a simplistic release scenario in which the entire tritium inventory in each year of operation for each waste site was instantaneously released to groundwater beneath the site, with no accounting for time of transit of liquids through the vadose zone. The second approach used a previously published release scenario that simulated transport of the tritium through the vadose zone beneath the source sites. This release scenario is documented in CP-47631, *Model Package Report: Central Plateau Model,* Version 8.4.5. This release scenario introduces a lag time between the release of tritium-bearing waste water at ground surface and the time of entry of the tritium into the underlying groundwater.

4 Results of Analysis

The detailed results of the groundwater flow and transport numerical simulations at the two study areas are documented in ECF-HANFORD-18-0021. The results are summarized in the following sections for the SWL/NRDWL vicinity historical tracer study and the 200 West Area tritium plume area.

4.1 Historical Tracer Study in Vicinity of SWL/NRDWL

Examination of the historical tracer study results was performed using the CPGWM and a simple analytical solution using three-point gradient solutions to estimate magnitude and direction of groundwater flow gradients during the period of the historical study. The tracer study conditions were described in HW-60601 and included identification of the initial tracer concentration, location of injection and observation wells, and the measured tracer concentration observed in downgradient wells. The calculated groundwater velocity derived from the tracer transport observations published in HW-60601 are shown in Table 5. Reviewers have observed that the hydraulic conditions required to achieve such groundwater velocities require the presence of high hydraulic conductivity, on the order of greater than 30,000 m/day. This is an extremely high hydraulic conductivity that has not been observed in other locations in the Central Plateau. Recent pumping tests conducted in the vicinity of the B Tank Farm Complex, in the northern portion of the 200 East Area, have generated hydraulic conductivity estimates of about 19,000 m/day. Aquifer hydraulic conductivity of 30,000 m/day is extremely high and is indicative of extraordinary conditions. There remains some uncertainty regarding whether the tracer concentration peaks observed during the study where actually the maximal peaks (e.g., it is possible that higher peaks may have occurred at some time beyond the 270-day test monitoring period).

Table 5. Historical Tracer Study Results

Observation Well Name	Distance from Injection Well (m [ft])	Dye Travel Time in Days		Dye Velocity (m/day [ft/day])	
		First Detection	Peak	First Detection	Peak
699-19-43	2,860 (9,400)	20	31	143 (470)	92 (303)
699-15-26*	3,510 (11,500)	67	134	52 (170)	26 (85)
699-20-20	4,020 (13,200)	67	129	59 (195)	30 (100)

Reference: HW-60601, *Aquifer Characteristics and Ground-Water Movement at Hanford.*

*Well 699-15-26 was formerly identified and reported as 699-14-27 in HW-60601.

4.1.1 Numerical Simulation of Groundwater Movement in Vicinity of Historical Tracer Study

A set of numerical simulations were performed using the CPGWM. Several shortcomings to using the model in this study area became immediately apparent. The CPGWM was not developed to simulate short-term local plume transients and other features affect the ability of the model to simulate the tracer study conditions. First of all, the study area in the vicinity of the SWL/NRDWL is located in the southeastern corner of the CPGWM domain. The study area lies very close to both the southern and eastern boundaries of the domain; in addition, the historical tracer observation wells lie outside the model domain (Figure 10). These conditions indicate that the model would not be anticipated to represent the target tracer conditions. In addition, the simulated water table contours generated by the CPGWM for the historical study period indicated a flow direction from west to east in the vicinity of the 1956 tracer test; the tracer test indicated a southerly flow in this vicinity, consistent with the derived three-point gradient solution. The CPGWM gradient direction and magnitude are more consistent with the observed direction and magnitude from conditions near SWL/NRDWL presently. Thus, the CPGWM is consistent with its purpose of predictive modeling.

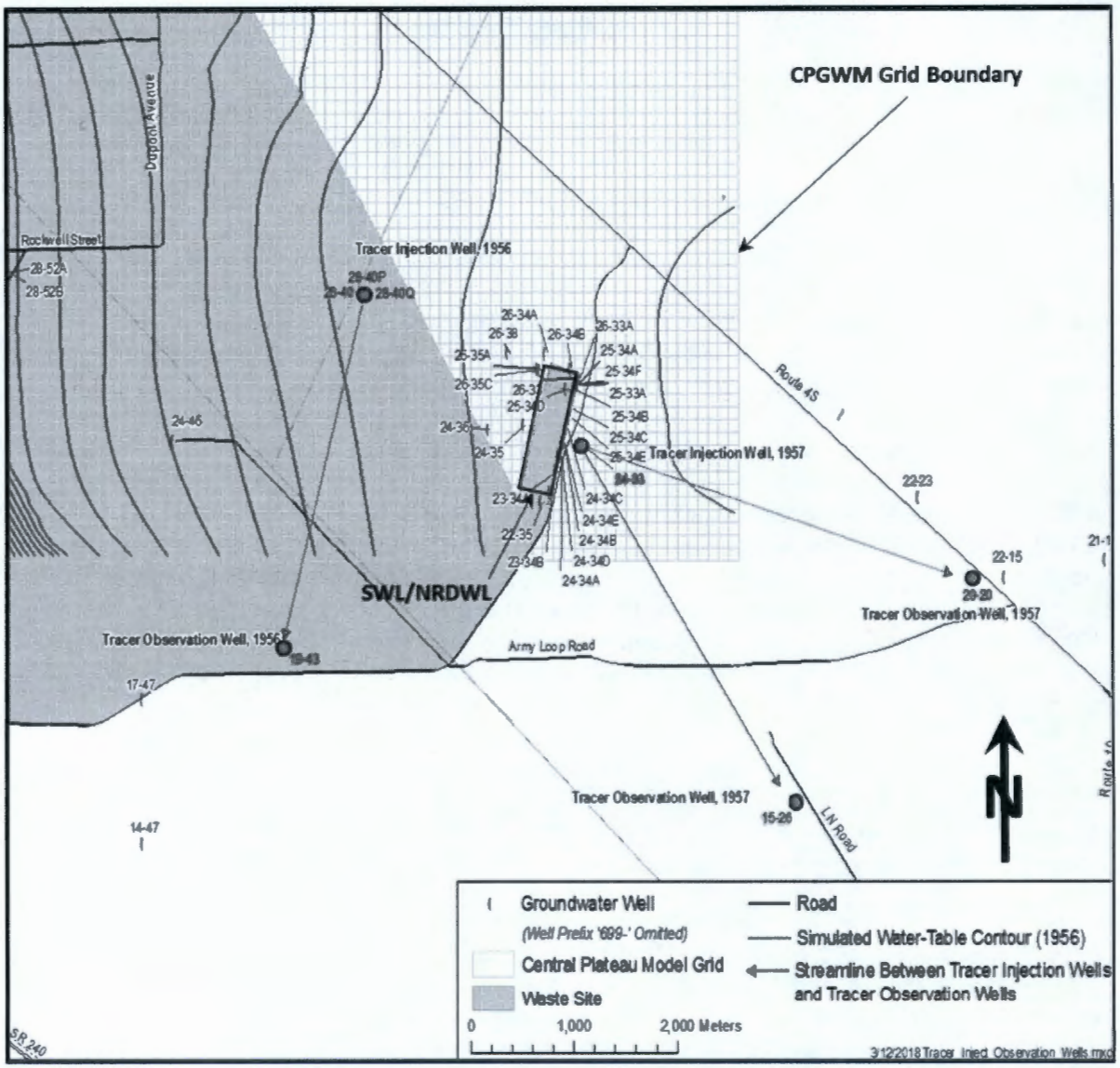

Figure 10. Plan View of Central Plateau Groundwater Model Domain Overlaid on Historical Dye Tracer Study Area

Simulated transport of the injected dye tracer using the CPGWM produced resultant plumes that extended eastward from the injection wells, consistent with the model-derived water table contours, but inconsistent with the dye tracer test results. The largest downgradient extent was produced using a reduced mobile porosity and increased horizontal dispersivity in the model. Figure 11 illustrates the resultant dye plume distribution from both dye injections (i.e., 1956 and 1957) projected to January 1958. In both instances, the resultant plumes extend only a fraction of the distance from the tracer injection wells to the historical observation wells.

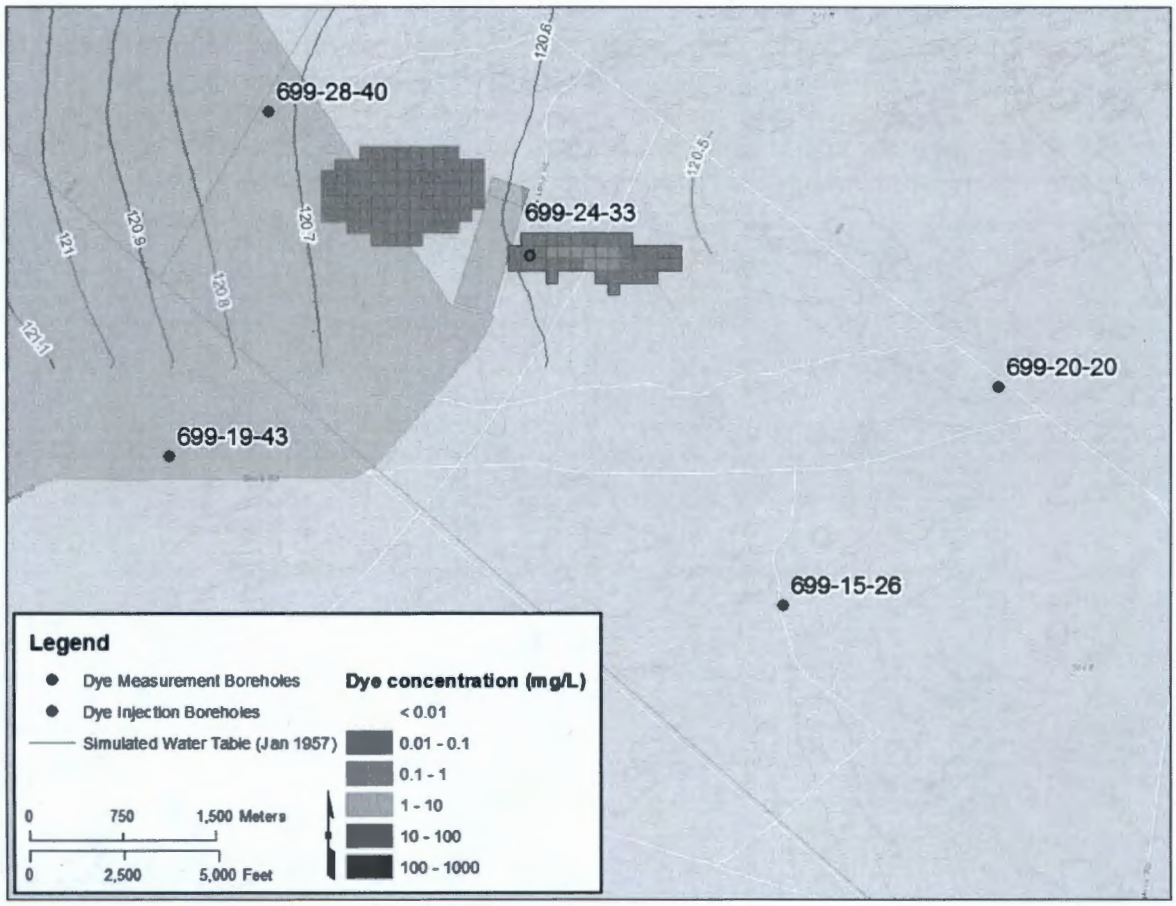

Figure 11. Resultant Simulated Dye Tracer Plumes after One Year, January 1958.

4.1.2 Analytical Solutions Compared to Historical Tracer Study Results

The groundwater velocity exhibited by the historical tracer study was apparently extremely rapid (i.e., 26 to 143 m/day [85 to 469 ft/day]). Comparison of analytical solutions to the site conditions provides some insight into the local flow conditions in the historical tracer study area. This vicinity is inferred to be a remnant paleochannel from the Missoula floods that reworked pre-existing deposits and ultimately deposited the Hanford formation that comprises the uppermost of the suprabasalt unconsolidated deposits at Hanford. This paleochannel extends from the study area generally north-northwest to Gable Gap and becomes somewhat diffuse to the south and east of 200 East Area. The channel is locally filled with Hanford formation sediments, Cold Creek unit gravel deposits, and is bounded on the west in the study area by Ringold Formation Unit E deposits.

Figure 12 illustrates a view of the inferred formation structures in the study area at the water table elevation. This view was generated using the LeapFrog™ solid model of the Hanford site by removing the surface features and the overlying Hanford formation. The blue areas identified as "water table" are Hanford formation-filled relict channels. The Ringold Formation Unit E deposits (purple color) are understood to exhibit substantially lower hydraulic conductivity than either the Hanford or Cold Creek Unit gravel deposits. The well triplets illustrating the derived three-point gradient solutions, previously shown in Figure 3, are overlaid on the formation map. This suggests that the groundwater flow direction in the study area may not be bounded by the Cold Creek deposits, but rather that the groundwater flow at the time of the tracer study was historically through the Cold Creek material at a rate similar to that expected from the Hanford formation deposits. This condition further suggests that the Cold Creek Unit gravel unit may exhibit hydraulic conductivity similar in magnitude to the neighboring Hanford formation. The flow directions derived through the three-point solutions are consistent with the historically-observed arrival of the dye tracer at downgradient locations. As noted above, these conditions indicate the apparent presence of extreme hydraulic conductivity in the vicinity.

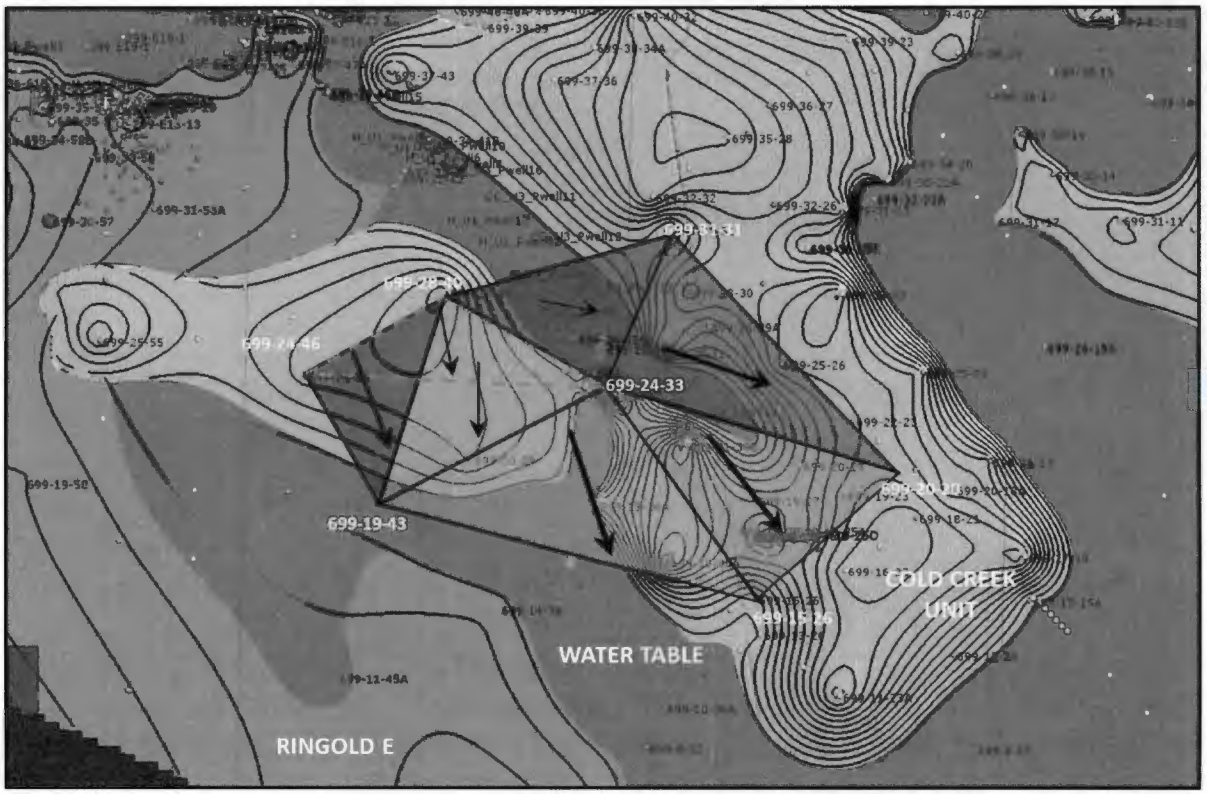

Figure 12. Derived Groundwater Flow Directions in 1956-1957 Overlaid on Subsurface Geological Conditions at the Water Table Elevation in the Vicinity of SWL/NRDWL

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4.2 Tritium Plume Downgradient from the 200 West Area

Examination of the tritium plume downgradient from 200 West Area using anthropogenic tritium as a groundwater tracer was more involved than examination of the historical dye tracer study. The tritium plume evolution and the activity concentration transients observed in downgradient wells were the result of historical discharge of complex wastewater streams from multiple facilities released at multiple locations. Simulation of the tritium migration in groundwater, therefore, requires derivation of the source term and specification of the timing of its entry into groundwater after passing through the vadose zone in the 200 West Area.

Pre-existing source term estimates were used for this exercise. The principal variable in source term behavior examined in this study was the arrival time of the inventory at the water table beneath the identified source waste sites. The simulation results are described in ECF-HANFORD-18-0021 and include the use of a retarded release of tritium after simulated passage of the waste through the vadose zone and a second case wherein the tritium inventory was released to groundwater simultaneously with the release of waste to the source site.

Tritium fate and transport simulations were performed in two steps: first, groundwater movement in the study area was examined using particle tracking with the CPGWM; second, the transport for tritium from source locations to the selected downgradient monitoring wells was simulated. The following subsections summarize the results of the simulations.

4.2.1 Numerical Simulation of Groundwater Movement in the Vicinity Downgradient of the 200 West Area

Particle track simulations were performed using simulated releases of particles every five years from 1952 to 1987 to cover the period of operation of the identified tritium source sites. This approach provides an assessment of both the effects of discharges to individual waste sites as well as changes in apparent groundwater velocity and flow direction over the discharge period. As expected, the earliest releases, occurring in 1952, travelled the farthest and intersected the largest number of the selected downgradient monitoring wells. Figure 13 illustrates the movement of particles of groundwater from their release in 1952 to the end of the simulation in 2016. Alternatively, Figure 14 illustrates the movement of particles released in 1987 from their release points toward the downgradient wells, ending in 2016. For clarity, these figures were prepared to only illustrate the particle tracks that actually moved within 100 m (328 ft) of the wells that exhibited tritium breakthrough. Both Figures 13 and 14 also illustrate the particle track migration overlaid on the 2016 inferred groundwater tritium plume. The simulation of groundwater movement from identified source discharge locations is consistent with the observed tritium in the selected downgradient monitoring wells. Based on the simulations of groundwater movement and flow direction, this evaluation indicates that the cumulative effects of historical discharges to the identified sites are the apparent sources of the currently-observed tritium plume in groundwater east of the 200 West Area (see Figure 6).

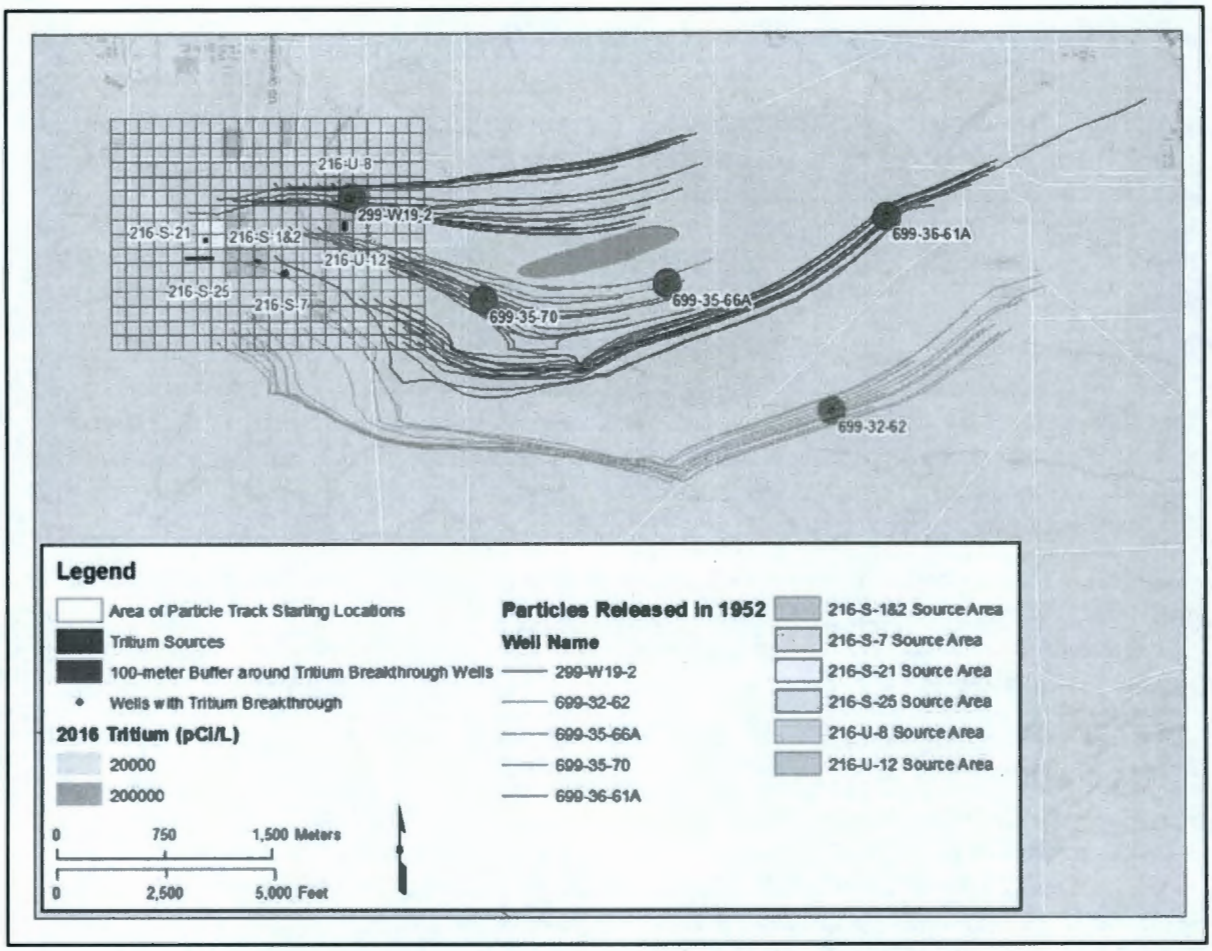

Figure 13. Groundwater Particle Tracks for Releases from Source Sites in 1952 Simulated to 2016

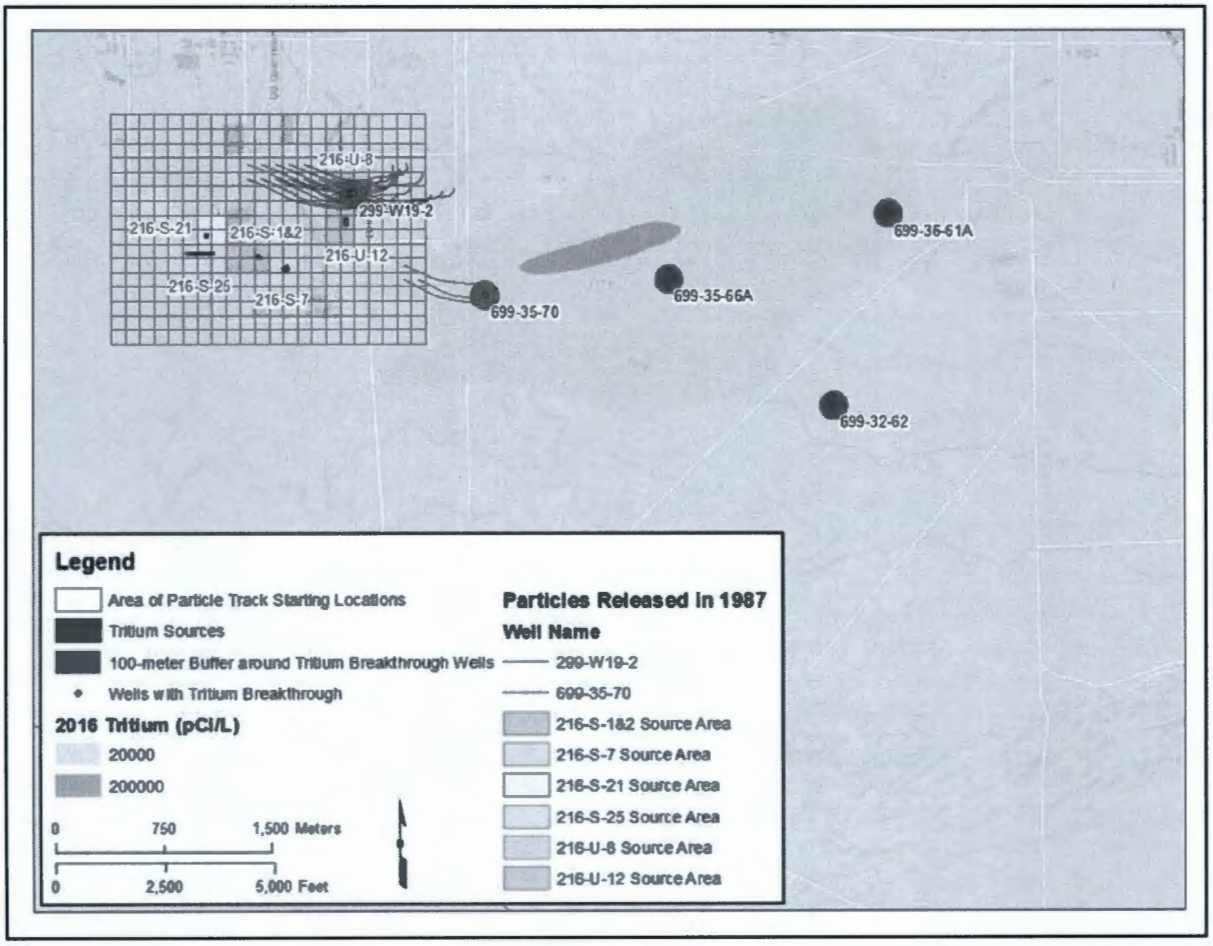

Figure 14. Groundwater Particle Tracks for Releases from Source Sites in 1987 Simulated to 2016

4.2.2 Numerical Simulation of Tritium Migration Near the 200 West Area Sources

Historical migration of tritium in groundwater away from the identified source locations was evaluated by comparing the observed tritium activity concentrations in downgradient monitoring wells to the simulated concentrations at those locations derived by the CPGWM. As previously described, two source cases were considered, the first representing a hypothetical instantaneous release of tritium to groundwater and the second representing a delayed release to groundwater based on simulated transport of the wastewater through the vadose zone. The results of these simulations are illustrated as tritium concentration breakthrough curves at the selected downgradient wells and are compared to the observed tritium activity concentrations in those same wells. Figures 15, 16, 17, 18, and 19 illustrate the simulated tritium activity concentration breakthrough curves for wells 299-W19-2, 699-32-62, 699-35-66A, 699-35-70, and 699-36-61A, respectively. Additional details regarding these simulated results are documented in ECF-HANFORD-18-0021.

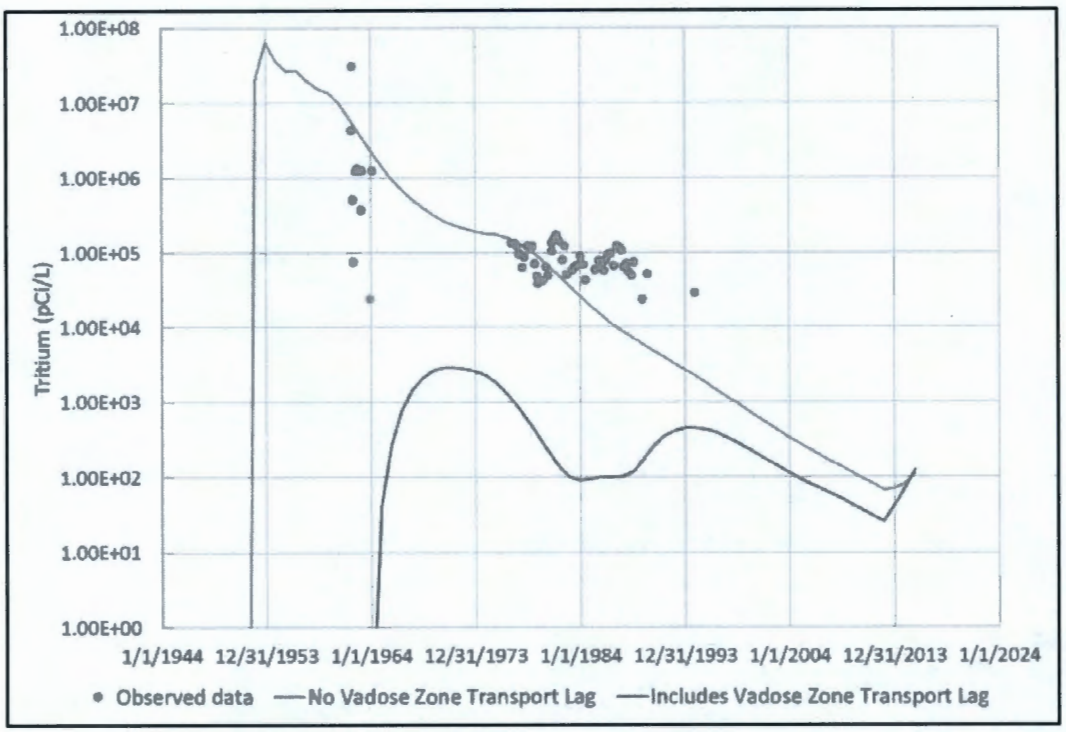

Figure 15. Simulated Tritium Breakthrough Compared to Observed Tritium Breakthrough at Well 299-W19-2

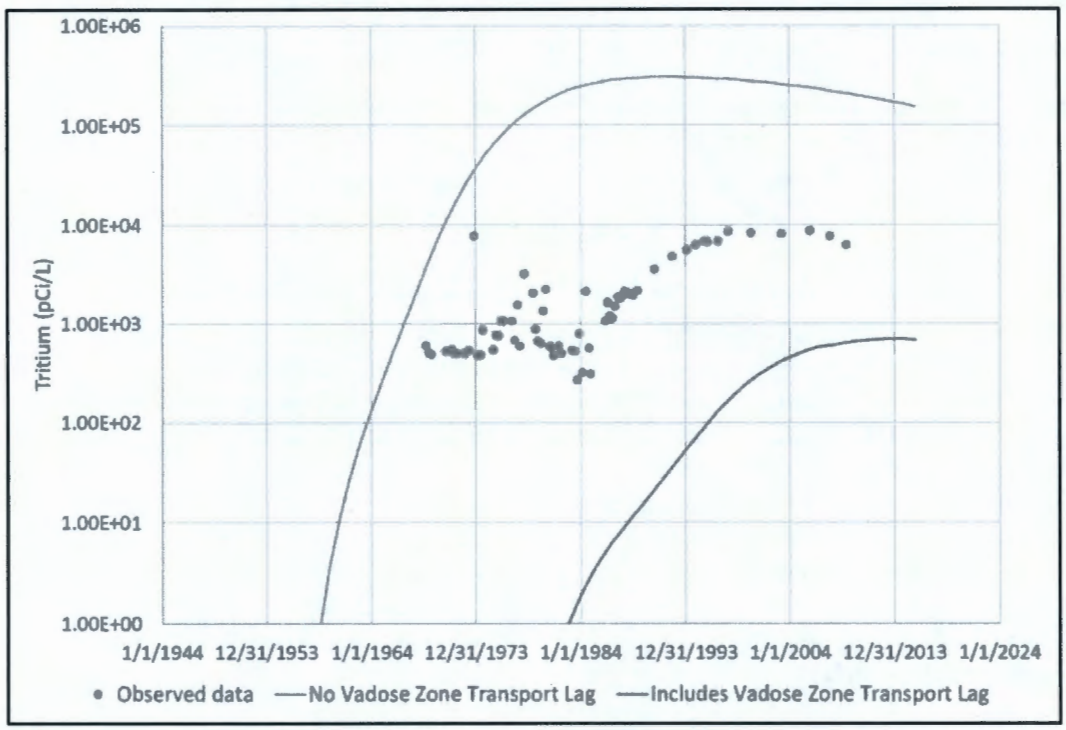

Figure 16. Simulated Tritium Breakthrough Compared to Observed Tritium Breakthrough at Well 699-32-62

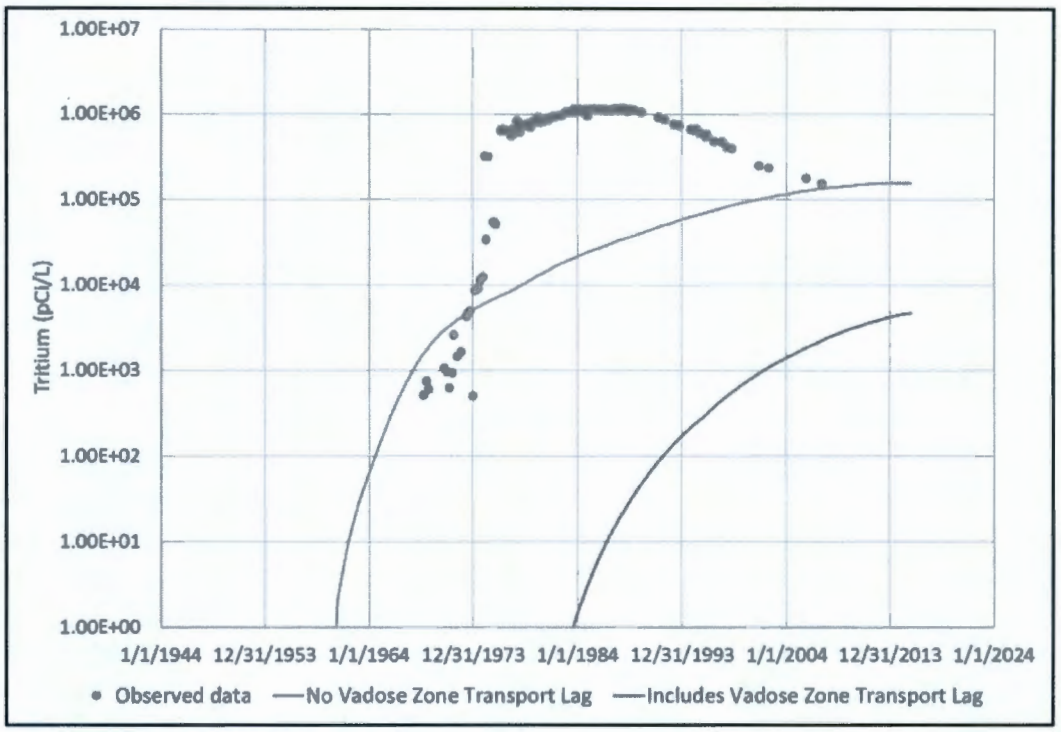

Figure 17. Simulated Tritium Breakthrough Compared to Observed Tritium Breakthrough at Well 699-35-66A

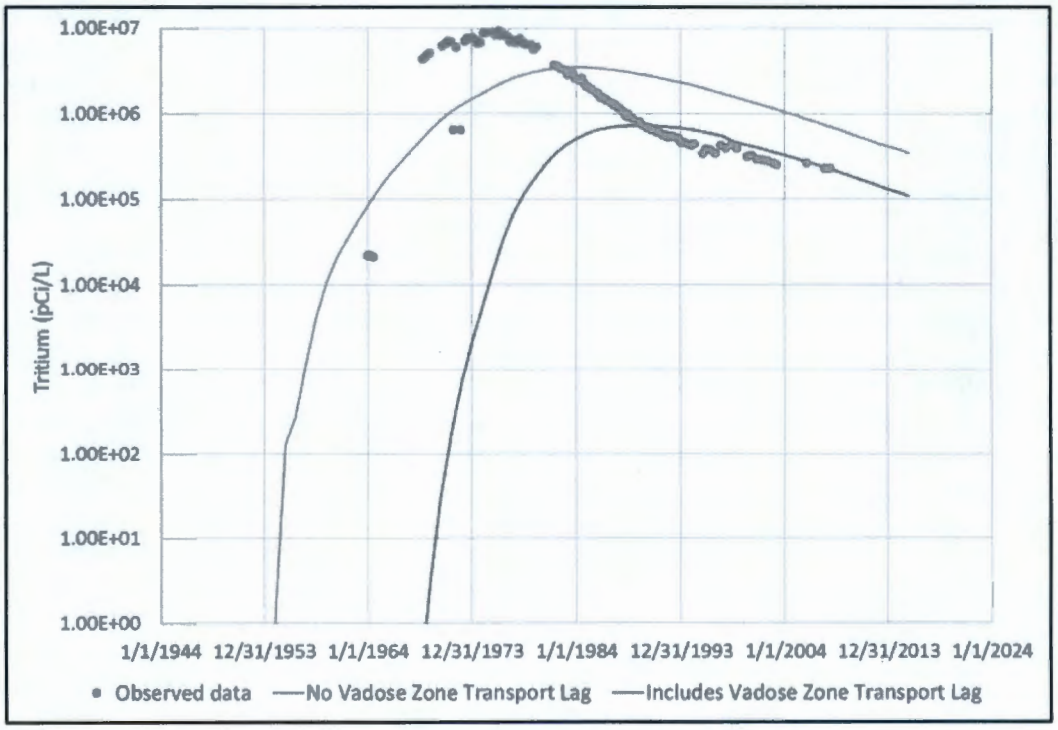

Figure 18. Simulated Tritium Breakthrough Compared to Observed Tritium Breakthrough at Well 699-35-70

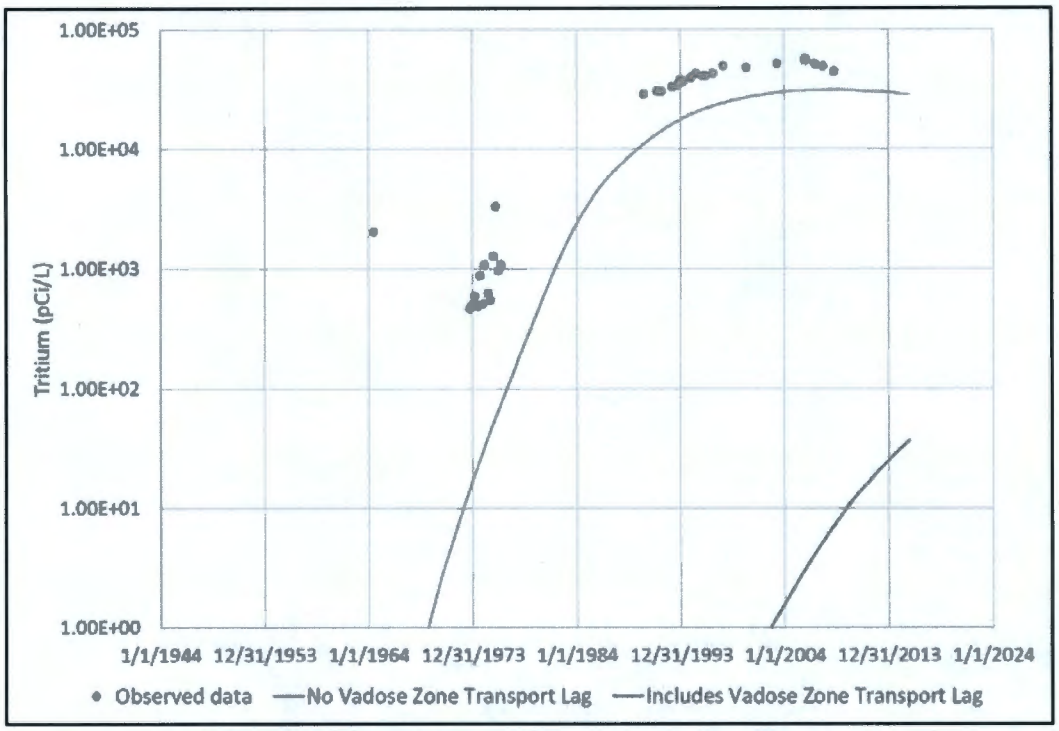

Figure 19. Simulated Tritium Breakthrough Compared to Observed Tritium Breakthrough at Well 699-36-61A

The simulated tritium breakthrough curves exhibit substantial variation, depending on the source term release scenario. Modeling results that incorporated delayed transport through the vadose zone exhibited delayed arrival of tritium and lower peak activity concentration, as compared with the observed data. The breakthrough curve resulting from the instantaneous-release source term consistently arrived earlier than that of the retarded source release, somewhat earlier than the measured response, and exhibited a peak activity concentration generally more similar to the measured response. This analysis indicates that a substantial source of uncertainty in historical transport evaluation is the source term. In this examination of tritium migration at the 200 West Area, additional uncertainty appears related to selected parameterization of hydraulic properties used in the simulation. Reduction in effective porosity would be expected to shorten travel time and increase downgradient tritium activity concentration.

4.2.3 Analytical Solutions Compared to Tritium Migration Near the 200 West Area

A series of three-point gradient solutions posted over the inferred tritium plume distribution in the vicinity of the 200 West Area (Figure 20) indicates that the historical hydraulic gradients are consistent with both the current tritium plume depiction and with the simulated groundwater flow direction as indicated by the particle track analysis.

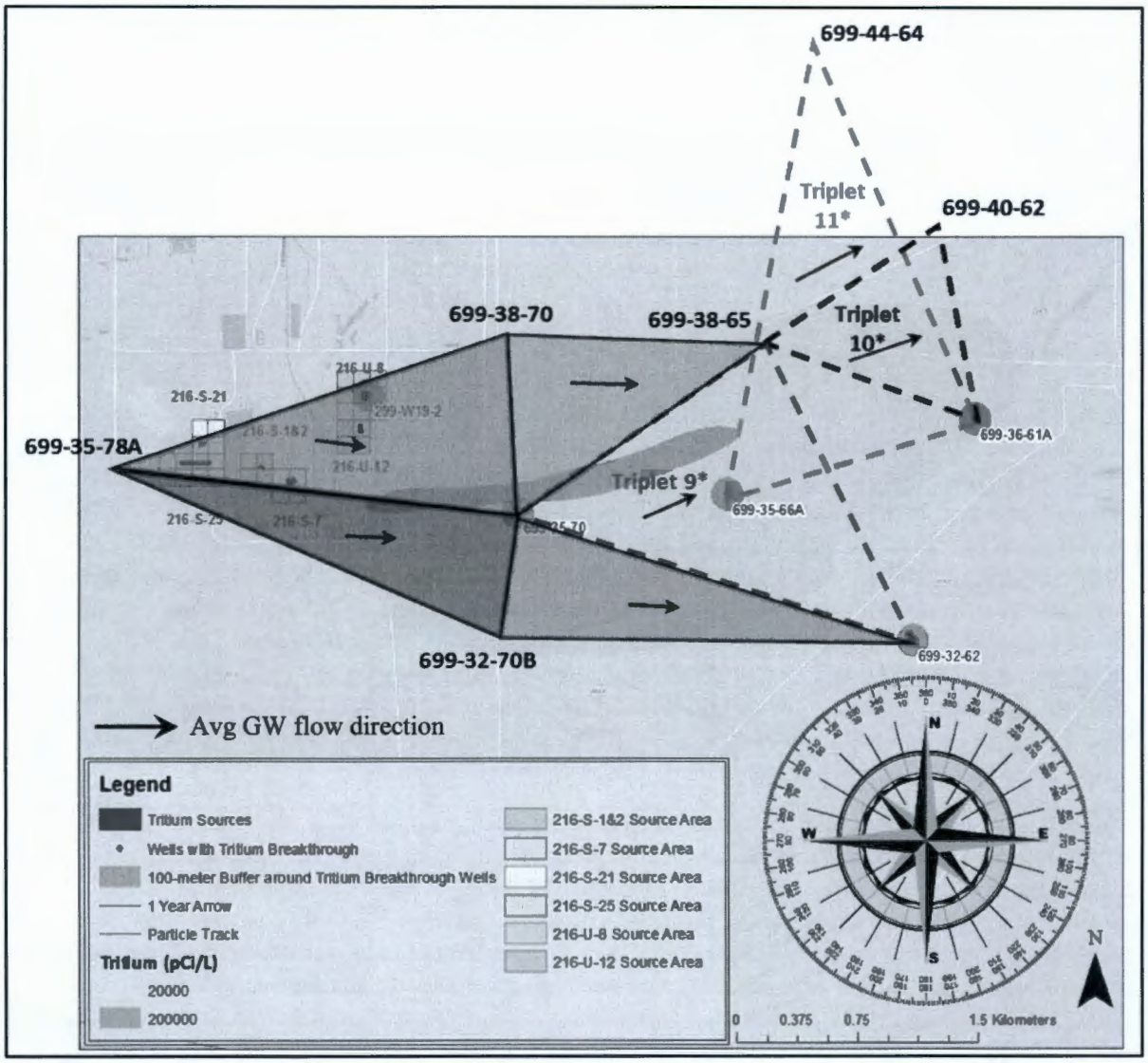

Figure 20. Three-Point Gradient Solution Overlaid on Tritium Plume at the 200 West Area

5 Conclusions and Recommendations

The Phase I study provides some insight into groundwater movement, contaminant migration, and uncertainties related to these features based on examination of historical groundwater monitoring records. The ability to simulate observed conditions is an important element of long-term remedial action planning and risk management. Identification of specific areas of uncertainty can provide opportunities for uncertainty reduction and improvement in predictive capabilities. The following sections discuss conclusions drawn from the study and recommendations.

5.1 Conclusions

Simulation of tracer dye migration from the historical tracer tests conducted in the vicinity of SWL/NRDWL in 1956 and 1957 indicates that the CPGWM does not adequately represent groundwater flow direction or velocity in that study area over the period of time of the historical study (i.e., 1956-1957). Representation of the historical conditions would not be reasonably expected from the CPGWM as it is currently constructed. Several factors contribute to this conclusion. The study area is located in a corner of the model domain; this presents inherent difficulties in matching observed conditions in the near-field vicinity. In addition, the tracer study observation wells were located outside the model domain, while the tracer injection wells were inside the domain. The resultant simulated groundwater flow directions and velocities for the historical study period, however, are largely defined by the boundary conditions. The simulated groundwater flow direction was off by as much as 90° as compared to the gradient indicated by three-point solutions using contemporary water levels and the simulated groundwater velocity was substantially slower in the study area. The flow direction in the study area during the time of the historical tracer study is consistent based on the historical water level/gradient analysis and the appearance of the dye tracer in downgradient wells.

Simulation of groundwater and tritium movement in the vicinity of 200 West Area indicates that the CPGWM provides representative flow direction; groundwater velocity may be underestimated. Uncertainties in the precise nature of tritium sources and timing of entry of contamination into the underlying aquifer present a challenge to reproducing observed tritium activity concentration breakthrough in groundwater at downgradient wells. Source term release scenario uncertainty appears to provide a substantial degree of uncertainty, followed by uncertainty in aquifer hydraulic properties (e.g., mobile porosity, hydraulic conductivity) that affect downgradient tritium concentration estimates and arrival times. The difference in arrival times of the two source release scenarios ranged from about 10 to as much as 40 years; these differences could account for one to more than 3 decay half-lives for tritium, substantially reducing the modeled concentration for the retarded release scenario. Inspection of the simulated tritium activity concentration breakthrough curves suggests that the simulated vadose transport source term is slow in its arrival at the aquifer and that the most likely case lies in a condition between the instantaneous-release case and the time-lagged release.

5.2 Recommendations

Recommendations derived from this study fall into two categories: (1) recommendations for supplemental characterization of aquifer hydraulic properties at selected locations, and (2) recommendations for evaluation of selected hydraulic property parameter values used in the CPGWM.

5.2.1 Suggested Characterization Opportunities

Inconsistency in apparent and simulated groundwater velocity in the vicinity of the historical dye tracer study (i.e., near SWL/NRDWL) indicates the need for better understanding of hydraulic conductivity of the saturated Cold Creek gravel unit and perhaps the saturated Hanford formation in that area.

Information collected during pumping from the Cold Creek gravel unit in the vicinity of B Tank Farm Complex indicates that the hydraulic conductivity of the unit is substantially higher than previously inferred. If the Cold Creek gravel in the SWL/NRDWL vicinity actually exhibits higher hydraulic conductivity (e.g., similar to the nearby Hanford formation deposits), this could substantially affect inferred groundwater flow velocity in this area. Supplemental characterization activities that may prove useful in refining the hydrogeologic conceptual site model include:

- Determination of aquifer hydraulic characteristics by aquifer pumping tests (the preferred method) conducted in existing wells
- Re-examination of historical pumping tests conducted in the vicinity
- Laboratory testing of intact core samples collected from new borings or wells in the study area
- Review current geophysical investigation approaches to identify a technique that may discriminate between the various unconsolidated saturated formations in the study area, and if a technique is identified, then initiate planning for a supplemental survey

5.2.2 Suggested Model Parameter Evaluations

Focused sensitivity evaluations performed in this study suggest that in some formations, reducing the effective porosity may provide improved groundwater velocity matching. Other studies (e.g., the tracer study documented in HW-60101 and SGW-60606, *100-K and 100-D Areas Sulfate Tracer Phase I Study Report*) suggest an effective porosity ranging from 0.09 to 0.10 for some formations.

Hydraulic conductivity of selected formations (e.g., Hanford formation and Cold Creek Unit gravel) may exhibit a higher range of variability than currently inferred. In areas of high-velocity deposition (e.g., the B Tank Farm Complex and possibly the general area south east of 200 East Area, including the historical dye tracer study area), these formations may be locally modified, exhibiting a coarser texture and less structured composition.

The boundary conditions established in the southeast corner of the CPGWM may need to be re-examined in light of the 90° variance in groundwater flow direction exhibited in the historical dye tracer study examination. However, this examination should consider the value derived from changes in the boundary conditions to prioritize predictive simulations over historical flow matching. It may be useful to delay this examination of boundary conditions until the Plateau to River model (which will replace the CPGWM) is in operation; the Plateau to River model will replace the arbitrarily-located CPGWM boundary conditions in this study area with the boundary condition defined by the Columbia River to the east.

6 References

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Appendix A

Gradient Direction Dye Tests

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Appendix B

Gradient Direction Tritium Evaluation 200 Area

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