APPENDIX V
BLACK ROCK RESERVOIR SENSITIVITY ANALYSIS

This appendix describes a variant of the regional-scale groundwater flow model for the Hanford Site.

V.1 BACKGROUND

The development of the *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* Base Case flow model that was used to analyze long-term groundwater impacts for the alternative and cumulative impact analyses is presented in Appendix L. The variant discussed in this appendix is presented to provide information on the potential influence of a reasonably foreseeable future scenario—construction of the Black Rock Reservoir (BRR) west of the Hanford Site (Hanford). Previous studies (see Section V.3.1) suggested that leakage from this reservoir has the potential to impact groundwater elevations and flow velocities beneath Hanford, which could in turn affect the comparison of the long-term impacts of the alternatives examined in this *TC & WM EIS*.

V.2 SENSITIVITY ANALYSIS PURPOSE AND SCOPE

V.2.1 Purpose of Analysis

The overall goal of the analysis is to illustrate the consequences of leakage from the proposed BRR on the potential differences among *TC & WM EIS* alternatives with respect to long-term groundwater impacts.

Specific purposes of this analysis are to determine the following:

- The change in water table elevation and flow velocities beneath Hanford resulting from water flux added by leakage from the BRR.
- Potential changes in vadose zone contaminant transport times resulting from a shortened vadose zone.
- Potential changes in groundwater plume predictions resulting from mobilization of vadose zone contaminants under rising water table supply activities. Excluded are evaluation of the BRR's impact on human health and the environment, as well as the comprehensive, long-term (10,000-year) impacts of any alternative addressed in this *TC & WM EIS*.

V.2.2 Scope of Modeling Effort

The scope of the modeling effort included:

- Obtaining predictions of the additional groundwater flux induced by leakage from the proposed BRR from the U.S. Department of the Interior, Bureau of Reclamation (BOR)
- Inserting these fluxes into the Base Case MODFLOW [modular three-dimensional finite-difference groundwater flow model] and predicting changes in water table elevation and flow velocities
- Comparing the BRR flow field with the Base Case flow field
- Using the STOMP [Subsurface Transport Over Multiple Phases] model (see Appendix N) to predict vadose zone travel times under shortened vadose zone conditions

- Comparing the BRR and Base Case flow fields with respect to the time to appearance of peak concentrations of technetium-99 at the Columbia River from a 1-curie release from various 200 Area release locations

- Evaluating the results to determine any differential impacts across the *TC & WM EIS* alternatives

V.3 MODEL DEVELOPMENT

V.3.1 Previous Studies

In preparation of the BRR sensitivity analysis performed by Science Applications International Corporation (SAIC), the following documents were reviewed:

1. *Final Planning Report/Environmental Impact Statement, Yakima River Basin Water Storage Feasibility Study, Yakima Project, Washington*, December 2008 (BOR 2008)

   This document "examined the feasibility and acceptability of storage augmentation for the benefit of fish, irrigation, and future municipal water supply for the Yakima River basin." In efforts to supply additional water storage in the Yakima River basin, the document considered three alternatives other than the No Action Alternative: (1) the Black Rock Reservoir Alternative, (2) the Wymer Dam and Reservoir Alternative, and (3) the Wymer Dam plus Yakima River Pump Exchange Alternative. Other programmatic joint alternatives discussed within the document include the Enhanced Water Conservation Alternative, the Market-Based Reallocation of Water Resources Alternative, and the Groundwater Storage Alternative. For a variety of reasons, most notably issues related to the cost-benefit ratio assessments of each alternative, BOR identified the No Action Alternative as the Preferred Alternative. No site-specific Hanford Reservation groundwater modeling was performed for the examined alternatives. SAIC utilized the document for background knowledge regarding the Black Rock Reservoir Alternative.

2. *Modeling Groundwater Hydrologic Impacts of the Potential Black Rock Reservoir: A Component of the Yakima River Basin Water Storage Feasibility Study, Washington Pacific Northwest Region*, September 2007 (BOR 2007)

   As a component of the *Final Planning Report/Environmental Impact Statement, Yakima River Basin Water Storage Feasibility Study, Yakima Project, Washington* (discussed above), this document was published to further examine the Black Rock Reservoir Alternative. The report documents results pertaining to a potential groundwater seepage analysis of the BRR. The analysis quantifies potential reservoir seepage to surrounding aquifers and provides an indication of flow direction associated with the seepage. The modeling in this report, performed using various MODFLOW software packages, further characterizes potential impacts on the western boundary of Hanford (e.g., increased hydraulic head, estimated groundwater flux, surface-water discharge). The analysis does not examine proposed seepage mitigation controls nor examine potential site-specific impacts on the Hanford Reservation.

   This seepage analysis, performed by BOR, ultimately provided flux values along the western boundary of Hanford, which were used to develop SAIC's BRR variant flow field model discussed in this "Black Rock Reservoir Sensitivity Analysis." The BOR flux values used by SAIC were requested via a formal data request (Schmidt 2007). Further discussion of development of the BRR variant flow field model is included in Section V.3.2. Initially, two BRR permeability cases were developed for analysis as proposed by BOR—BRR Permeability Case 1 and BRR Permeability Case 2. During this analysis, direction was given to SAIC to only proceed with Permeability Case 2.

3. *Potential Impact of Leakage from Black Rock Reservoir on the Hanford Site Unconfined Aquifer: Initial Hypothetical Simulations of Flow and Contaminant Transport*, March 2007 (Freedman 2008)

   This analysis was performed by Pacific Northwest National Laboratory (PNNL) to identify potential impacts associated with the development of the BRR at Hanford. Simulated lateral recharge (or flux) along the western boundary of Hanford was calculated using water table elevations (hydraulic head values) no greater than the highest groundwater elevation attained in the Central Plateau of Hanford during the Hanford operational period. PNNL developed three steady state flow fields to assess the fate and transport of site contaminants; varying western boundary fluxes of (1) 27,000 acre-feet/year, (2) 16,000 acre-feet/year, and (3) a no additional flux Base Case of 365 acre-feet/year. The transport of four radionuclides (hydrogen-3 [tritium], iodine-129, technetium-99, and uranium-238) was modeled over a 300-year period. Simulated radionuclide concentration distributions across Hanford in 2005 were used as initial model conditions prior to running each model. Model transport analysis provided (1) peak concentration downstream and points of compliance, (2) areas of Hanford contaminated above drinking water standards, and (3) the total activity within the model domain at the end of transport simulation.

   PNNL's analysis results of all three simulated BRR models indicated that the models (1) "had little impact on regional flow directions," (2) "accelerated contaminant transport," and (3) "the accelerated transport caused dilution and a more-rapid decline of concentration relative to the Base Case." Further, PNNL results indicated that increased western boundary flux caused an increase in the highly retarded uranium-238, but the concentrations were found not to exceed drinking water standards. PNNL noted no significant effects of contaminant concentrations at the designated Hanford Core Zone or the Columbia River.

   No specific data or results derived from the PNNL study were used for the BRR variant flow field analysis discussed in this appendix. The PNNL study was used as background information only.

V.3.2 Relationship to *TC & WM EIS* Modeling Framework

The *TC & WM EIS* Base Case groundwater flow model was developed for input to the *TC & WM EIS* groundwater transport model, which is used for simulating the fate and transport of contaminants to analyze the alternatives and cumulative impacts. The Base Case groundwater flow model development and the associated flow field extraction methods are discussed in Appendix L. The *TC & WM EIS* Base Case groundwater transport model development and application are discussed in Appendix O.

The Base Case groundwater flow and transport models are calibrated to historical field observations of groundwater hydraulic heads and contaminant concentrations. This calibration to historical field observations provides an indication that the Base Case models can reasonably predict future hydraulic heads and contaminant concentrations. The calibrated results produced in the Base Case groundwater modeling simulations are used as inputs to the long-term impacts analysis in this *TC & WM EIS*.

The BRR is considered to be a reasonably foreseeable future scenario that may impact groundwater flow and transport beneath Hanford. BOR has developed a separate groundwater flow model that simulates the additional water flux to groundwater in areas surrounding the proposed reservoir, including Hanford.

The BOR flow model covers an area of about 4,480.7 square kilometers (1,730 square miles) with discrete model cells that range from 0.2 to 0.83 square kilometers (0.08 to 0.32 square miles) (Schmidt 2007). The *TC & WM EIS* groundwater flow model covers an area of about 1,942.5 square kilometers (750 square miles) with discrete model cells that cover 0.039 square kilometers (0.015 square miles) each. The larger scale and coarser gridding of the BOR model allow macro-level encoding of model properties and macro-level analysis, which are appropriate for the BOR study; however, the

smaller scale and finer gridding of the *TC & WM EIS* Base Case flow model is preferred to make predictions about the impacts of the proposed reservoir on contaminant fate and transport beneath Hanford.

To simulate the impacts on Hanford resulting from the proposed BRR, the *TC & WM EIS* groundwater modeling team worked with the BOR groundwater modeling team to identify a line of model interface (line of flux), where the agreed-upon line is included geographically in both the BOR model and the *TC & WM EIS* Base Case flow model. This line of flux or interface was then used to represent the changes in flux into and out of the *TC & WM EIS* model based on the results of the BOR flow model simulation. The line of model interface (as encoded into the *TC & WM EIS* Base Case model) is illustrated in Figure V–1.

This line of water flux from the BOR model was provided to SAIC's *TC & WM EIS* groundwater modeling team in "Data Request #279 Related to Hanford *Tank Closure & Waste Management Environmental Impact Statement*" (Schmidt 2007). This data set provided flux values along the line of flux based on the model gridding in the BOR model. This data set was processed by the *TC & WM EIS* groundwater modeling team to translate the locations and values from the coarser BOR model gridding to the finer *TC & WM EIS* model gridding. This revised data set was then encoded as recharge flux into a BRR variant of the *TC & WM EIS* Base Case flow model. Encoded flux values include positive and negative values and are from the perspective of the BOR model. Therefore, negative values represent fluxes into the BRR variant model, and positive values represent fluxes out of the BRR variant model. Cell (model row and column) specific flux values are included in Table V–1. Within the BRR variant model, row 1 is the first row starting from the north, and column 1 is the first column starting from the west.

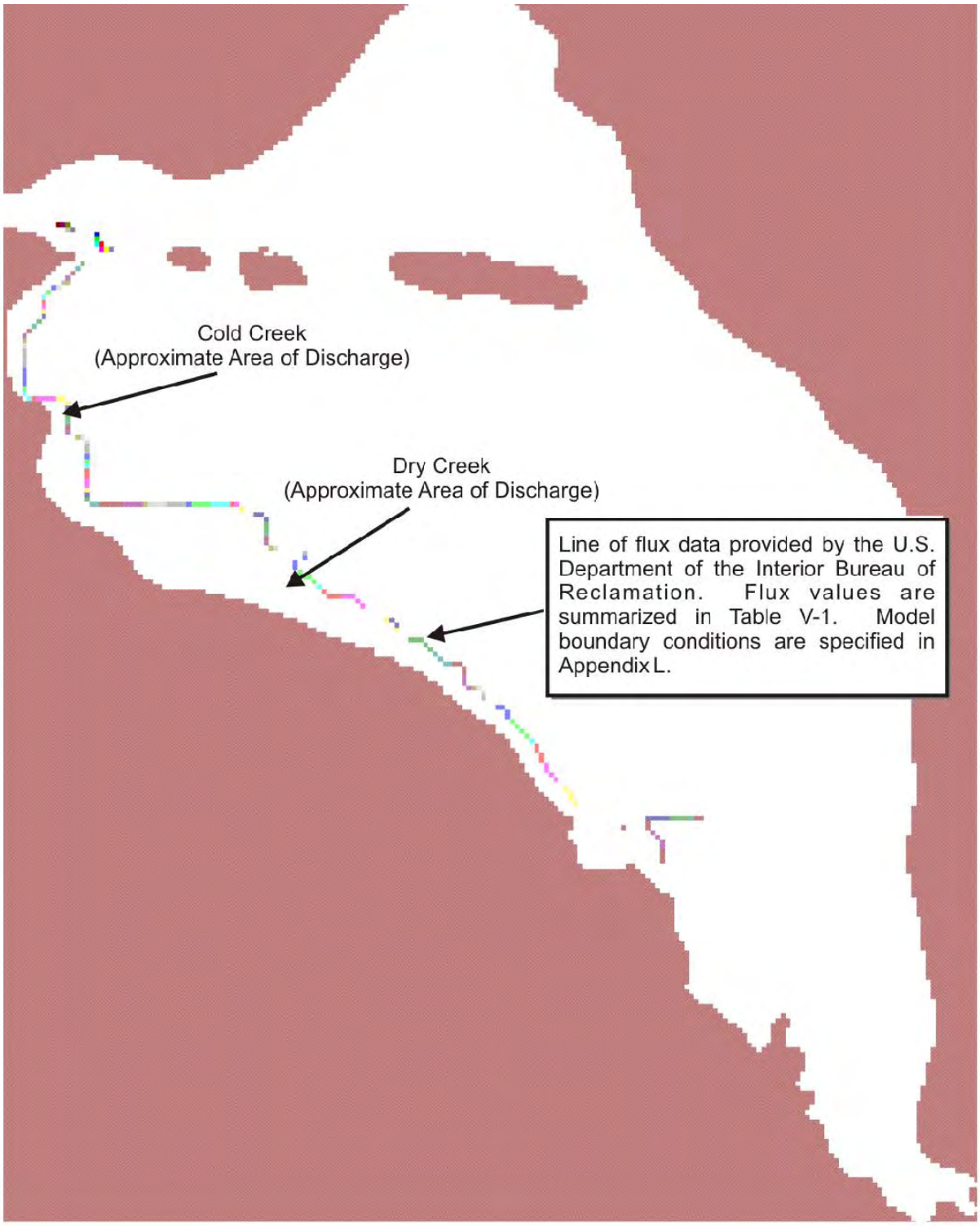

Figure V–1. Black Rock Reservoir Variant Flow Field – Additional Recharge Cell Locations

Table V–1. Black Rock Reservoir Variant Flow Field Flux Values

Model Row	Model Column	BRR Variant Model Cell Specific Flux Values (mm/yr)		Model Row	Model Column	BRR Variant Model Cell Specific Flux Values (mm/yr)[a]
57	1	5.37		93	8	539.65
57	2	5.37		93	9	539.65
57	3	3,467.07		93	10	539.65
57	4	3,467.07		93	11	539.65
57	5	3,467.07		93	12	222.91
58	6	3,467.07		93	13	222.91
59	7	3,467.07		94	14	222.91
60	8	3,032.67		95	14	130.78
61	9	3,032.67		96	14	38.65
62	10	3,032.67		97	14	38.65
62	11	3,032.67		98	14	282.98
62	12	3,085.83		99	14	527.31
62	13	3,085.83		100	14	263.66
63	14	3,085.83		101	15	0.00
64	13	3,085.83		101	16	219.00
65	12	707.64		101	17	438.01
66	11	1,670.54		102	18	438.01
66	10	1,670.54		103	18	200.93
67	9	1,670.54		104	18	200.93
68	9	1,670.54		105	18	327.97
69	9	575.08		106	18	455.00
70	9	575.08		107	18	458.16
71	9	575.08		108	18	461.32
72	9	575.08		109	18	461.32
73	9	973.90		110	18	314.17
74	9	1,372.73		111	18	314.17
75	9	1,372.73		112	18	300.40
76	9	1,372.73		113	18	286.63
77	8	1,372.73		114	18	200.61
78	7	743.31		115	19	114.59
79	6	743.31		115	20	114.59
80	5	743.31		115	21	888.35
81	5	743.31		115	22	888.35
82	5	396.77		115	23	888.35
83	5	50.23		115	24	888.35
84	5	50.23		115	25	888.35
85	5	50.23		115	26	1,518.69
86	5	50.23		115	27	1,518.69
87	5	191.19		115	28	1,518.69
88	5	191.19		115	29	1,518.69
89	5	191.19		115	30	6,650.76
90	5	191.19		115	31	11,782.83
91	5	28.52		115	32	11,782.83
92	5	134.14		115	33	11,782.83

Table V–1. Black Rock Reservoir Variant Flow Field Flux Values *(continued)*

Model Row	Model Column	BRR Variant Model Cell Specific Flux Values (mm/yr)		Model Row	Model Column	BRR Variant Model Cell Specific Flux Values (mm/yr)[a]
93	6	134.14		115	34	11,782.83
93	7	336.89		115	35	10,320.61
115	40	23,680.24		115	36	10,320.61
115	41	23,680.24		115	37	10,320.61
115	42	23,680.24		115	38	10,320.61
115	43	23,680.24		115	39	17,000.42
115	44	19,860.70		143	85	1,447.49
115	45	19,860.70		143	86	1,447.49
115	46	19,860.70		143	87	1,447.49
115	47	19,860.70		144	88	1,447.49
115	48	31,186.16		145	89	1,447.49
115	49	42,511.63		146	90	189.80
116	50	21,255.81		147	91	189.80
117	51	0.00		148	92	189.80
117	52	0.00		148	93	189.80
117	53	35,797.38		148	94	855.88
117	54	35,797.38		148	95	855.88
118	55	35,797.38		149	96	855.88
119	55	16,700.60		150	96	855.88
120	55	16,700.60		151	96	211.89
121	55	17,731.08		152	96	211.89
122	55	18,761.56		153	97	211.89
123	55	9,380.78		153	98	429.64
124	56	0.00		153	99	1,071.18
124	57	8,256.15		154	100	1,071.18
124	58	16,512.31		155	100	535.59
125	59	9,447.78		156	100	0.00
126	59	2,383.26		157	101	0.00
127	60	2,383.26		157	102	0.00
128	61	2,383.26		157	103	543.89
129	62	5,675.52		157	104	543.89
130	63	5,675.52		158	105	543.89
130	64	5,675.52		159	105	543.89
131	65	5,675.52		160	105	255.88
132	66	3,152.26		161	105	255.88
133	67	629.01		162	105	255.88
134	68	629.01		163	106	255.88
134	69	629.01		164	107	136.23
134	70	629.01		165	108	16.58
134	71	2,256.53		166	109	16.58
134	72	2,256.53		167	110	16.58
134	73	2,256.53		168	111	16.58
135	74	2,256.53		169	112	33.72
136	75	2,256.53		170	113	33.72
137	76	0.00		171	114	33.72

Table V–1. Black Rock Reservoir Variant Flow Field Flux Values *(continued)*

Model Row	Model Column	BRR Variant Model Cell Specific Flux Values (mm/yr)		Model Row	Model Column	BRR Variant Model Cell Specific Flux Values (mm/yr)[a]
138	77	0.00		172	115	33.72
139	78	0.00		173	116	3.94
139	79	0.00		174	117	25.83
139	80	1,424.88		175	118	25.83
139	81	2,849.75		176	118	25.83
140	82	2,849.75		177	118	25.83
141	82	1,424.88		178	118	0.00
142	82	0.00		179	118	0.00
143	83	0.00		180	119	0.00
143	84	0.00		180	120	0.00
180	125	403.84		180	121	403.84
180	126	183.45		182	134	421.85
180	127	183.45		183	135	780.18
180	128	183.45		184	136	780.18
180	129	183.45		185	137	780.18
180	130	302.65		186	137	780.18
180	131	421.85		187	137	423.08
180	132	421.85		188	137	423.08
181	133	421.85		189	137	423.08
180	123	403.84		180	122	403.84
180	124	403.84		180	123	403.84

[a] Encoded flux values include positive and negative values and are from the perspective of the U.S. Department of the Interior, Bureau of Reclamation model. Therefore, negative values represent fluxes into the BRR variant model, and positive values represent fluxes out of the BRR variant model.

Note: Values provided by the U.S. Department of the Interior, Bureau of Reclamation.

Key: BRR=Black Rock Reservoir; mm/yr=millimeters per year.

This BRR variant flow field model of the *TC & WM EIS* Base Case flow model included the following modifications to the Base Case flow model:

- Removed all anthropogenic recharge zones except for the long-term expected water fluxes and extractions from the city of Richland, the North Richland Well Field (NR-1100B), and the Richland Wellsian Way Well Field (1182 Pump House)
- Added the water flux values from the BOR flow model, as described above
- Changed the model time-stepping algorithm to ramp up to the BOR total flux values over a period of 45 years to aid model convergence
- Changed the duration of the simulation to 500 years

Sections V.3.3 and V.3.5 describe the methodology and application of the BRR variant flow field model to analyze the impacts of the additional water flux values from the BOR flow model.

Section V.3.4 describes the methodology for evaluating changes to vadose zone thickness and travel times and uses variants of the *TC & WM EIS* Base Case STOMP models. The *TC & WM EIS* Base Case STOMP model development and application are described in Appendix N.

V.3.3 Methodology for Evaluating Changes in Flow Field and Transport Patterns

The BRR variant flow field spread of recharge (flux along the western model domain boundary) extends from Cold Creek (northeastern region of the model domain) surface water discharge, along the western model domain past the Dry Creek discharge regions, to near the northern reaches of West Richland. To aid model convergence, the BRR flux was stepped in at 20 percent flux intervals over the first five model time periods prior to reaching the full designated flux volume.

To evaluate and characterize how the BRR variant flow field model's additional western boundary fluxes affect the flow and transport patterns across Hanford, the following investigative methods were used:

1. **Steady state flow field head distribution analysis generated by MODFLOW.** The BRR variant flow field head distributions were compared to the head distributions in the *TC & WM EIS* Base Case flow field. Standard color ramp scales were used to compare model hydraulic head values. Head information was provided at the end-of-time (long-term steady state) model simulation time step of both models.

2. **Hanford Central Plateau directional flow field tracers (particle pathlines) analysis.** Central Plateau–originating directional flow pathlines (generated by MODPATH [MODFLOW particle-tracking postprocessing package]) from the long-term steady state flow field of the BRR variant flow field model were compared to those from the long-term steady state *TC & WM EIS* Base Case flow model.

3. **Steady state flow field vector analysis.** Groundwater Vistas, Version 4.2.5, Build 22 (ESI 2004), was utilized to interpret MODFLOW-generated flow field vectors within the BRR variant flow field model and compare them to the *TC & WM EIS* Base Case flow model vectors. Groundwater Vistas utilizes end-of-time (long-term steady state) MODFLOW output files to internally calculate model cell X and Y flow vectors. Vector length is on a logarithmic scale for display purposes. Standard color ramp and logarithmic scales used to distinguish vector lengths equally represent the velocities in the two flow fields. Contour lines are used to indicate a relative ratio of velocities between the two models.

The results of these analyses are included in Section V.4.1.

V.3.4 Methodology for Evaluating Vadose Zone Inundation

To determine the inundation depth to be applied to each Base Case STOMP model result, the *TC & WM EIS* Base Case flow model and the BRR variant flow field model were interrogated at each STOMP model location across Hanford to determine the inundation depth resulting from the additional flux from the BOR flow model. The inundation depth at these locations is equal to the calculated difference between the hydraulic head or water table elevation (above mean sea level [amsl]) in the *TC & WM EIS* Base Case flow model and the hydraulic head in the BRR variant flow field model. The inundation depth results from the rising water table. A calculation of the vadose zone decrease in depth (percentage) under BRR variant conditions compared to *TC & WM EIS* Base Case vadose zone depths was also performed.

The results of this analysis are included in Section V.4.2.

V.3.5 Methodology for Evaluating Changes to Vadose Zone Thickness and Travel Times

Analysis of the movement of water and various solutes through the vadose zone (unsaturated zone between the ground surface and groundwater) was required to evaluate the *TC & WM EIS* long-term

impacts on groundwater quality. Within this *TC & WM EIS*, simulations of site-specific vadose zones were completed using the STOMP computer code. Further description of the *TC & WM EIS* STOMP modeling effort is included in Appendix N.

To evaluate the effects of the additional flux as described by the BOR model, vadose zone thickness (depth) must first be obtained at selected Hanford sites within the BRR variant flow field model and compared to the same location within the *TC & WM EIS* Base Case flow field model. Selected locations were interrogated in both models to determine the change in vadose zone thickness resulting from the additional BRR flux. The change of vadose zone thickness is the calculated difference between the hydraulic head in the *TC & WM EIS* Base Case model and the hydraulic head in the BRR variant flow field model. Table V–2 provides a summary of the *TC & WM EIS* Base Case model and the BRR variant flow field model head comparisons at selected locations related to the *TC & WM EIS* alternatives presented in Chapter 2.

Table V–2. Changes to Vadose Zone Thickness (Inundation Depth) Resulting from Black Rock Reservoir—Selected Hanford Site Locations Related to the *TC & WM EIS* Alternatives

Hanford Site Location	*TC & WM EIS* Base Case Flow Model Hydraulic Head	BRR Variant Flow Field Model Hydraulic Head	BRR Variant Change to Vadose Zone Thickness
	(meters)		
Core Zone, 200-East Area Integrated Disposal Facility	122.8	124.5	–1.7
Core Zone, 200-West Area Integrated Disposal Facility	137.5	146.9	–9.4
Core Zone, River Protection Project Disposal Facility	128.5	134.8	–6.3
200-West Area, trenches 31 and 34	136.8	146.3	–9.5

Note: To convert meters to feet, multiply by 3.281.
Key: BRR=Black Rock Reservoir; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.*

Selection of these Hanford locations for vadose zone analysis was based on a preference for the Waste Management alternatives involving the greatest variety of waste forms evaluated in this *TC & WM EIS*. Those Waste Management alternatives are described in Chapter 2.

Using the change to vadose zone thickness results included in Table V–1, variants to the *TC & WM EIS* Base Case STOMP models used at the selected locations were developed by removing an equivalent number of nodes at the bottom of the STOMP model to account for a shortened vadose zone. Further, the bottom boundary condition was adjusted accordingly to the lowest active layer. These site-specific BRR variant STOMP models and site-equivalent *TC & WM EIS* Base Case STOMP models were run at identical Waste Management alternative locations (10,000 years) using 1 curie of technetium-99, as described in Appendix N. Technetium-99 was chosen as a conservative tracer radionuclide because it is highly mobile and has a relatively long half-life of 2.13×10^5 years (decays approximately 3.2 percent in 10,000 years).

The results of this analysis are included in Section V.4.2.

V.3.6 Methodology for Evaluating Changes to the Year of Peak Concentration at the Columbia River

A groundwater flow and transport analysis was performed using the BRR variant flow field and *TC & WM EIS* Base Case flow field to evaluate peak concentration arrival time to the Columbia River. Particle tracking computer code was used to simulate the migration of contaminants through each flow

field (aquifer). Comprehensive discussion of the Base Case flow field development and extraction for use is included in Appendix L. Detailed groundwater transport information can be found in Appendix O.

Contaminant transport analysis was performed to compare the concentration results for technetium-99 at the Columbia River for the *TC & WM EIS* Base Case model and BRR variant model flow fields during the 500-year Hanford postoperational period (1940–2440). This comparison was based on the release of 1 curie of technetium-99 from each of the 10 barriers (A, B, S, T, and U Barrier boundaries; trenches 31 and 34; the 200-East and 200-West Area Integrated Disposal Facilities; the Fast Flux Test Facility (FFTF); and the River Protection Project Disposal Facility). For purposes of analysis, this unit release is assumed to have occurred in calendar year 2090, a time after which the BRR will have achieved long-term steady state condition. These releases occurred in the center of each barrier in a 10- by 10-meter (32.8- by 32.8-foot) square. The peak concentrations results for technetium-99 at the Columbia River for both the *TC & WM EIS* Base Case model and BRR variant model flow fields are further discussed in Section V.4.3.

V.4 MODEL RESULTS

This section describes the results of the analyses described in Sections V.3.3, V.3.4, V.3.5, and V.3.6. In all analyses, the BRR variant flow field model was compared and contrasted with the *TC & WM EIS* Base Case flow model.

V.4.1 Changes to Flow Field and Transport Patterns

<u>Steady State Head Distribution</u>

Model long-term steady state groundwater head values are illustrated in Figure V–2 (*TC & WM EIS* Base Case flow field model), Figure V–3 (BRR variant flow field model), and Figure V–4 (hydraulic head difference between the *TC & WM EIS* Base Case and BRR variant flow field models).

The distribution of head values across the *TC & WM EIS* Base Case flow model indicates a progressive slope across the model from west to east towards the Columbia River. Groundwater head is the highest along the western regions of the model between Cold Creek and Dry Creek at 156 meters (512 feet); the lowest modeled groundwater head along the Columbia River (or eastern model domain) ranges from 106 to 114 meters (348 to 374 feet).

Unlike the *TC & WM EIS* Base Case model, the distribution of head values across the BRR variant flow field model has a steeper slope west to east across the model domain. A mounded groundwater head, 162 meters (532 feet) at its highest point, is observed within the northwestern portion of the model between Cold Creek and Dry Creek east of the flux line provided by BOR. This mound within the western region of the flow field is due to the prominence of relatively low hydraulic conductivity values of the Ringold Formation along with increased recharge from BRR along the western regions of the model. The mounded slope (west to east) of groundwater caused by the increased recharge quickly dissipates in the middle of the model (east of Gable Mountain–Gable Butte Gap [Gable Gap] and east of the 400 Area) where higher hydraulic conductivity values of the Hanford formation are encountered. Eastern region head values in the BRR variant flow field model resemble the head values observed in the *TC & WM EIS* Base Case flow model.

Within the Core Zone of the BRR variant flow field model, the west to east slope of hydraulic head values is steep. Compared to the *TC & WM EIS* Base Case flow field, the head values in the 200-West Area are 9 to 14 meters (30 to 46 feet) higher and those in the 200-East Area are 1 to 2 meters (3 to 7 feet) higher. Tables V–1 and V–2 list the various head differences between the two models at specific site locations.

For comparison, in general, the Hanford operational period increased the groundwater elevation beneath the Core Zone more than 20 meters (66 feet) in the 200-West Area and approximately 10 meters (33 feet) in the 200-East Area through direct injection of wastewater discharge from the surface (Freedman 2008). The BRR variant flow field rise in groundwater elevation in the Core Zone (compared to the *TC & WM EIS* Base Case flow field) is less than the elevations observed during the Hanford operational period.

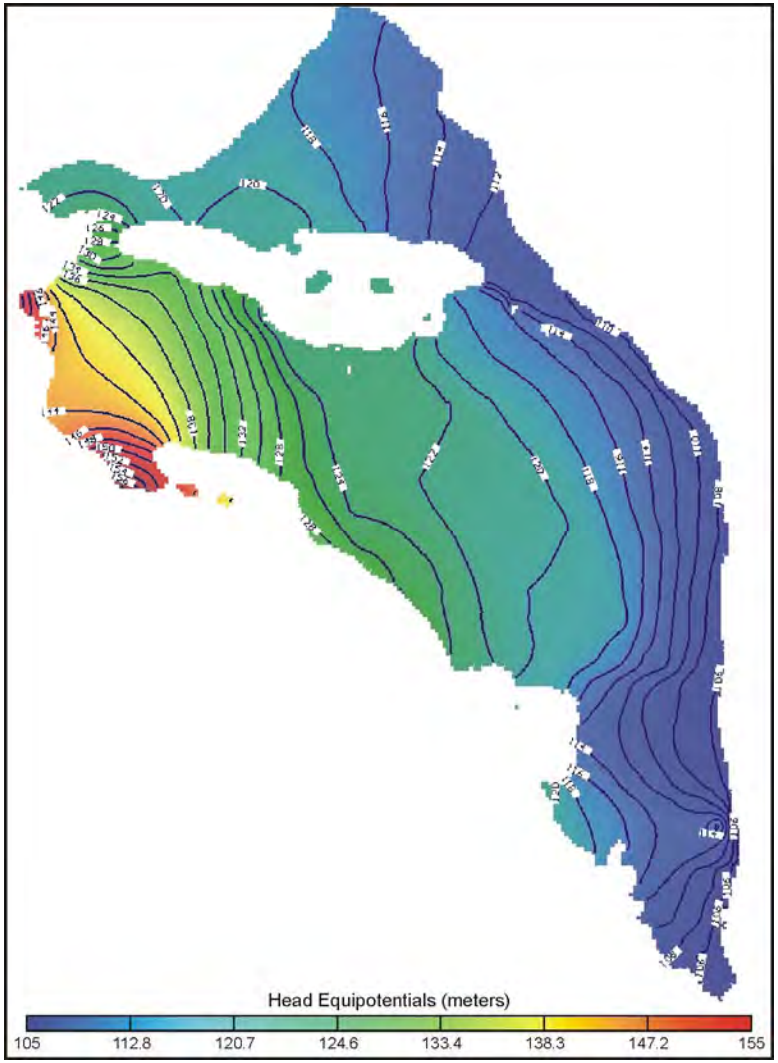

Figure V–2. *TC & WM EIS* Base Case Flow Model – Long-Term Steady State Head Distribution (Hydraulic Head from Model Layer 19, 105–110 meters above mean sea level)

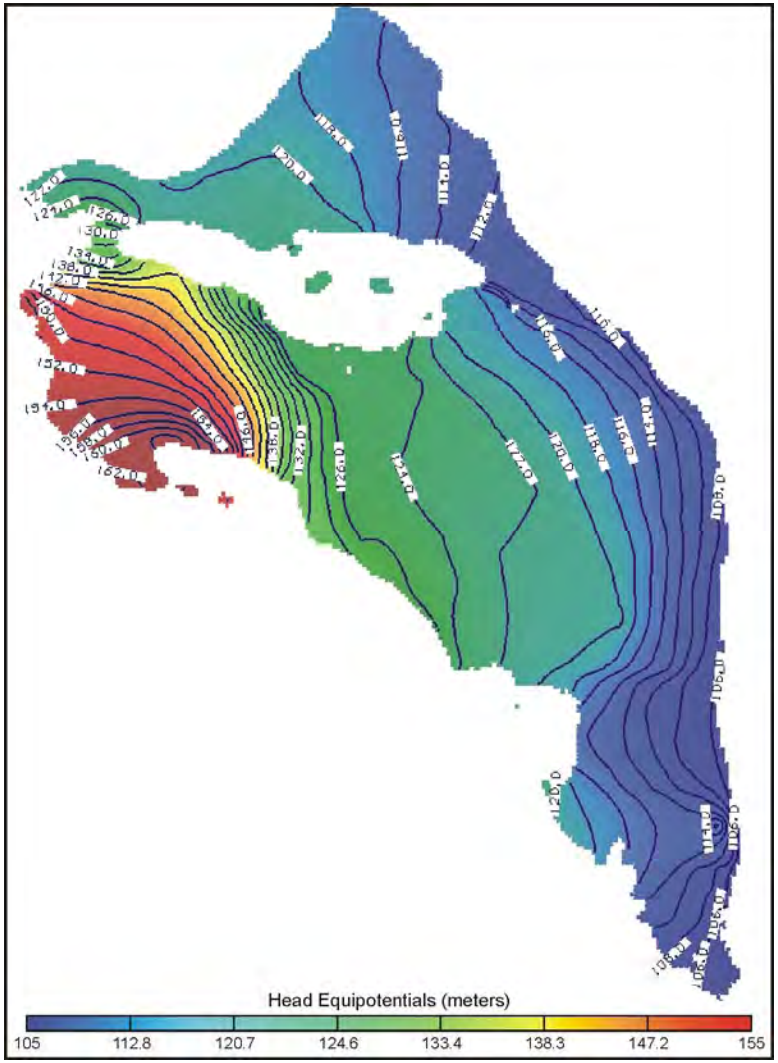

Figure V–3. Black Rock Reservoir Variant Flow Field Model – Long-Term Steady State Head Distribution (Hydraulic Head from Model Layer 19, 105–110 meters above mean sea level)

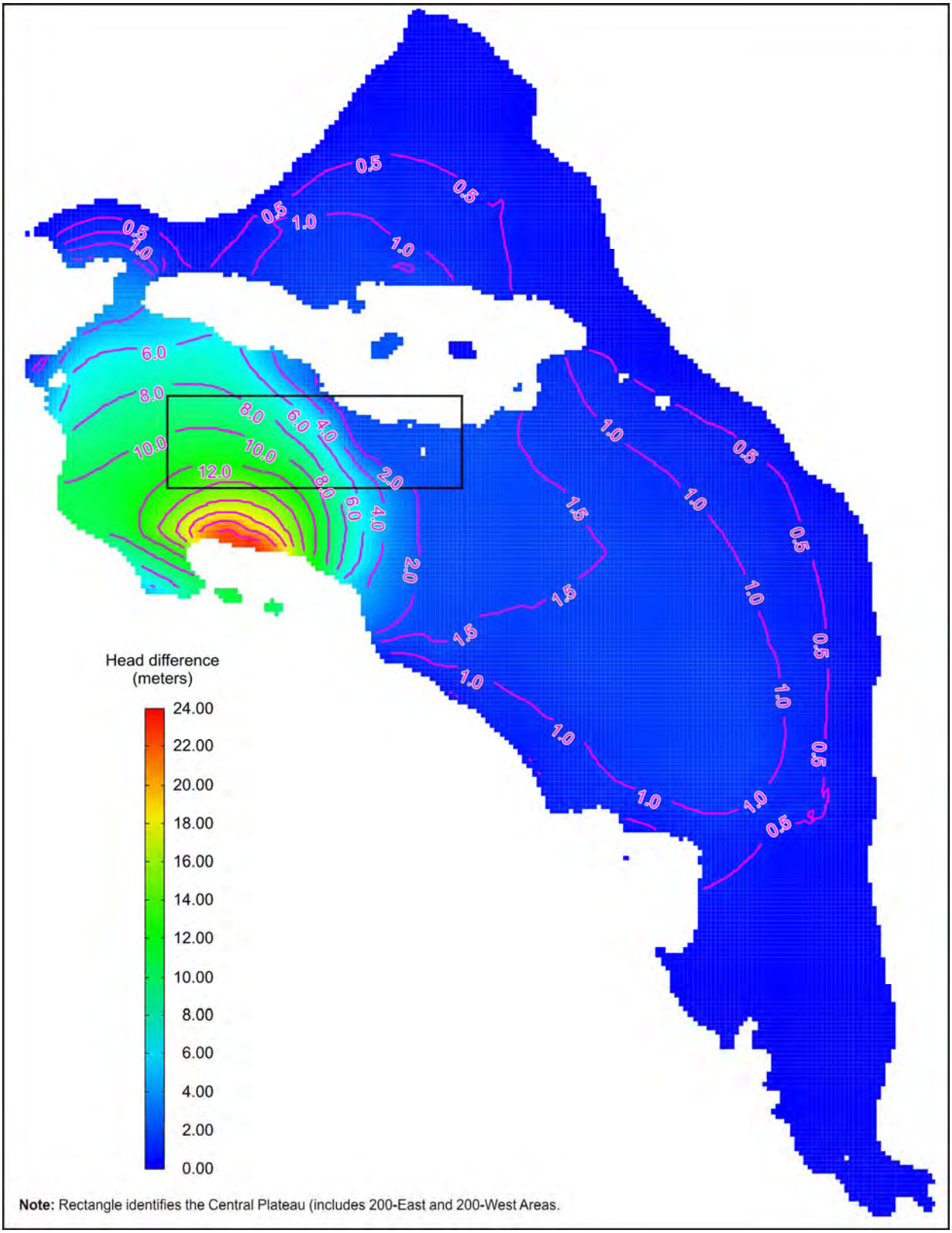

Figure V–4. Hydraulic Head Difference (meters) Between the Base Case Flow Model and Black Rock Reservoir Variant Flow Field Model (Hydraulic Head Difference from Model Layer 19, 105–110 meters above mean sea level)

Hanford Central Plateau Flow Field Particle Pathlines

The Central Plateau is an area located just south of Gable Gap. The Hanford Core Zone, which includes the 200-East and 200-West Areas, is part of the Central Plateau identified by the rectangle in Figure V–4. For particles released from the Central Plateau, there are significant differences in the direction of particle pathlines between the BRR variant flow field and the *TC & WM EIS* Base Case flow field. Directional flow field particle pathlines originating from a fixed Central Plateau regional box (64 square kilometers [24.7 square miles]) are illustrated in Figure V–5 (*TC & WM EIS* Base Case flow model) and Figure V–6 (BRR variant flow field model). In general, under BRR variant conditions, there is a western shift of the bifurcated groundwater divide separating flow to the north through Gable Gap and flow to the east across the flow field. Table V–3 summarizes the differences in the Central Plateau groundwater divide area between the *TC & WM EIS* Base Case flow field and the BRR variant flow field.

Table V–3. Central Plateau Particle Pathline Direction to the Columbia River

Flow Field Model	Area of Central Plateau with Particles Directed North Through Gable Mountain–Gable Butte Gap to the Columbia River		Area of Central Plateau with Particles Directed East to the Columbia River	
	Area (square kilometers)	Area (percent)	Area (square kilometers)	Area (percent)
TC & WM EIS Base Case flow field	24.8	39	39.2	61
BRR variant flow field	39.2	61	24.9	39

Note: To convert square kilometers to square miles, multiply by 0.3861.

Key: BRR=Black Rock Reservoir; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

In the *TC & WM EIS* Base Case flow model, the majority of particles released in the Central Plateau travel east towards the Columbia River. In general, particles released in the 200-East Area and the southern reaches of the 200-West Area are directed east. Approximately 61 percent (39.2 square kilometers [15.14 square miles]) of the particles released from the Central Plateau Area move to the east. For the remaining 39 percent (24.8 square kilometers [9.58 square miles]) of the Central Plateau, the majority of the 200-West Area, particles flow north through Gable Gap. Once through Gable Gap, the majority of particles move east towards the Columbia River, with a relatively small quantity of particles continuing in a northern direction also towards the Columbia River.

In contrast to the *TC & WM EIS* Base Case flow field, the BRR variant flow field shows significantly more particles in the Central Plateau directed northerly through Gable Gap. Approximately 39 percent (24.9 square kilometers [9.61 square miles]) of the particles released from the Central Plateau move east towards the Columbia River and approximately 61 percent (39.2 square kilometers [15.14 square miles]) move north through Gable Gap. Once through Gable Gap, particles in the BRR variant flow field model have a greater tendency to continue north towards the Columbia River rather than take the longer track turning east towards the Columbia River.

In general, the BRR variant flow field model has a greater amount of particles reaching the Columbia River in a shorter distance (directly north through Gable Gap). Unlike the *TC & WM EIS* Base Case flow field, the BRR variant flow field model shows a larger portion of particles released in the 200-East Area flowing to the north rather than across the model to the east. These additional redirected portions in the 200-East Area include the northern B, BX, and BY tank farms (and associated cribs and trenches [ditches]) and the proposed location of the River Protection Project Disposal Facility located in the northern part of the Central Plateau between the 200-East and 200-West Areas.

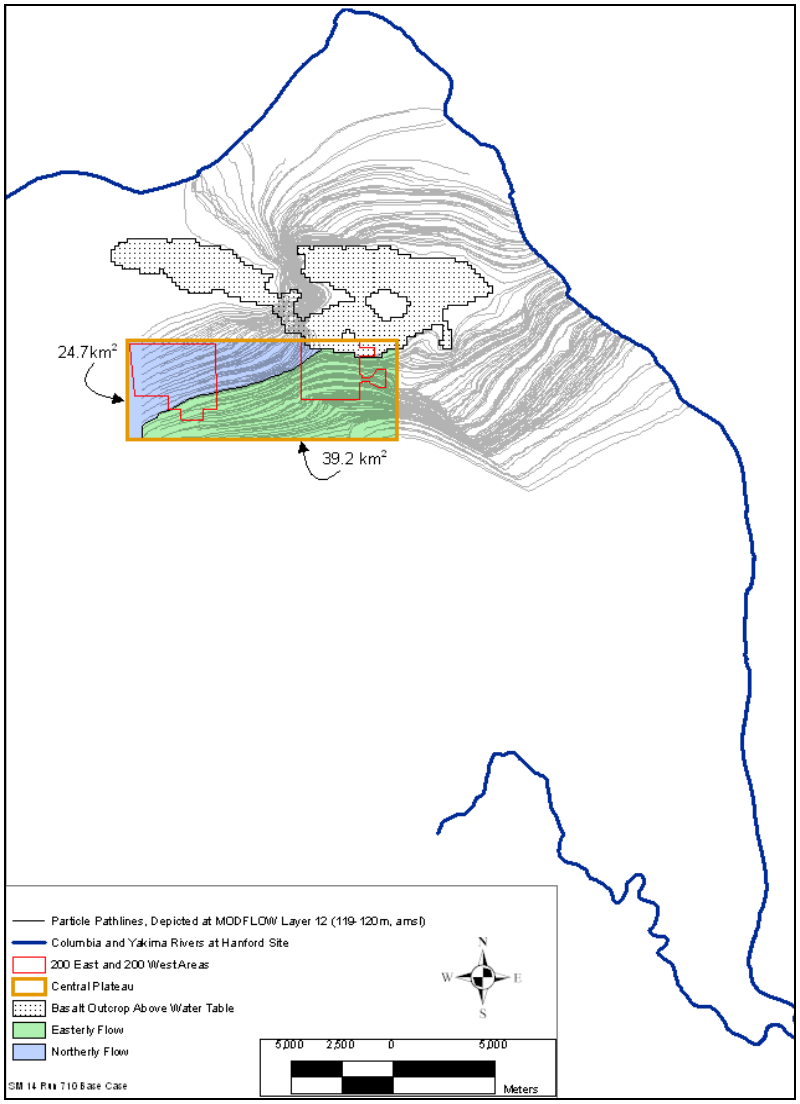

Figure V–5. Base Case Flow Field – Central Plateau Delineated Particle Pathlines

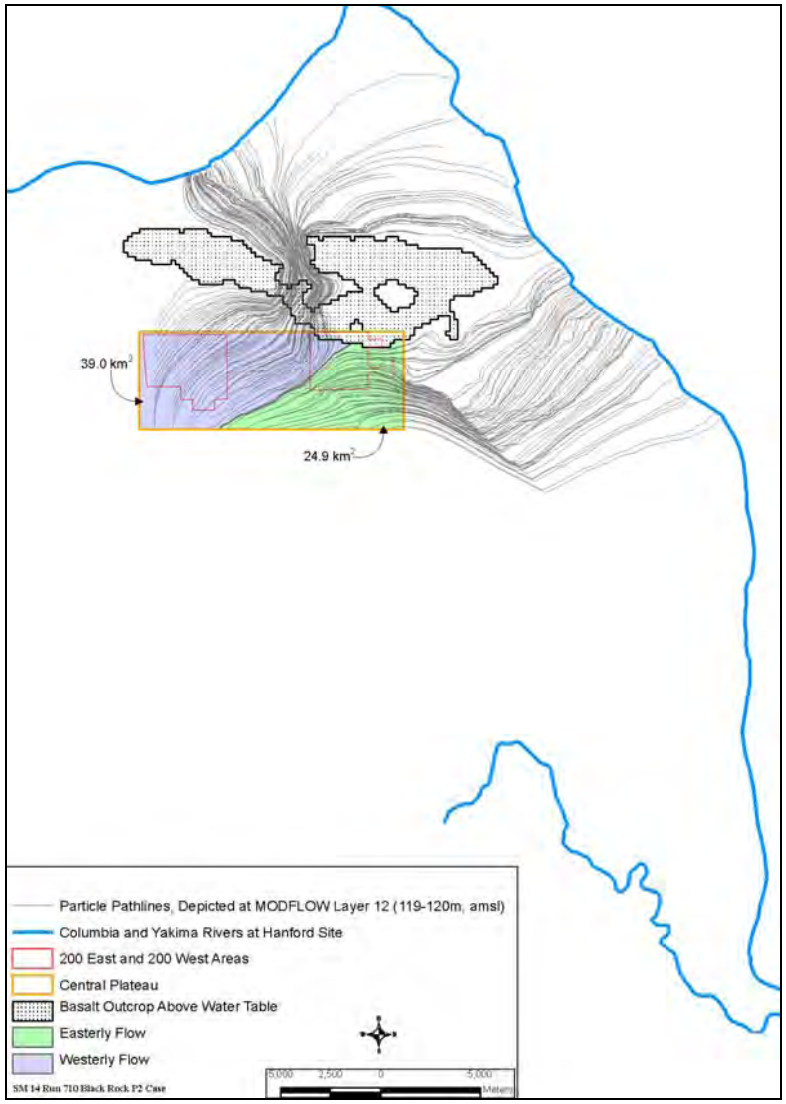

Figure V–6. Black Rock Reservoir Variant Flow Field – Central Plateau Delineated Particle Pathlines

Steady State Flow Field Vectors

Considering that the BRR variant flow field significantly increased recharge flux along the western model boundary and the subsequent increase in hydraulic gradient, groundwater flow velocities have increased relative to the *TC & WM EIS* Base Case flow field. Model cell X and Y steady state vector velocities are used to help quantify lateral flow direction of the BRR variant flow field relative to the *TC & WM EIS* Base Case flow field. Figures V–7 through V–20 are flow field vector illustrations generated by Groundwater Vistas comparing multiple layers within the BRR variant and *TC & WM EIS* Base Case flow fields. Groundwater Vistas utilizes end-of-time (long-term steady state) MODFLOW output files to internally calculate model cell X and Y flow vectors. Vector length is calculated using a logarithmic scale for purposes of display clarity. Standardized color ramps and logarithmic scales are used to uniformly distinguish and equally compare groundwater vectors between the two flow fields. Contour lines are used within the BRR variant flow field vector illustrations to indicate a relative ratio of velocity compared to the *TC & WM EIS* Base Case flow field. Model layers range in thickness but are identical in both models. Depending on model layer elevation, portions of Hanford may not have groundwater available for vector analysis (e.g., the model layer is above the specified water table elevation). Appendix L, Section L.4, further discusses groundwater flow field model grid design, cell properties, and boundary conditions and includes a sample cross section illustrating the depth of each model layer.

Model Layers 3 (135 to 140 meters [442.9 to 459.3 feet] amsl), 9 (122 to 123 meters [400.3 to 403.6 feet] amsl), 11 (120 to 121 meters [393.7 to 397 feet] amsl), 14 (117 to 118 meters [383.9 to 387.2 feet] amsl), 15 (116 to 117 meters [380.6 to 383.9 feet] amsl), 16 (115 to 116 meters [377.3 to 380.6 feet] amsl), and 20 (100 to 105 meters [328.1 to 344.5 feet] amsl) were compared between the two models.

The highest groundwater elevations that are easily comparable are observed in Layer 3 (135 to 140 meters [442.9 to 459.3 feet] amsl) of each model. In Layer 3, groundwater flow is only represented in the western reaches of the model domain near Cold Creek. The area of saturation within the model domain at this elevation is greater in the BRR model. BRR velocities within the Central Plateau are slightly higher, and there is a tendency for vectors to indicate direction to the north rather than to the east (as displayed in the *TC & WM EIS* Base Case model) beneath the Central Plateau. South of the Central Plateau, unlike the *TC & WM EIS* Base Case model, velocities are higher in the BRR model due to saturation of highly conductive Hanford formations due to the rising water table.

In Layer 9 (122 to 123 meters [400.3 to 403.6 feet] amsl) of both models, groundwater covers the entire Central Plateau. In general, velocities (0.1 to 1.5 meters [0.33 to 4.9 feet]/day) found in the area are similar beneath the Central Plateau with the exception of velocities closest to and within Gable Gap, where there is significantly greater velocity (greater than 10 meters [32.8 feet]/day) directed to the north within the BRR variant flow field model. In general, a larger area of the Hanford formation within the BRR model is covered with groundwater flow at this model layer elevation. Within the BRR variant flow field model, significantly more groundwater is flowing at higher velocities between the 200-East Area and the 400 Area, where the highly conductive Hanford formation is encountered.

Similar to Layer 9, Layer 11 (120 to 121 meters [393.7 to 397 feet] amsl) of both models indicates vectors beneath the western regions of the Central Plateau are similar, except the BRR model vector has a general tendency more to the north, while the *TC & WM EIS* Base Case model vector has a general tendency to the east. Order of magnitude velocity differences between the two models are noted in and north of Gable Gap. Unlike the *TC & WM EIS* Base Case model, the BRR model indicates a relatively high velocity channel of groundwater tracking through Gable Gap in a northwestern direction towards the Columbia River. This northwestern channel is further supplied by high velocity flow emitting from another shallow basalt gap west of Gable Gap. No significant differences in flow vectors between the two models are noted in the central and southern regions of Hanford.

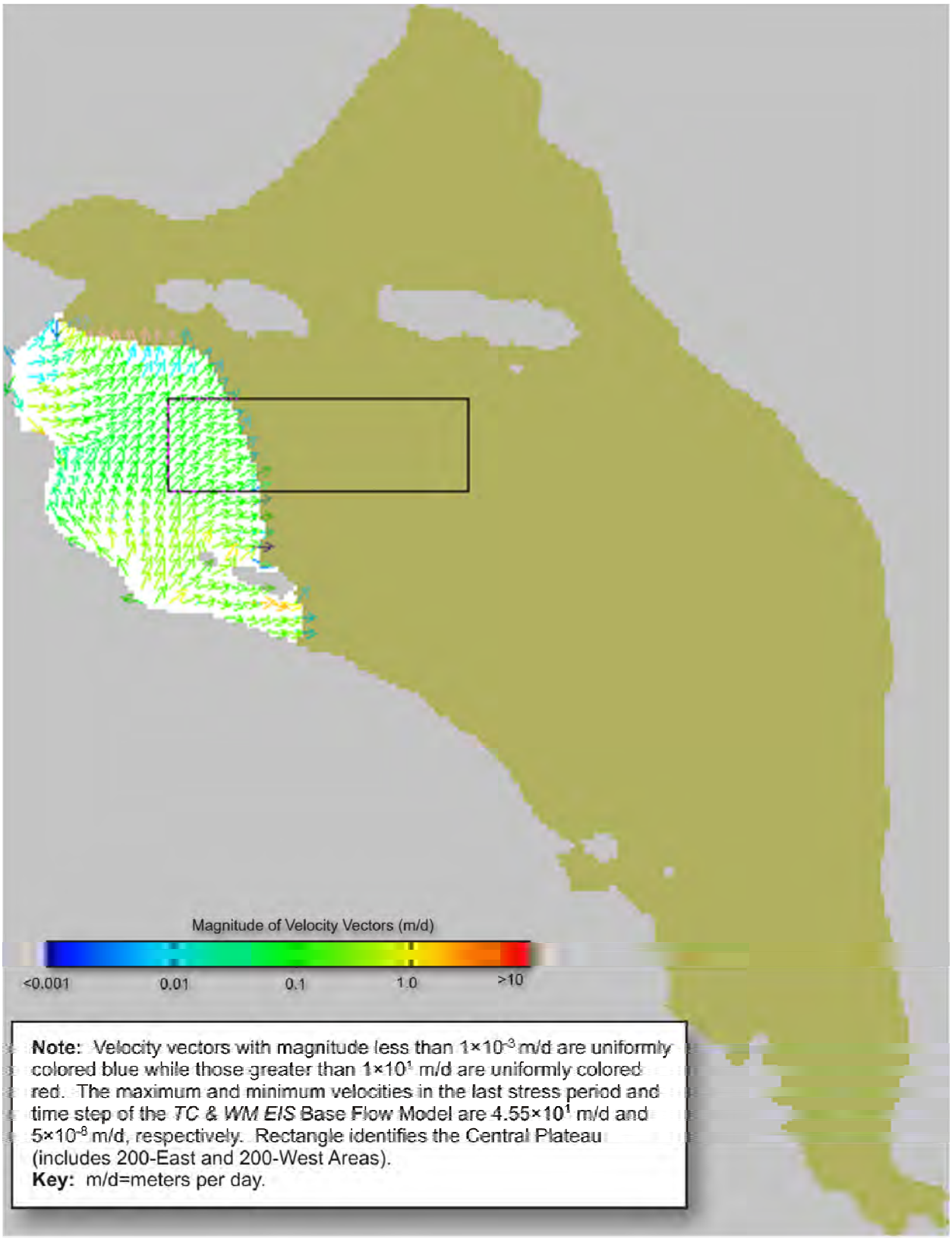

Figure V–7. Base Case Flow Model, Layer 3 (135–140 meters above mean sea level) Vector Velocities

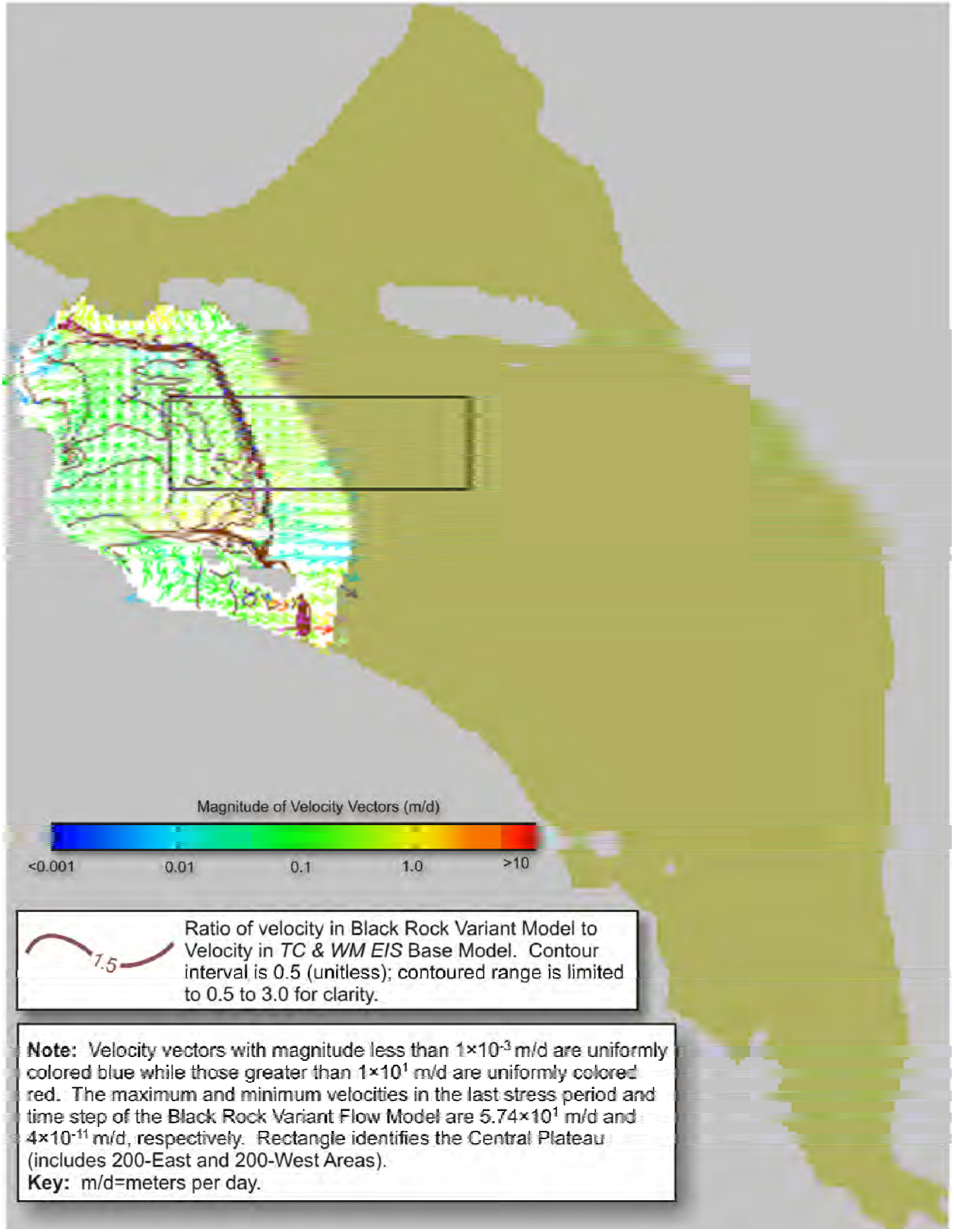

Figure V–8. Black Rock Reservoir Variant Flow Field Model, Layer 3 (135–140 meters above mean sea level) Vector Velocities

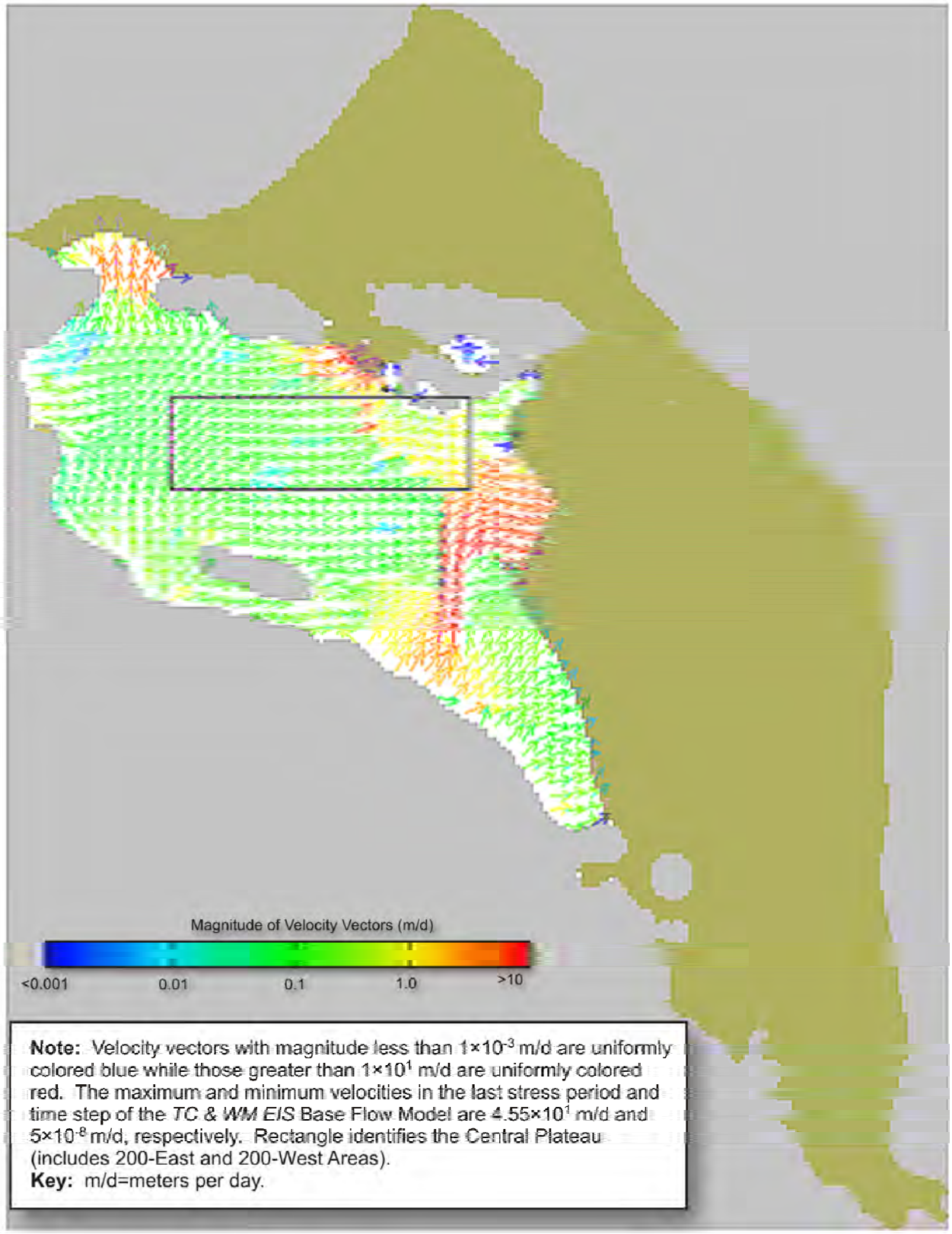

Figure V–9. Base Case Flow Model, Layer 9 (122–123 meters above mean sea level) Vector Velocities

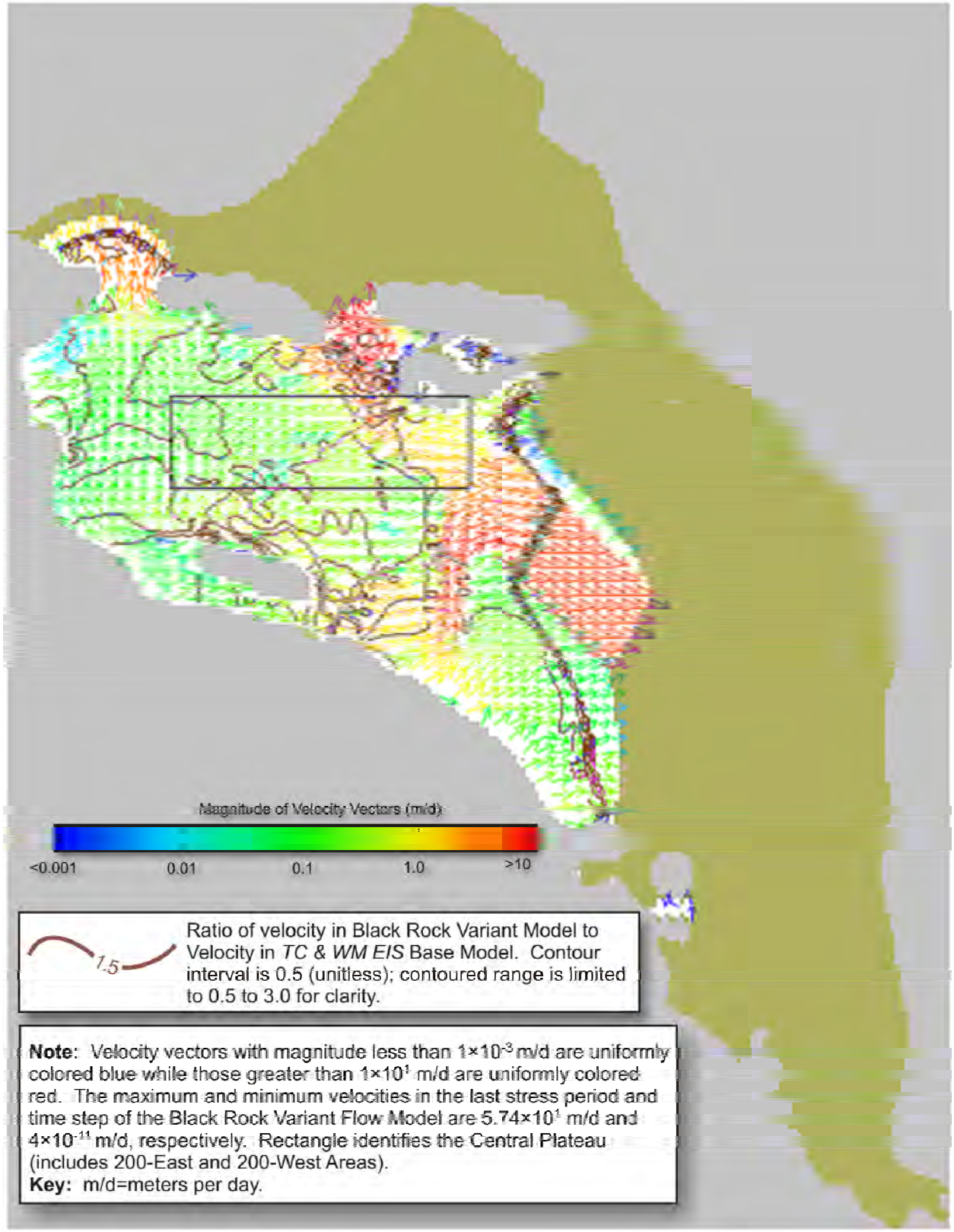

Figure V–10. Black Rock Reservoir Variant Flow Field Model, Layer 9 (122–123 meters above mean sea level) Vector Velocities

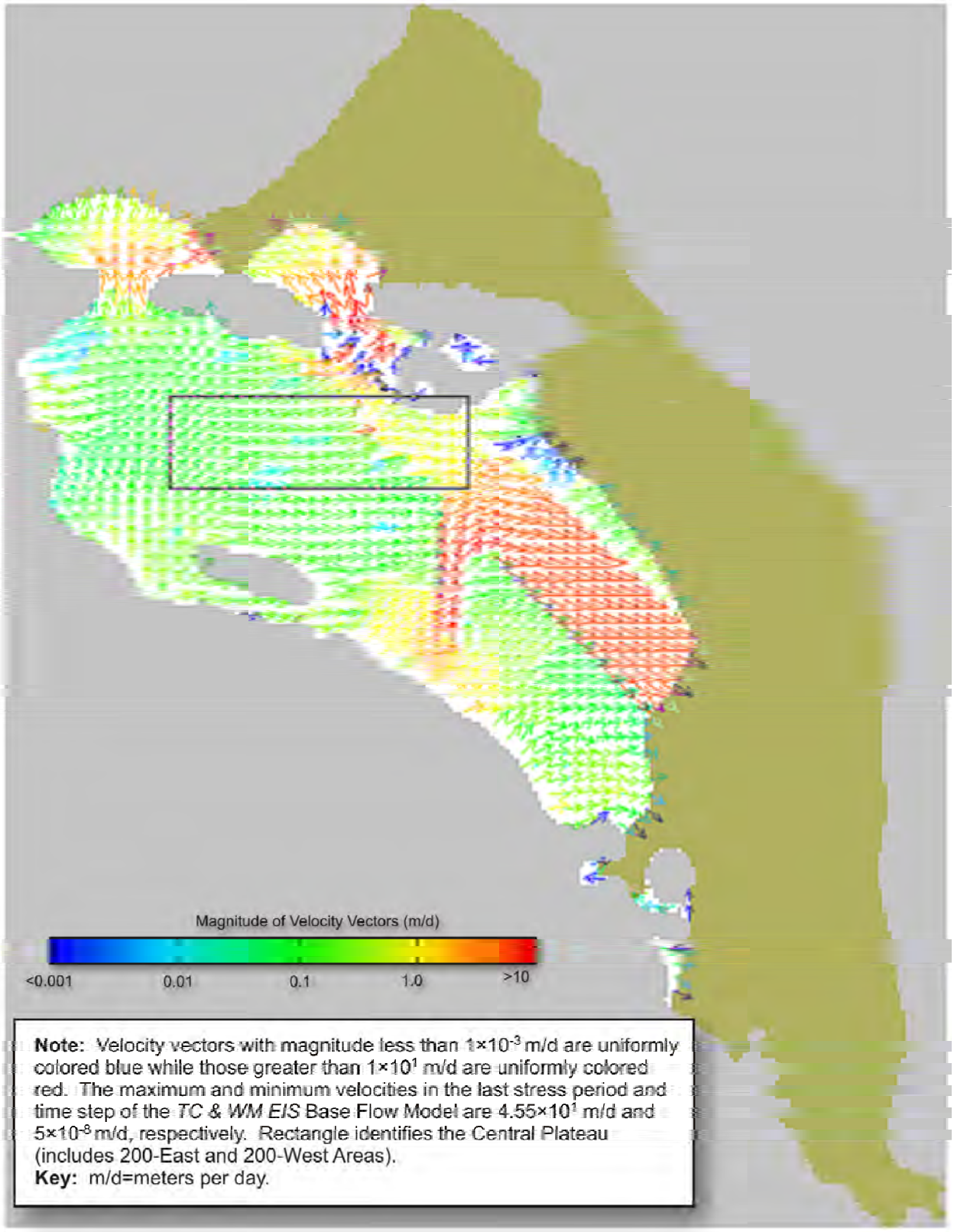

Figure V–11. Base Case Flow Model, Layer 11 (120–121 meters above mean sea level) Vector Velocities

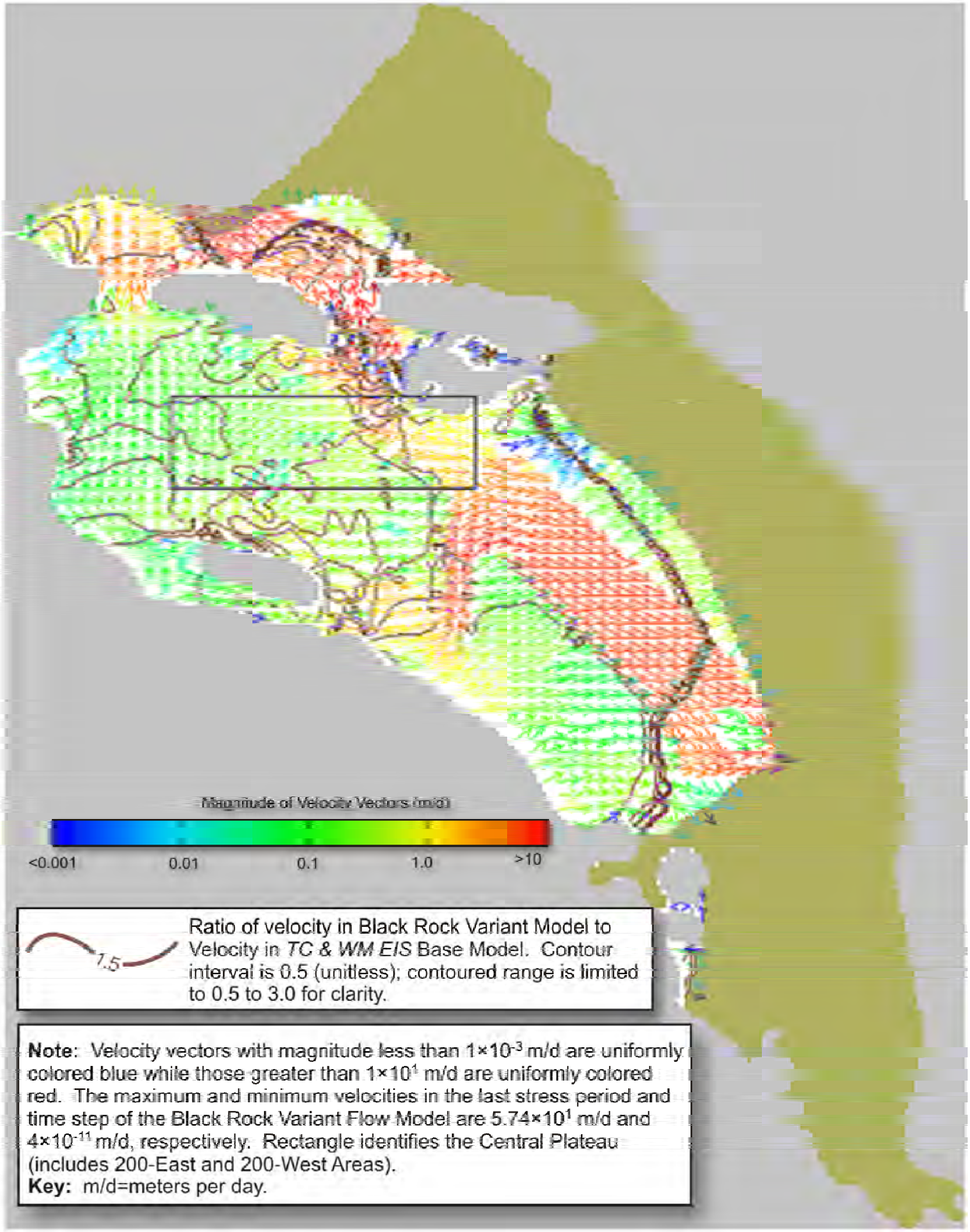

Figure V–12. Black Rock Reservoir Variant Flow Field Model, Layer 11 (120–121 meters above mean sea level) Vector Velocities

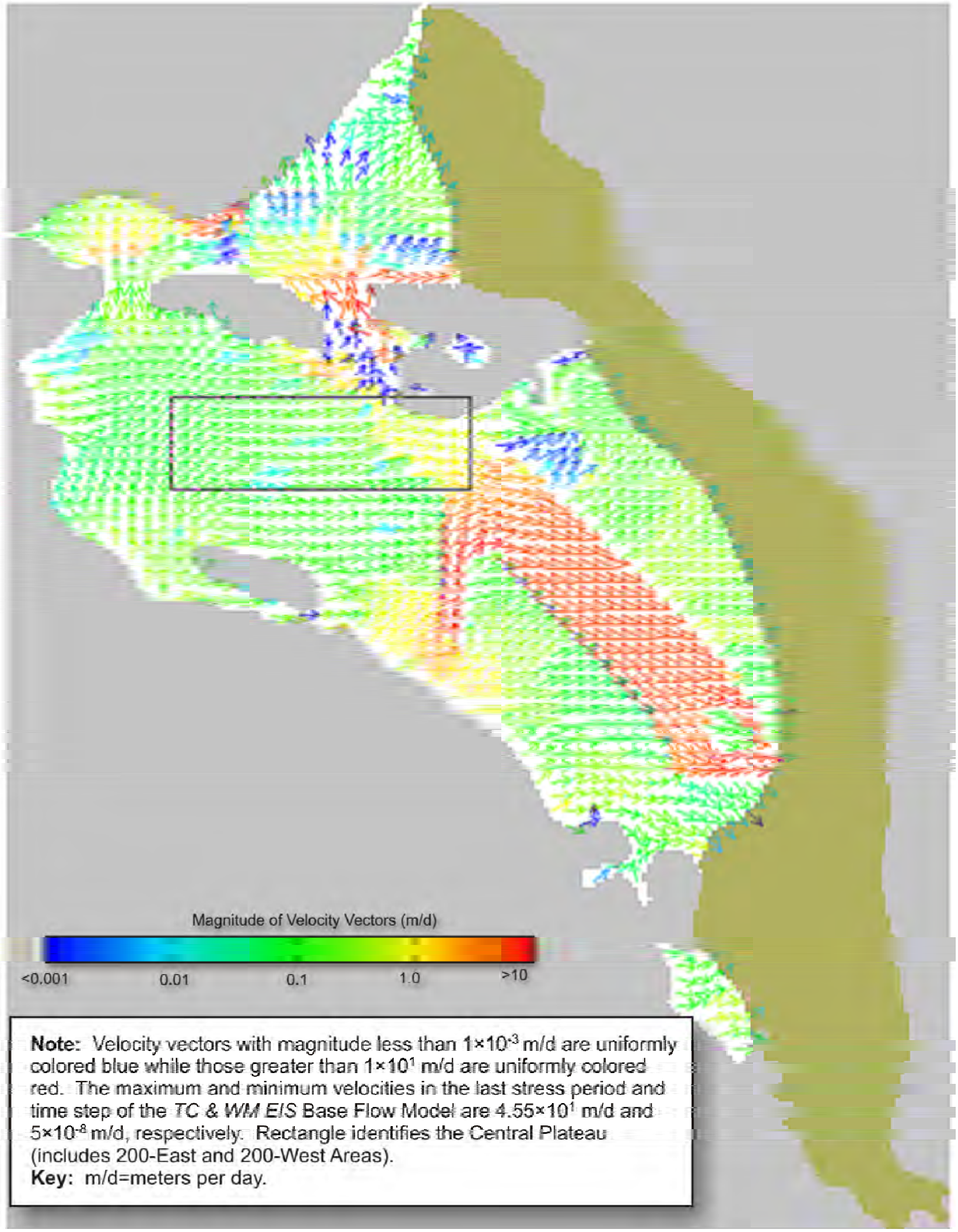

Figure V–13. Base Case Flow Model, Layer 14 (117–118 meters above mean sea level) Vector Velocities

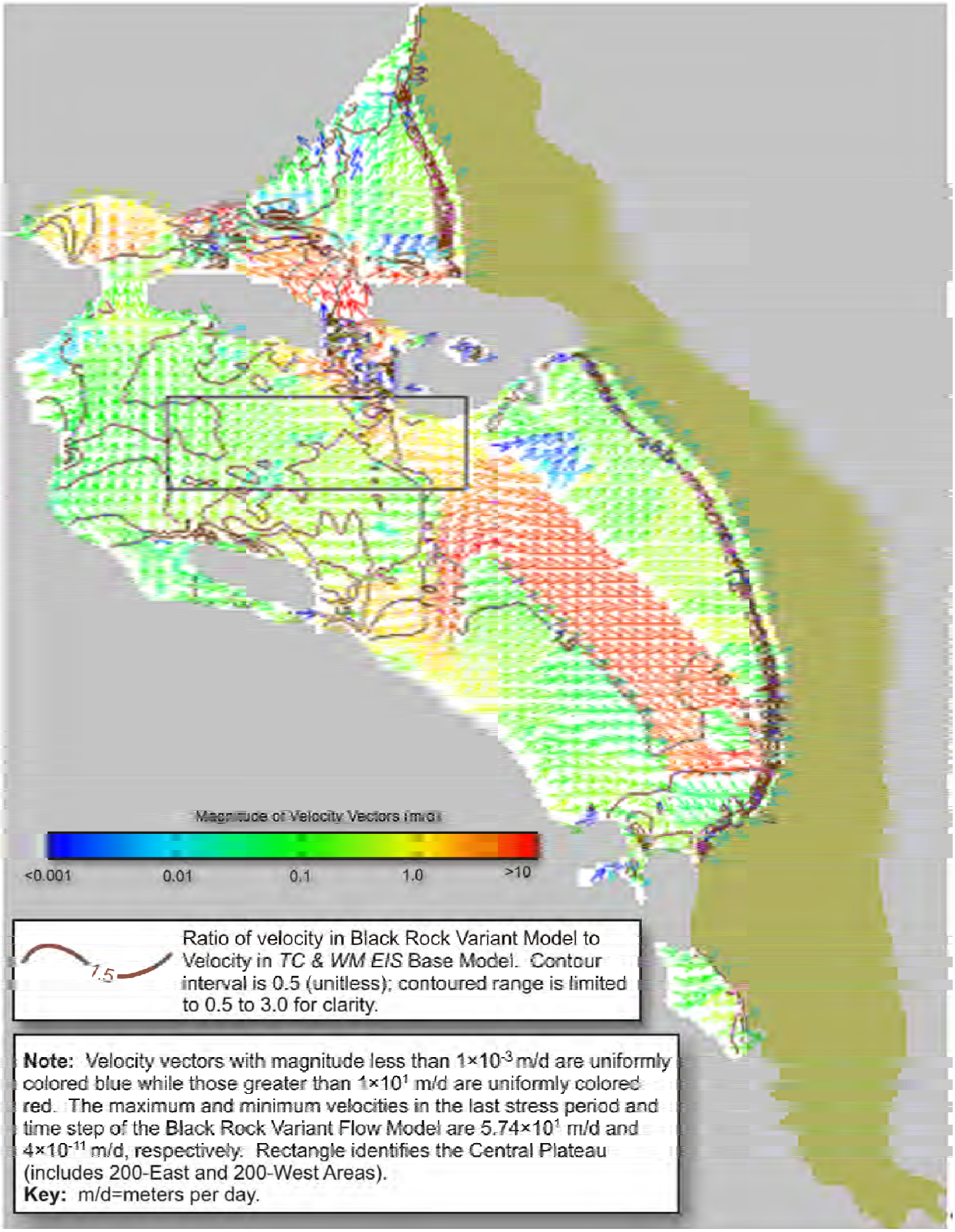

Figure V–14. Black Rock Reservoir Variant Flow Field Model, Layer 14 (117–118 meters above mean sea level) Vector Velocities

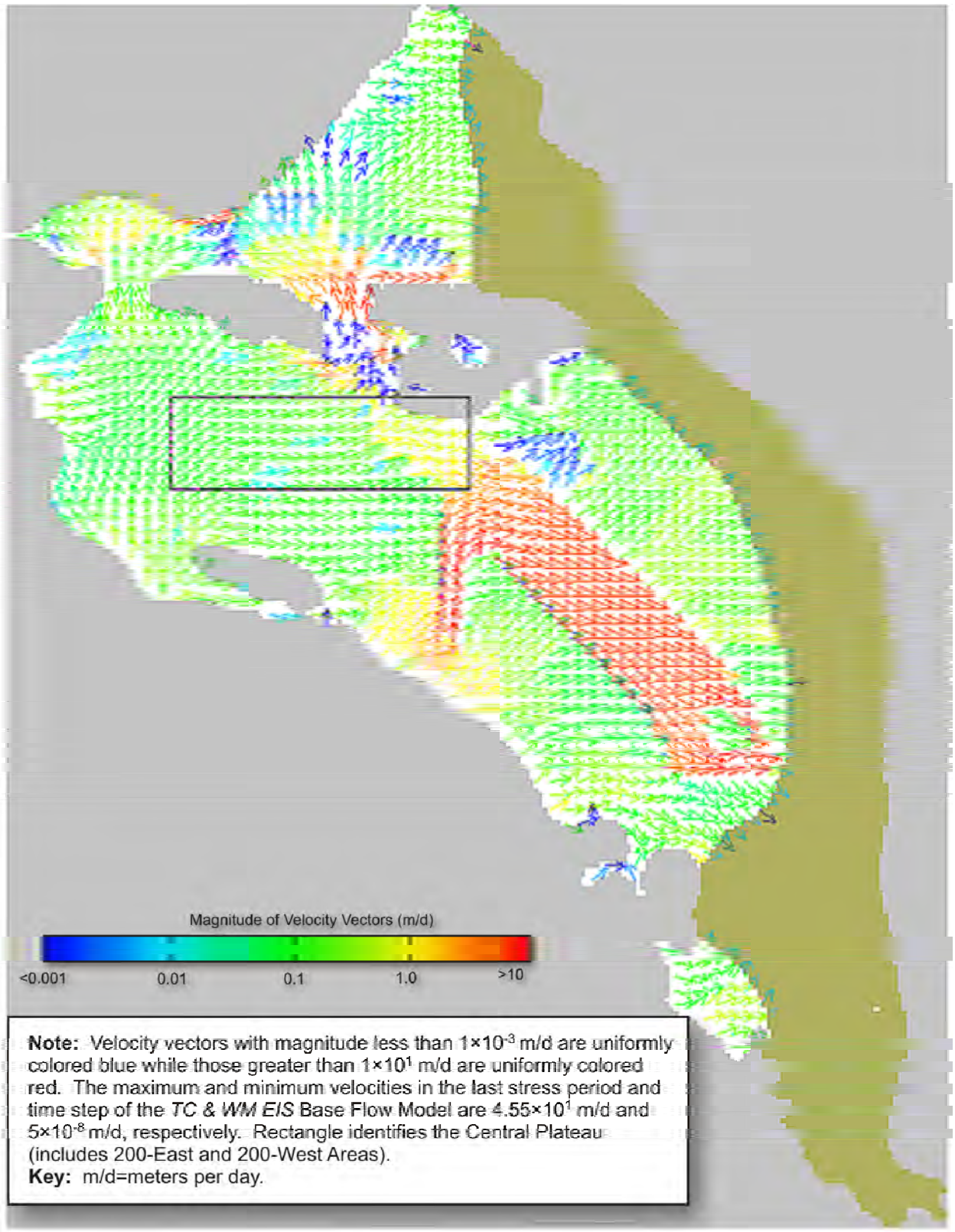

Figure V–15. Base Case Flow Model, Layer 15 (116–117 meters above mean sea level) Vector Velocities

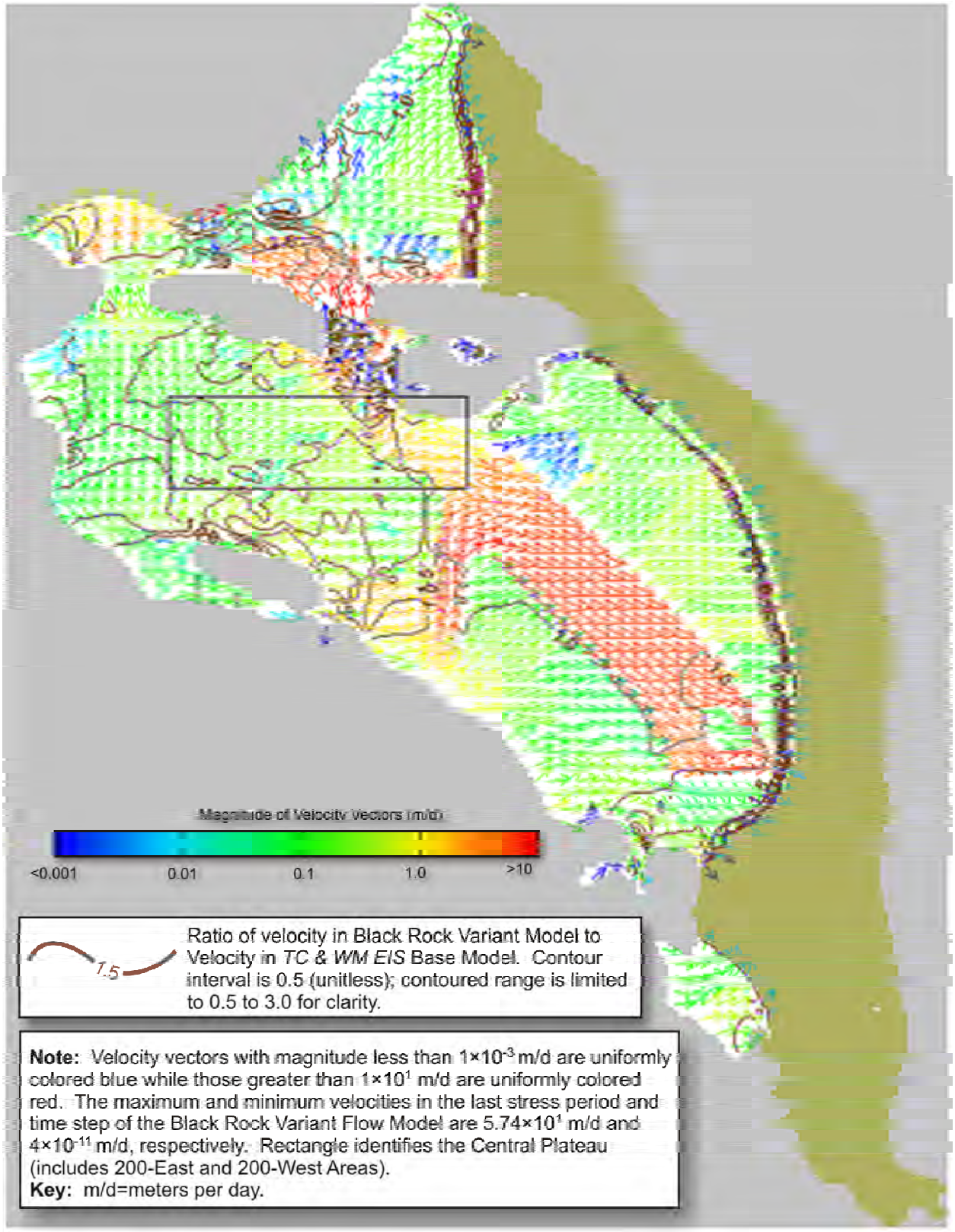

Figure V–16. Black Rock Reservoir Variant Flow Field Model, Layer 15 (116–117 meters above mean sea level) Vector Velocities

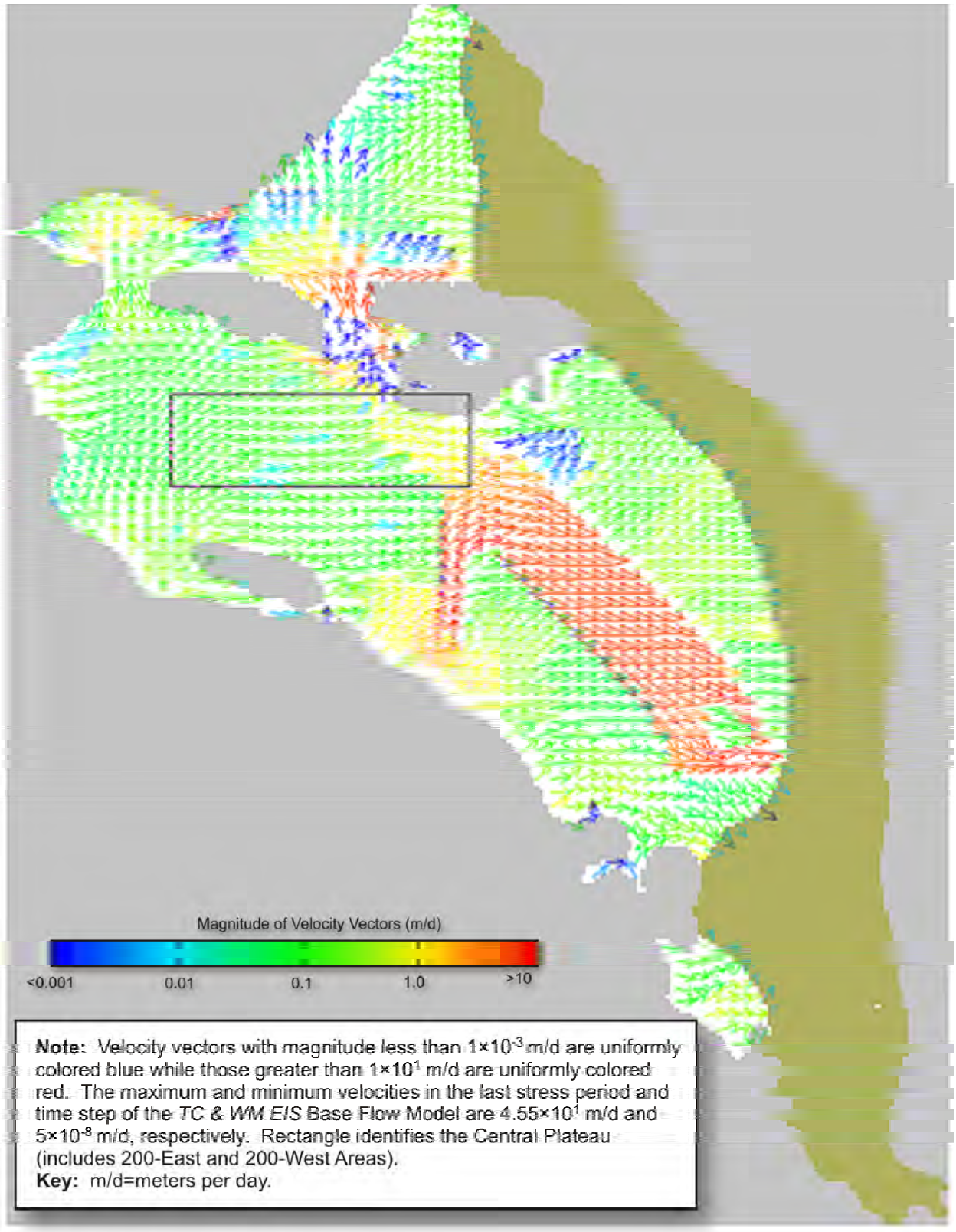

Figure V–17. Base Case Flow Model, Layer 16 (115–116 meters above mean sea level) Vector Velocities

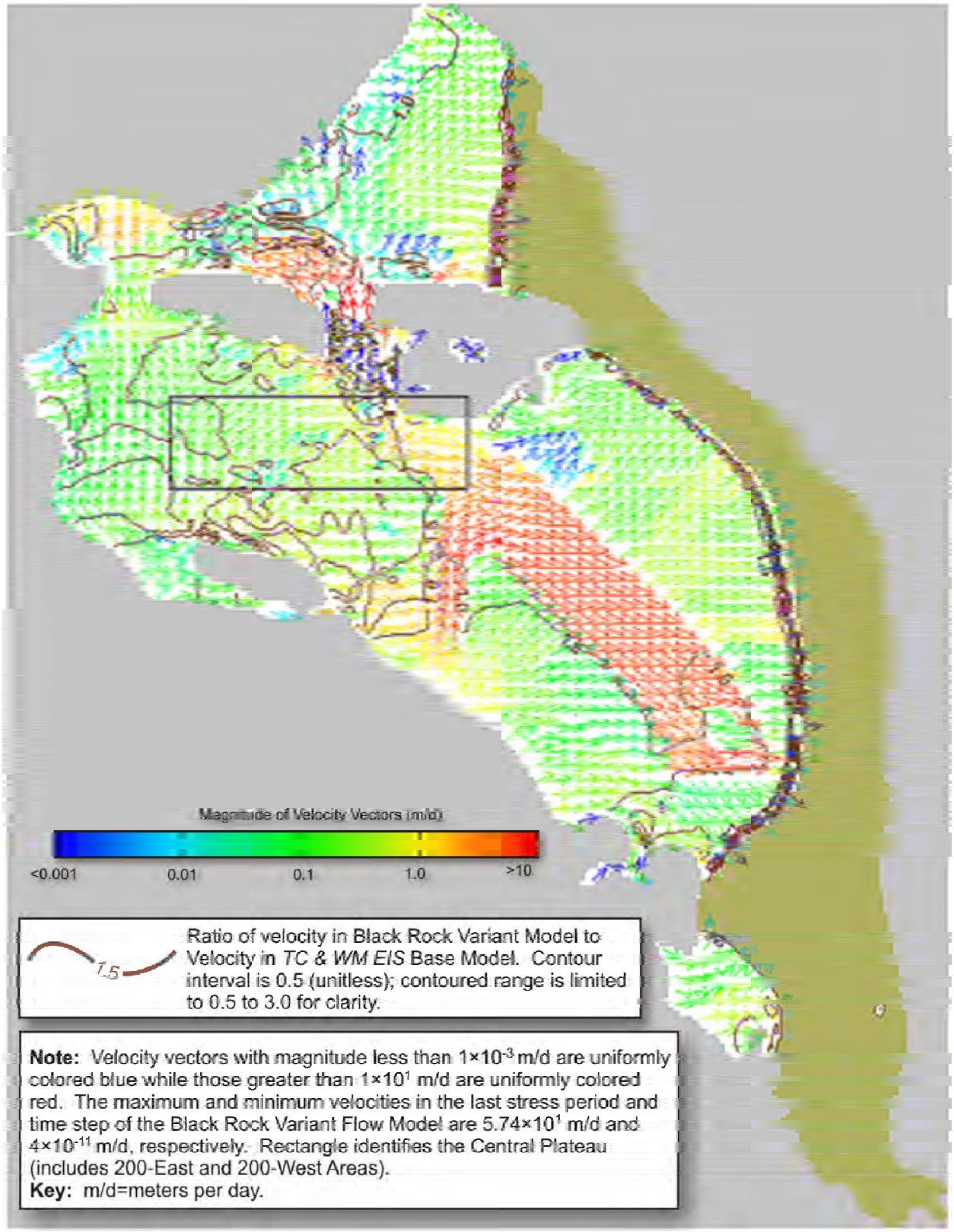

Figure V–18. Black Rock Reservoir Variant Flow Field Model, Layer 16 (115–116 meters above mean sea level) Vector Velocities

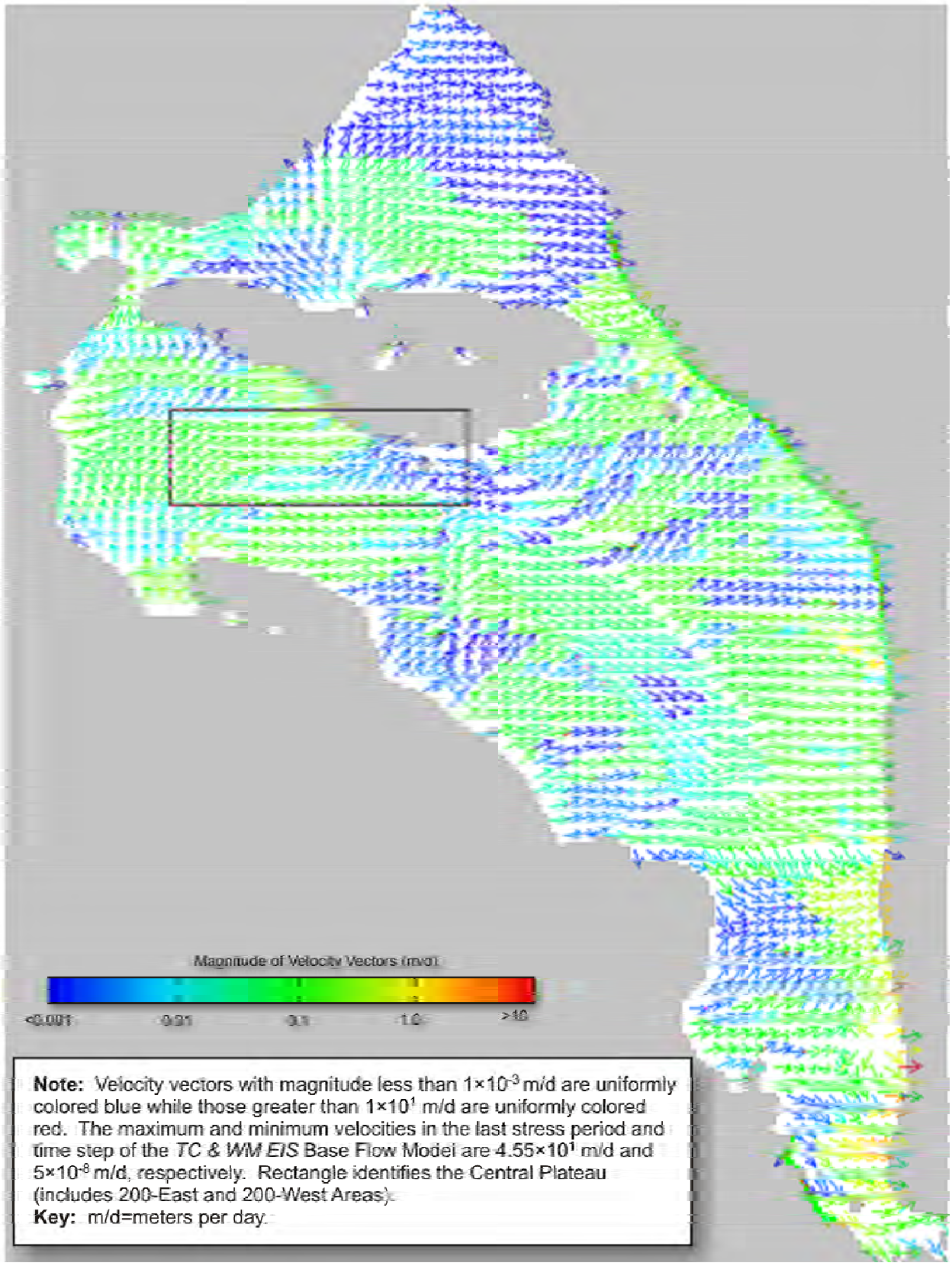

Figure V–19. Base Case Flow Model, Layer 20 (100–105 meters above mean sea level) Vector Velocities

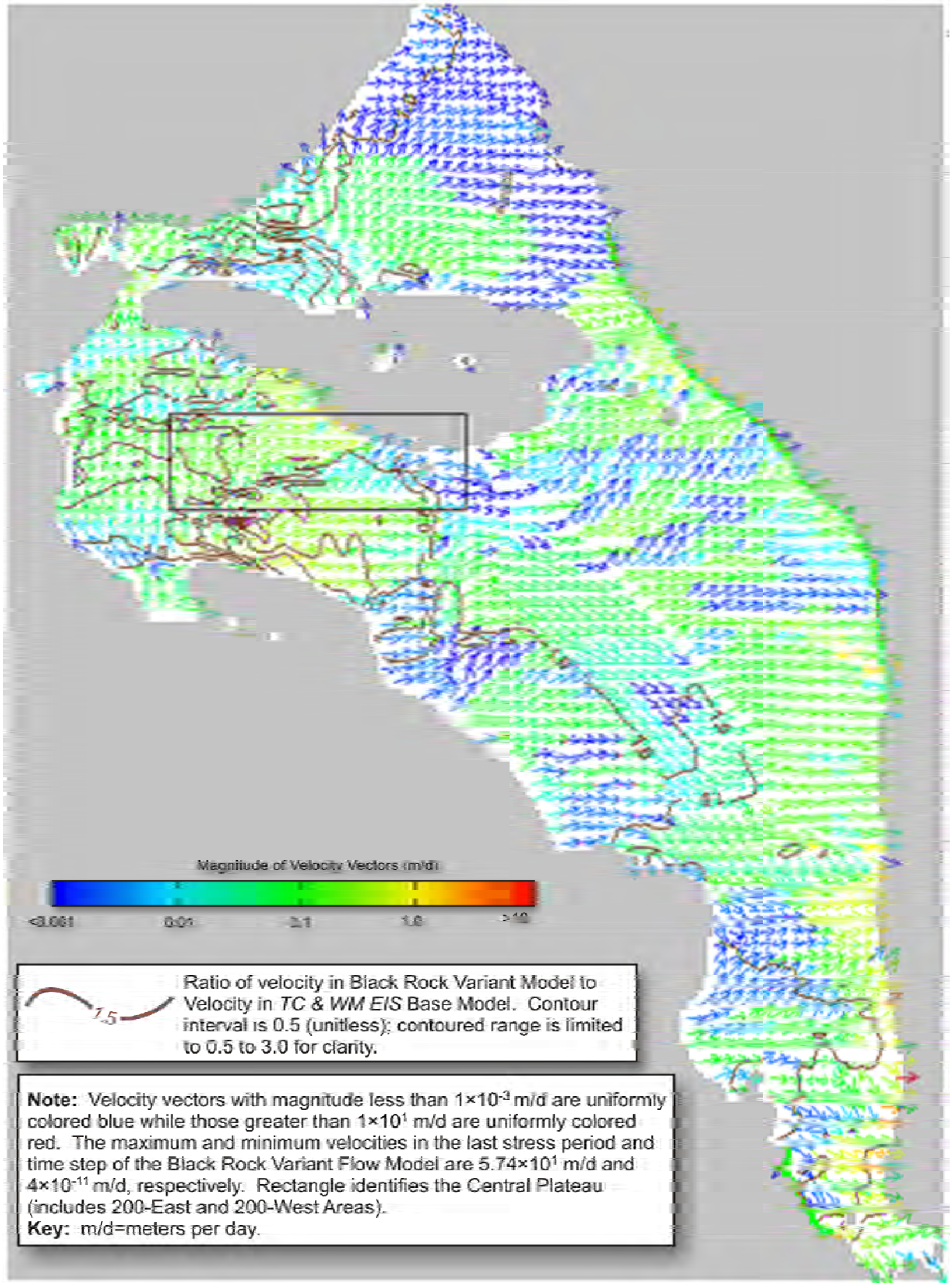

Figure V–20. Black Rock Reservoir Variant Flow Field Model, Layer 20 (100–105 meters above mean sea level) Vector Velocities

In Layers 14 (117 to 118 meters [383.9 to 387.2 feet] amsl), 15 (116 to 117 meters [380.6 to 383.9 feet] amsl), 16 (115 to 116 meters [377.3 to 380.6 feet] amsl), and 20 (100 to 105 meters [328.1 to 344.5 feet] amsl), only minor differences in groundwater flow vectors are noted between the models, with the exception of the tendency of flow through the Central Plateau to the north-northeast and into Gable Gap depicted in the BRR model. In general, the *TC & WM EIS* Base Case model depicts the area in the Central Plateau moving to the east at relatively low velocities. In all layers, unlike the *TC & WM EIS* Base Case model, the BRR model depicts a high velocity of flow channel through Gable Gap and in a northwesterly direction toward the Columbia River.

V.4.2 Changes to Vadose Zone Depth and Transport Travel Times

The inundation depth results from the rising water table associated with the BRR variant model are summarized in Table V–4. A calculation of the vadose zone decrease in depth (percentage) under BRR variant conditions compared to *TC & WM EIS* Base Case vadose zone depths is also included in Table V–4.

Table V–4. Inundation Depths Resulting from the Black Rock Reservoir Variant Flow Field Model – All Hanford Site STOMP Model Locations

Location	*TC & WM EIS* Base Case Flow Field Head (meters)	BRR Variant Flow Field Head (meters)	*TC & WM EIS* Base Case Vadose Zone Length (meters)	BRR Variant Inundation Depth (meters)	BRR Variant Decrease in Vadose Zone (percent)
T Barrier[a]	135.6	145.3	77	9.7	12.6
U Barrier[a]	136.6	148.4	68	11.8	17.4
S Barrier[a]	137.2	150.6	72	13.5	18.8
B Barrier[a]	122.8	124.5	81	1.7	2.1
A Barrier[a]	122.7	124.5	83	1.8	2.2
IDFW Barrier[a]	137.5	146.9	74	9.4	12.7
IDFE Barrier[a]	122.8	124.5	100	1.7	1.7
RPPDF Barrier[a]	128.5	134.8	90	6.3	7.0
FFTF Barrier[a]	119.3	120.7	44	1.4	3.2
T31 & T34 Barrier[a]	136.8	146.3	74	9.5	12.8
116-B-4	120.0	120.2	20	0.2	<1
116-B-6B	120.0	120.3	24	0.3	1.3
116-K-2d	118.6	118.8	12	0.2	1.7
116-K-2e	118.6	118.8	12	0.2	1.7
116-KE-4	118.9	119.3	18	0.4	2.2
116-KW-3	118.7	119	24	0.3	1.3
116-KE-1	119.0	119.5	24	0.5	2.1
116-KW-1	119.0	119.4	24	0.4	1.7
116-KE-2	119.0	119.4	24	0.4	1.7
120-KE-1	119.3	120.0	32	0.7	2.2
116-N-1a	118.2	118.2	24	0.0	0
116-N-1b	118.2	118.2	24	0.0	0
316-5	105.9	105.9	16	0.0	0
116-N-1c	118.2	118.2	24	0.0	0
116-N-1d	118.2	118.2	24	0.0	0
116-N-1e	118.2	118.2	24	0.0	0
116-N-1f	118.2	118.2	24	0.0	0
116-N-3a	118.1	118.2	24	0.1	<1

Table V–4. Inundation Depths Resulting from the Black Rock Reservoir Variant Flow Field Model – All Hanford Site STOMP Model Locations *(continued)*

Location	*TC & WM EIS* Base Case Flow Field Head (meters)	BRR Variant Flow Field Head (meters)	*TC & WM EIS* Base Case Vadose Zone Length (meters)	BRR Variant Inundation Depth (meters)	BRR Variant Decrease in Vadose Zone (percent)
116-N-3b	118.1	118.2	24	0.1	<1
116-N-3c	118.1	118.2	24	0.1	<1
116-N-3d	118.1	118.2	24	0.1	<1
116-N-3e	118.1	118.2	24	0.1	<1
116-N-3f	118.1	118.2	24	0.1	<1
316-1	105.7	105.8	12	0.1	<1
UPR-100-N-7	118.3	118.3	24	0.0	0
UPR-100-N-3	118.3	118.3	24	0.0	0
216-B-14	123.2	125.6	106	2.4	2.3
216-B-15	123.2	125.6	106	2.4	2.3
216-B-16	123.5	126.1	106	2.6	2.5
216-B-17	123.7	126.6	106	2.9	2.7
216-B-18	123.7	126.6	106	2.9	2.7
216-B-19	123.7	126.6	106	2.9	2.7
216-B-20	123.7	126.6	106	2.9	2.7
216-B-21	123.9	127.1	106	3.2	3.0
316-2	105.7	105.7	16	0.0	0
216-B-22	123.9	127.1	106	3.2	3.0
216-B-23	123.9	127.1	106	3.2	3.0
216-B-24	123.9	127.1	106	3.2	3.0
216-B-25	124.1	127.6	106	3.5	3.3
216-B-26	124.1	127.6	106	3.5	3.3
216-B-27	124.1	127.6	106	3.5	3.3
216-B-28	124.1	127.6	106	3.5	3.3
216-B-29	123.8	126.9	106	3.1	2.9
216-B-30	123.8	126.9	106	3.1	2.9
216-B-31	124.1	127.5	106	3.4	3.2
316-4	114.5	115.4	22	0.9	4.1
216-B-32	124.1	127.5	106	3.4	3.2
216-B-33	124.1	127.5	106	3.4	3.2
216-B-34	124.1	127.5	106	3.4	3.2
216-B-52	123.9	127.1	106	3.2	3.0
216-B-53A	123.6	126.4	106	2.8	2.6
216-B-53B	123.6	126.4	106	2.8	2.6
216-B-58	123.9	127.1	106	3.2	3.0
600 NRDWL[b]	122.0	123.6	42	1.6	3.8
600-148[b]	130.0	139.9	90	9.9	11.0
USEcol[b]	125.6	130.8	104	5.2	5.0
618-9	107.3	107.4	16	0.1	<1
200-E-103	122.7	124.5	100	1.8	1.8
200-E-107	122.7	124.5	100	1.8	1.8
200-E-136	122.8	124.5	100	1.7	1.7
200-E-54	122.7	124.5	100	1.8	1.8
200-E-61	122.7	124.5	100	1.8	1.8

Table V–4. Inundation Depths Resulting from the Black Rock Reservoir Variant Flow Field Model – All Hanford Site STOMP Model Locations *(continued)*

Location	*TC & WM EIS* Base Case Flow Field Head (meters)	BRR Variant Flow Field Head (meters)	*TC & WM EIS* Base Case Vadose Zone Length (meters)	BRR Variant Inundation Depth (meters)	BRR Variant Decrease in Vadose Zone (percent)
200-E-78	122.7	124.5	100	1.8	1.8
200-E-85	122.8	124.5	100	1.7	1.7
201-C	122.8	124.5	90	1.7	1.9
216-A-1	122.7	124.5	86	1.8	2.1
216-A-10	122.8	124.5	98	1.7	1.7
618-11	117.7	118.9	20	1.2	6.0
216-A-13	122.8	124.5	100	1.7	1.7
216-A-15	122.7	124.5	100	1.8	1.8
216-A-16	122.7	124.5	90	1.8	2.0
216-A-17	122.7	124.5	90	1.8	2.0
216-A-18	122.7	124.5	86	1.8	2.1
216-A-19	122.7	124.4	86	1.7	2.0
216-A-2	122.7	124.5	100	1.8	1.8
216-A-20	122.7	124.4	86	1.7	2.0
216-A-21	122.7	124.5	98	1.8	1.8
216-A-22	122.7	124.5	100	1.8	1.8
316-3	105.8	105.8	18	0.0	0
216-A-24	122.7	124.4	64	1.7	2.7
216-A-26	122.7	124.5	100	1.8	1.8
216-A-26A	122.7	124.5	100	1.8	1.8
216-A-27	122.7	124.5	98	1.8	1.8
216-A-28	122.7	124.5	100	1.8	1.8
216-A-3	122.7	124.5	100	1.8	1.8
216-A-30	122.7	124.4	86	1.7	2.0
216-A-31	122.7	124.5	98	1.8	1.8
216-A-32	122.7	124.5	100	1.8	1.8
216-A-35	122.8	124.5	100	1.7	1.7
UPR-300-1	106.0	106.1	14	0.1	<1
216-A-36-A	122.7	124.5	98	1.8	1.8
216-A-36-B	122.7	124.5	98	1.8	1.8
216-A-37-1	122.7	124.4	86	1.7	2.0
216-A-37-2	122.7	124.4	86	1.7	2.0
216-A-39	122.7	124.5	82	1.8	2.2
216-A-4	122.7	124.5	100	1.8	1.8
216-A-40	122.7	124.5	90	1.8	2.0
216-A-41	122.7	124.5	90	1.8	2.0
216-A-45	122.8	124.5	100	1.7	1.7
216-A-5	122.7	124.5	98	1.8	1.8
309-WS-1	106.1	106.1	20	0.0	0
216-A-6	122.7	124.5	92	1.8	2.0
216-A-7	122.7	124.5	86	1.8	2.1
216-A-8	122.7	124.4	86	1.7	2.0
216-A-9	122.7	124.5	90	1.8	2.0
216-C-1	122.8	124.5	90	1.7	1.9

Table V–4. Inundation Depths Resulting from the Black Rock Reservoir Variant Flow Field Model – All Hanford Site STOMP Model Locations *(continued)*

Location	*TC & WM EIS* Base Case Flow Field Head (meters)	BRR Variant Flow Field Head (meters)	*TC & WM EIS* Base Case Vadose Zone Length (meters)	BRR Variant Inundation Depth (meters)	BRR Variant Decrease in Vadose Zone (percent)
216-C-10	122.8	124.5	88	1.7	1.9
216-C-2	122.8	124.5	90	1.7	1.9
216-C-3	122.8	124.5	90	1.7	1.9
216-C-4	122.8	124.5	90	1.7	1.9
216-C-5	122.8	124.5	90	1.7	1.9
116-C-2A	120.0	120.4	36	0.4	1.1
300-264	106.3	106.3	14	0.0	0
216-C-6	122.8	124.5	90	1.7	1.9
216-C-9	122.8	124.5	88	1.7	1.9
218-C-9	122.8	124.5	88	1.7	1.9
218-E-1	122.8	124.5	100	1.7	1.7
218-E-12A	122.8	124.5	72	1.7	2.4
218-E-12B[b]	124.3	124.3	72	0.0	0
218-E-14	122.7	124.5	94	1.8	1.9
218-E-15	122.7	124.5	94	1.8	1.9
218-E-8	124.0	N/A	72	N/A	N/A
241-CX-72	122.8	124.5	90	1.7	1.9
216-B-3[b]	122.7	124.4	56	1.7	3.0
242-A	122.7	124.5	90	1.8	2.0
291-C-1	122.8	124.5	90	1.7	1.9
UPR-200-E-145	122.7	124.5	86	1.8	2.1
UPR-200-E-39	122.7	124.5	100	1.8	1.8
UPR-200-E-40	122.7	124.5	100	1.8	1.8
UPR-200-E-86	122.7	124.5	72	1.8	2.5
200-W-22	136.4	150.3	72	13.9	19.3
200-W-69	136.4	150.3	72	13.9	19.3
202-S	136.5	150.9	72	14.4	20.0
216-S-1&2	137.0	150.5	74	13.5	18.2
200-E-28	122.8	124.6	100	1.8	1.8
216-S-10P	138.4	154.2	72	15.8	21.9
216-S-11P	138.4	154.2	72	15.8	21.9
216-S-12	136.0	149.7	74	13.7	18.5
216-S-13	136.8	150.7	72	13.9	19.3
216-S-14	136.3	151.2	72	14.9	20.7
216-S-16P[b]	140.5	156.2	72	15.7	21.8
216-S-17[b]	139.1	154.8	72	15.6	21.7
216-S-19	135.8	151.2	72	15.4	21.4
216-S-20	136.1	150.5	72	14.4	20.0
216-S-22	135.6	149.7	74	14.1	19.1
200-E-30	122.8	124.6	100	1.8	1.8
216-S-23	136.3	148.5	74	12.2	16.5
216-S-25	137.8	151.4	68	13.6	20.0
216-S-26	136.1	150.8	72	14.7	20.4
216-S-3	136.8	149.6	74	12.8	17.3

Table V–4. Inundation Depths Resulting from the Black Rock Reservoir Variant Flow Field Model – All Hanford Site STOMP Model Locations *(continued)*

Location	*TC & WM EIS* Base Case Flow Field Head (meters)	BRR Variant Flow Field Head (meters)	*TC & WM EIS* Base Case Vadose Zone Length (meters)	BRR Variant Inundation Depth (meters)	BRR Variant Decrease in Vadose Zone (percent)
216-S-5	138.3	153.5	72	15.2	21.1
216-S-6	138.6	153.8	72	15.2	21.1
216-S-7	136.8	150.7	74	13.9	18.8
216-S-8	137.0	150.5	74	13.5	18.2
216-S-9	136.4	149.2	74	12.8	17.3
218-W-7	136.1	150.3	72	14.2	19.7
200-E-55	122.8	124.6	100	1.8	1.8
233-S	136.4	150.4	72	14.0	19.4
291-S	136.0	149.7	72	13.7	19.0
UPR-200-W-61	136.5	150.9	72	14.4	20.0
UPR-200-W-95	137.3	151.7	72	14.4	20.0
200-W-PP	135.5	145.9	76	10.4	13.7
200-W-45	133.7	142.5	88	8.8	10.0
200-W-9	134.3	143.4	88	9.1	10.3
216-T-1	134.0	142.6	88	8.6	9.8
216-T-12	135.7	144.7	86	9.0	10.5
216-T-13	135.8	145.5	72	9.7	13.5
200-E-95	122.8	124.6	100	1.8	1.8
216-T-2	134.3	143.4	88	9.1	10.3
216-T-20	135.4	145.5	70	10.1	14.4
216-T-27	135.6	145.5	70	9.9	14.1
216-T-29	133.7	142.5	88	8.8	10.0
216-T-3	134.6	143.8	86	9.2	10.7
216-T-33	134.0	143.0	88	9.0	10.2
216-T-34	134.4	143.1	82	8.7	10.6
216-T-35	134.7	143.6	82	8.9	10.9
216-T-36	135.7	145.1	72	9.4	13.1
216-T-4A[b]	135.7	144.8	76	9.1	12.0
200-E-97	122.8	124.6	100	1.8	1.8
216-T-6	135.0	144.3	86	9.3	10.8
216-T-8	133.9	142.8	88	8.9	10.1
216-TY-201	135.5	145.1	74	9.6	13.0
216-W-LWC	134.1	143.9	82	9.8	12.0
224-T	134.3	143.4	88	9.1	10.3
241-T-361	134.6	143.8	86	9.2	10.7
200-W-20a	134.0	143.0	88	9.0	10.2
200-W-20b	134.0	143.0	88	9.0	10.2
TRUSAF	134.3	143.4	88	9.1	10.3
UPR-200-W-102	134.3	143.4	88	9.1	10.3
2101-M-Pond	122.9	124.6	100	1.7	1.7
UPR-200-W-135	135.4	145.5	70	10.1	14.4
UPR-200-W-21	134.0	143.0	88	9.0	10.2
UPR-200-W-28	135.4	145.5	70	10.1	14.4
UPR-200-W-29	135.4	145.5	74	10.1	13.6

Table V–4. Inundation Depths Resulting from the Black Rock Reservoir Variant Flow Field Model – All Hanford Site STOMP Model Locations *(continued)*

Location	*TC & WM EIS* Base Case Flow Field Head (meters)	BRR Variant Flow Field Head (meters)	*TC & WM EIS* Base Case Vadose Zone Length (meters)	BRR Variant Inundation Depth (meters)	BRR Variant Decrease in Vadose Zone (percent)
UPR-200-W-38	134.3	143.4	88	9.1	10.3
UPR-200-W-97	135.5	145.1	74	9.6	13.0
200-W-44	134.8	145.7	78	10.9	14.0
207-U	136.3	148.0	72	11.7	16.3
216-S-21	137.1	150.1	68	13.0	19.1
216-S-4	137.5	150.5	68	13.0	19.1
212-B-CLS	122.8	124.6	100	1.8	1.8
216-U-1&2	135.7	147.1	78	11.4	14.6
216-U-10[b]	137.7	149.7	68	12.0	17.6
216-U-12	135.7	148.4	80	12.7	15.9
216-U-13	136.7	148.3	68	11.6	17.1
216-U-15	135.4	146.7	78	11.3	14.5
216-U-16	135.8	147.6	78	11.8	15.1
216-U-17	134.6	146.0	80	11.4	14.3
216-U-3	136.5	148.4	68	11.9	17.5
216-U-4	135.4	146.7	78	11.3	14.5
216-U-4A	135.4	146.7	78	11.3	14.5
216-B-10A	122.8	124.6	100	1.8	1.8
216-U-5	134.8	145.7	78	10.9	14.0
216-U-6	134.8	145.7	78	10.9	14.0
216-U-7	134.8	145.7	78	10.9	14.0
216-U-8	135.2	147.0	80	11.8	14.8
221-U	135.4	146.7	78	11.3	14.5
241-U-361	135.7	147.1	78	11.4	14.6
241-WR-Vault	134.8	145.7	78	10.9	14.0
UPR-200-W-101	135.4	146.7	78	11.3	14.5
UPR-200-W-138	134.8	145.7	78	10.9	14.0
UPR-200-W-163	135.0	146.5	76	11.5	15.1
116-C-2C	120.0	120.4	36	0.4	1.1
216-B-10B	122.8	124.6	100	1.8	1.8
UPR-200-W-39	135.4	146.7	78	11.3	14.5
216-Z-1&2	136.8	147.9	76	11.1	14.6
216-Z-10	136.5	147.1	76	10.6	13.9
216-Z-11	136.7	148.3	70	11.6	16.6
216-Z-12	137.1	148.2	76	11.1	14.6
216-Z-13	136.8	147.9	74	11.1	15.0
216-Z-14	136.8	147.9	74	11.1	15.0
216-Z-15	136.7	147.5	74	10.8	14.6
216-Z-16	136.5	147.1	76	10.6	13.9
216-B-11A & B	122.8	124.5	78	1.7	2.2
216-Z-17	136.5	147.1	76	10.6	13.9
216-Z-18	136.9	148.3	76	11.4	15.0
216-Z-1A	136.8	147.9	76	11.1	14.6
216-Z-20	136.6	147.9	70	11.3	16.1

Table V–4. Inundation Depths Resulting from the Black Rock Reservoir Variant Flow Field Model – All Hanford Site STOMP Model Locations *(continued)*

Location	*TC & WM EIS* Base Case Flow Field Head (meters)	BRR Variant Flow Field Head (meters)	*TC & WM EIS* Base Case Vadose Zone Length (meters)	BRR Variant Inundation Depth (meters)	BRR Variant Decrease in Vadose Zone (percent)
216-Z-21	136.1	147.1	72	11.0	15.3
216-Z-3	136.8	147.9	76	11.1	14.6
216-Z-4	136.5	147.1	76	10.6	13.9
216-Z-5	136.5	147.1	76	10.6	13.9
216-Z-6	136.5	147.1	76	10.6	13.9
216-Z-7	136.2	146.7	70	10.5	15.0
216-B-12	122.8	124.5	90	1.7	1.9
216-Z-8	136.3	147.1	68	10.8	15.9
216-Z-9	136.3	147.1	72	10.8	15.0
218-W-1	136.6	146.7	74	10.1	13.6
218-W-1A[b]	134.3	142.9	82	8.6	10.5
218-W-2	136.7	147.1	74	10.4	14.1
218-W-2A[b]	135.8	145.0	76	9.2	12.1
218-W-3	136.6	146.3	78	9.7	12.4
218-W-3A[b]	136.0	145.0	74	9.0	12.2
218-W-3AE[b]	135.4	144.2	74	8.8	11.9
218-W-4A[b]	136.3	146.1	78	9.8	12.6
216-B-4	122.8	124.6	100	1.8	1.8
218-W-4B	137.2	147.8	74	10.6	14.3
218-W-4C[b]	137.0	148.8	76	11.8	15.5
218-W-5[b]	136.6	145.8	74	9.2	12.4
231-Z-PuIF	136.5	147.1	76	10.6	13.9
232-Z	136.8	147.9	74	11.1	15.0
236-Z-PuRF	136.7	147.5	74	10.8	14.6
241-Z-361	136.8	147.9	72	11.1	15.4
242-Z-AmRF	136.7	147.5	74	10.8	14.6
2736-Z-PuFP	136.8	147.9	74	11.1	15.0
216-B-5	122.8	124.5	84	1.7	2.0
291-Z-EFCH	136.8	147.9	74	11.1	15.0
UPR-200-W-103	136.8	147.9	74	11.1	15.0
216-B-50	122.8	124.4	76	1.6	2.1
216-B-51	122.8	124.5	72	1.7	2.4
216-B-54	123.9	127.1	106	3.2	3.0
216-B-55	122.8	124.6	90	1.8	2.0
216-B-57	122.8	124.5	76	1.7	2.2
116-B-1	119.9	119.9	16	0.0	0
216-B-59	122.8	124.5	84	1.7	2.0
216-B-6	122.8	124.5	100	1.7	1.7
216-B-60	122.8	124.6	100	1.8	1.8
216-B-62	122.8	124.5	90	1.7	1.9
216-B-63	122.7	124.5	78	1.8	2.3
216-B-9	122.8	124.5	84	1.7	2.0
218-E-10[b]	122.8	124.5	86	1.7	2.0
218-E-2	122.8	124.5	84	1.7	2.0

Table V–4. Inundation Depths Resulting from the Black Rock Reservoir Variant Flow Field Model – All Hanford Site STOMP Model Locations *(continued)*

Location	*TC & WM EIS* Base Case Flow Field Head (meters)	BRR Variant Flow Field Head (meters)	*TC & WM EIS* Base Case Vadose Zone Length (meters)	BRR Variant Inundation Depth (meters)	BRR Variant Decrease in Vadose Zone (percent)
218-E-4	122.8	124.5	84	1.7	2.0
218-E-5	122.8	124.5	84	1.7	2.0
116-B-11	119.9	119.9	16	0.0	0
218-E-5A	122.8	124.5	84	1.7	2.0
221-B-BPS	122.8	124.5	100	1.7	1.7
224-B	122.8	124.6	100	1.8	1.8
241-B-361	122.8	124.5	84	1.7	2.0
UPR-200-E-7	122.8	124.5	84	1.7	2.0
UPR-200-E-77	122.8	124.5	90	1.7	1.9
UPR-200-E-78	122.8	124.5	84	1.7	2.0
UPR-200-E-79	122.8	124.5	80	1.7	2.1
UPR-200-E-84	122.8	124.6	80	1.8	2.3
UPR-200-E-85	122.8	124.5	100	1.7	1.7
116-C-1	119.7	119.8	16	0.1	<1
UPR-200-E-87	122.8	124.6	100	1.8	1.8
UPR-200-E-9	122.8	124.5	76	1.7	2.2
WESF	122.8	124.6	100	1.8	1.8
116-D-1A	117.3	117.4	26	0.1	<1
116-D-1B	117.3	117.4	26	0.1	<1
116-DR-7	117.4	117.5	28	0.1	<1
116-D-7	117.5	117.5	20	0.0	0
116-DR-1&2	117.3	117.3	20	0.0	0
116-DR-9	117.3	117.4	20	0.1	<1
116-DR-6	117.2	117.4	28	0.2	<1
116-C-5	119.9	120.0	16	0.1	<1
116-F-6	113.8	113.9	14	0.1	<1
116-F-10	113.8	113.9	14	0.1	<1
116-F-4	113.9	114.0	14	0.1	<1
116-F-3	113.8	113.9	14	0.1	<1
116-F-2	113.6	113.7	18	0.1	<1
116-F-14	113.6	113.7	18	0.1	<1
116-F-9	113.7	113.7	18	0.0	0
216-A-25a[b]	121.3	123.1	16	1.8	11.3
216-A-25b	123.0	N/A	16	N/A	N/A
216-A-25a[b]	121.3	123.1	16	1.8	11.3
216-A-25b	123.0	N/A	16	N/A	N/A
216-A-25c	123.0	N/A	16	N/A	N/A
116-B-5	120.0	120.2	20	0.2	<1
216-A-25d	123.0	N/A	16	N/A	N/A
216-A-25e	123.0	N/A	16	N/A	N/A
216-A-25f	123.0	N/A	16	N/A	N/A
216-N-1	125.5	128.2	54	2.7	5.0
216-N-2	125.5	N/A	54	N/A	N/A
216-N-3	125.5	N/A	54	N/A	N/A

Table V–4. Inundation Depths Resulting from the Black Rock Reservoir Variant Flow Field Model – All Hanford Site STOMP Model Locations *(continued)*

Location	*TC & WM EIS* Base Case Flow Field Head (meters)	BRR Variant Flow Field Head (meters)	*TC & WM EIS* Base Case Vadose Zone Length (meters)	BRR Variant Inundation Depth (meters)	BRR Variant Decrease in Vadose Zone (percent)
216-N-4	122.8	123.9	54	1.1	2.0
216-N-5	121.5	122.8	54	1.3	2.4
216-N-6	121.7	123.3	58	1.6	2.8
216-N-7	121.0	122.8	54	1.8	3.3
116-B-6A	120.0	120.3	24	0.3	1.3
116-H-3	115.4	115.4	16	0.0	0
116-H-4	115.5	115.5	16	0.0	0
116-H-1	115.2	115.2	14	0.0	0
116-H-7	115.2	115.3	14	0.1	<1
116-H-2	115.5	115.5	16	0.0	0
100-H-33	115.3	115.4	14	0.1	<1
116-K-1	118.6	118.8	8	0.2	2.5
116-K-2a	118.6	118.8	12	0.2	1.7
116-K-2b	118.6	118.8	12	0.2	1.7
116-K-2c	118.6	118.8	12	0.2	1.7

[a] Average values were calculated at barriers. These values were used for all sites within that barrier for STOMP models used in the *TC & WM EIS* alternatives impact analysis. All other STOMP model sites were part of the *TC & WM EIS* cumulative impact analyses.

[b] Site footprint covers more than one model cell. Head values are expressed as an average of all model cells covered.

Note: N/A indicates that the top of basalt is above the water table at these waste sites. To convert meters to feet, multiply by 3.281.

Key: BRR=Black Rock Reservoir; FFTF=Fast Flux Test Facility; IDFE=200-East Area Integrated Disposal Facility; IDFW=200-West Area Integrated Disposal Facility; N/A=not applicable; NRDWL=Nonradioactive Dangerous Waste Landfill; RPPDF=River Protection Project Disposal Facility; STOMP=Subsurface Transport Over Multiple Phases; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; WESF=the Waste Encapsulation and Storage Facility.

The results comparing vadose zone travel times under BRR variant flow field model conditions (elevated water table) and *TC & WM EIS* Base Case flow model conditions are illustrated in vadose zone STOMP flux output graphs, included as Figures V–21 through V–32. STOMP vadose zone transport simulations were run at identical Waste Management alternative locations (10,000 years) for each of the compared flow fields using 1 curie of technetium-99. The Hanford *TC & WM EIS* STOMP vadose zone simulation Waste Management alternative descriptions are summarized in Table V–5. Further description of the STOMP modeling process can be found in Appendix N.

Figures V–21 through V–32 are vadose zone STOMP flux output graphs comparing the BRR variant STOMP model conditions to the *TC & WM EIS* Base Case STOMP model conditions. Each graph displays flux output to the flow field (bottom of the vadose zone/top of the water table) over the 10,000-year period of analysis. Output to the flow field is measured in three concentric areas: “Flux 1,” “Flux 2,” and “Flux 3.” “Flux 1” is the solute flux amount released to the flow field in a rectangular area directly below the source of technetium-99, “Flux 2” is the solute flux amount released to the flow field along a 50-meter (164.1-foot) perimeter surrounding the “Flux 1” area, and “Flux 3” is the solute flux amount released to the flow field along the outermost area of the site-specific STOMP modeled domain.

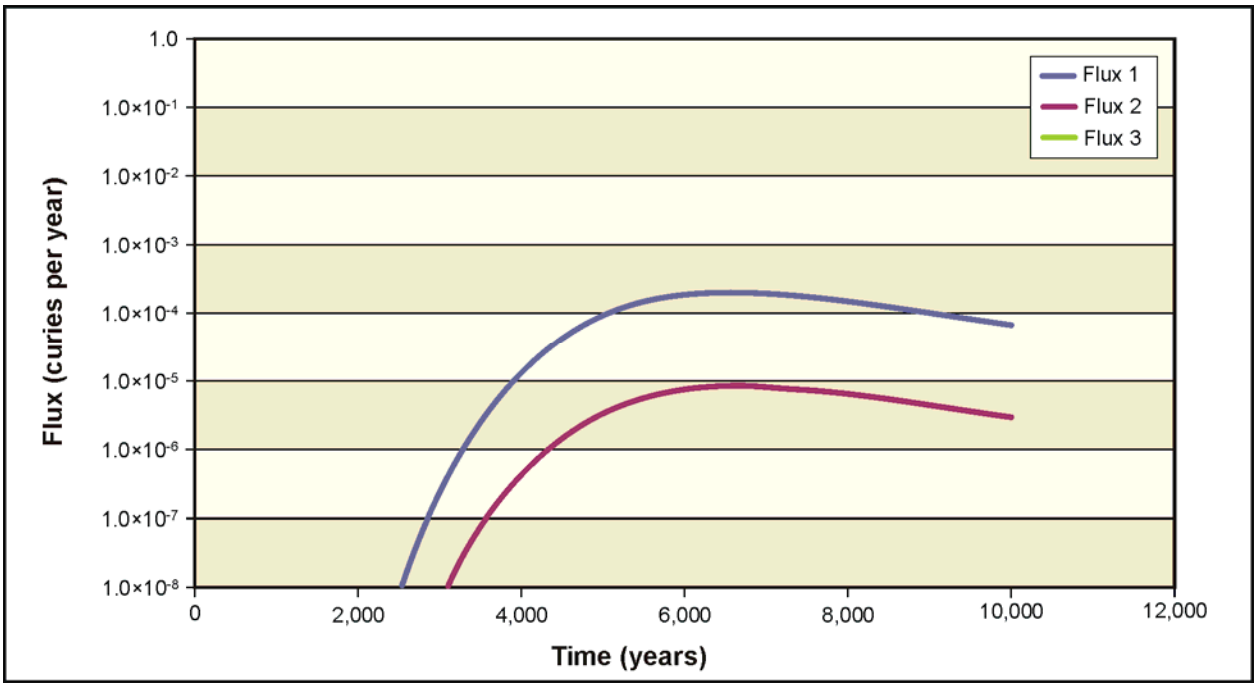

Figure V–21. Base Case Flow Model – Vadose Zone Flux Release over Time, 200-East Area Integrated Disposal Facility

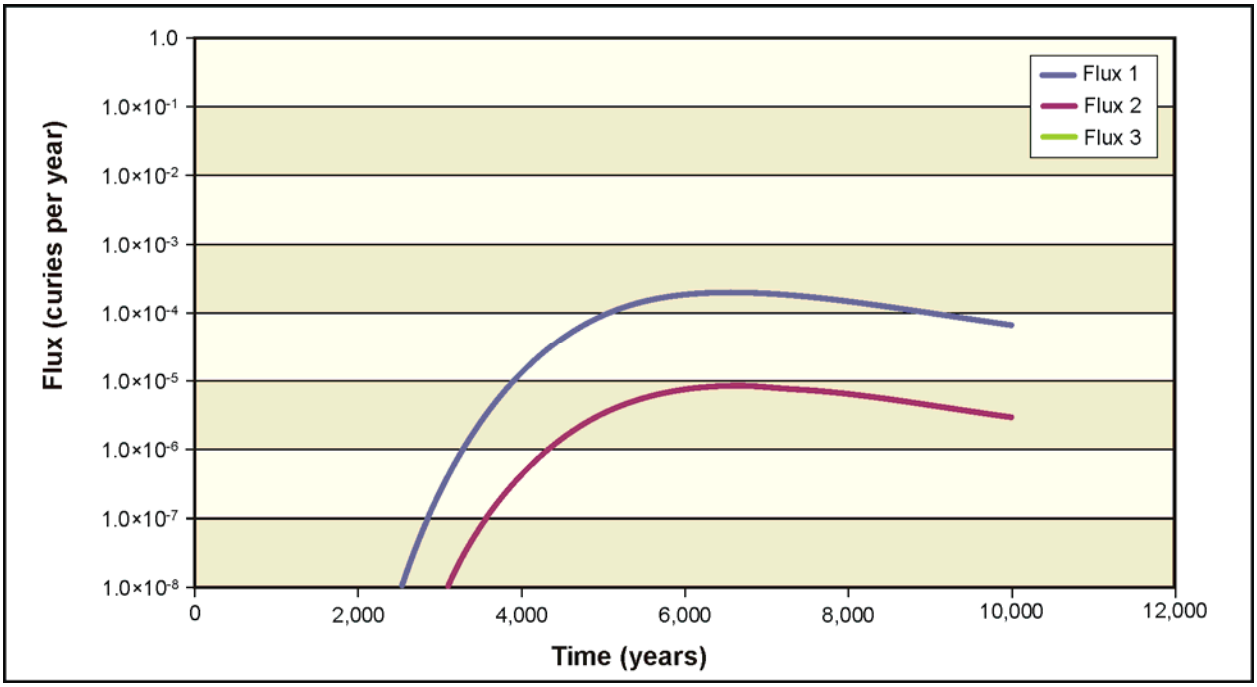

Figure V–22. Black Rock Reservoir Variant Flow Field Model – Vadose Zone Flux Release over Time, 200-East Area Integrated Disposal Facility

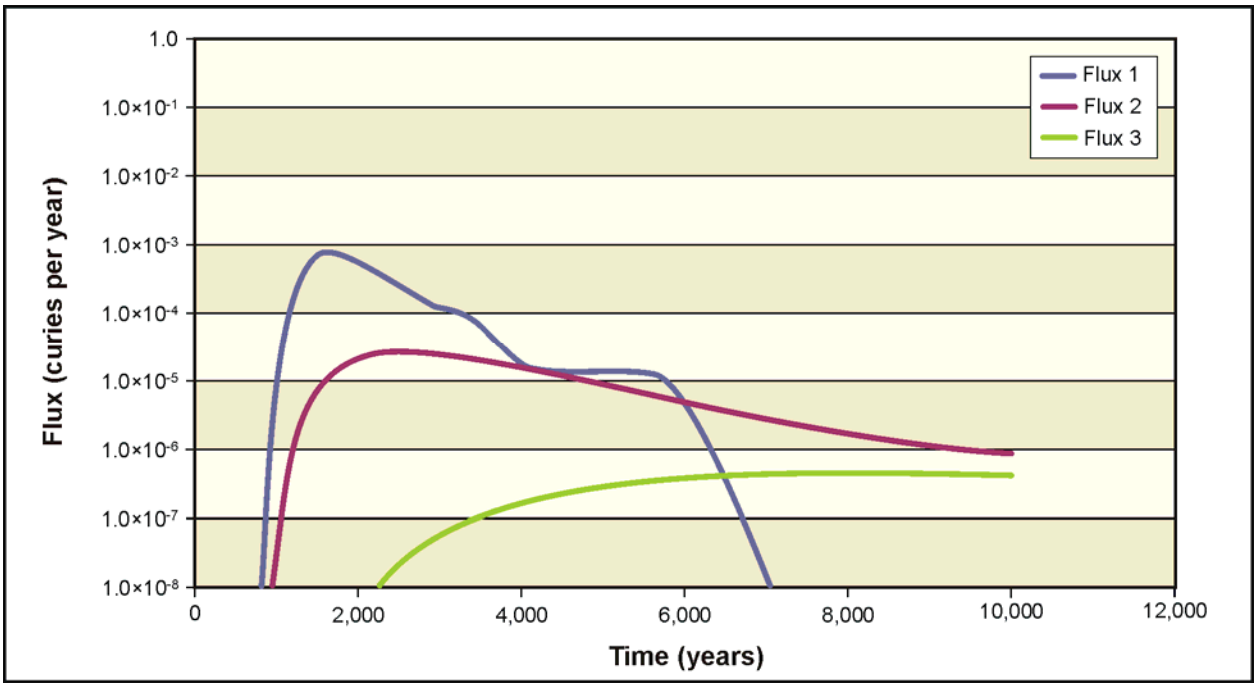

Figure V–23. Base Case Flow Model – Vadose Zone Flux Release over Time, 200-West Area Integrated Disposal Facility

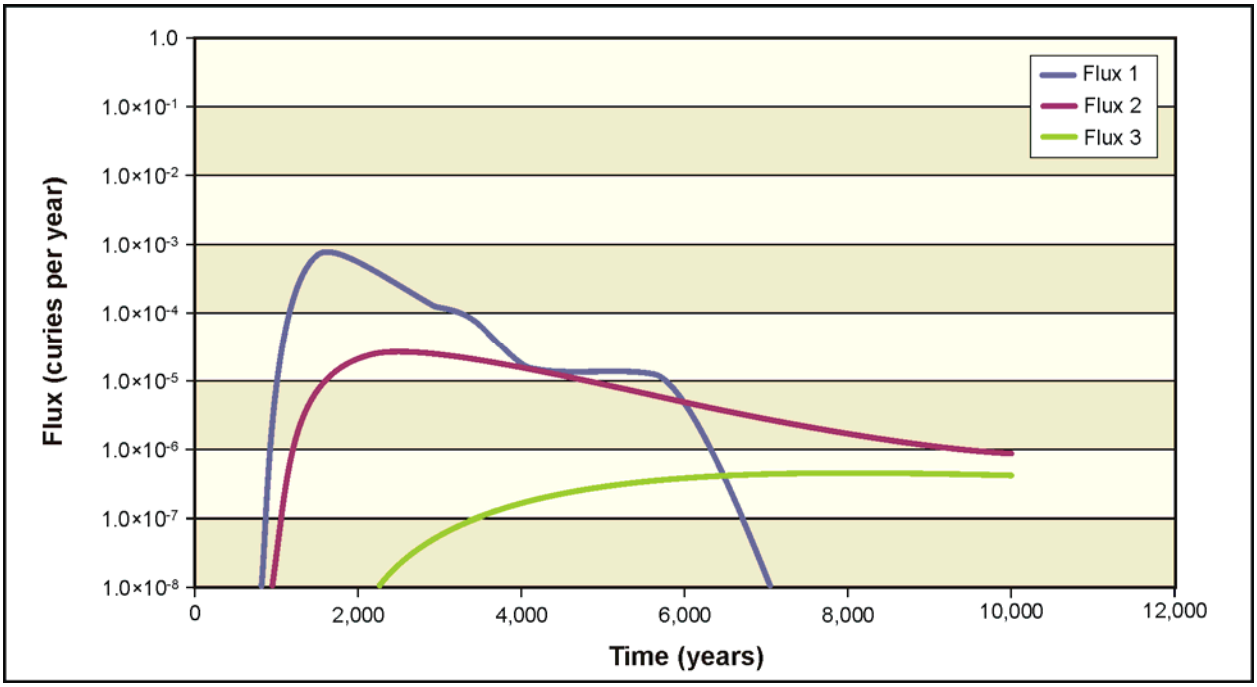

Figure V–24. Black Rock Reservoir Variant Flow Field Model – Vadose Zone Flux Release over Time, 200-West Area Integrated Disposal Facility

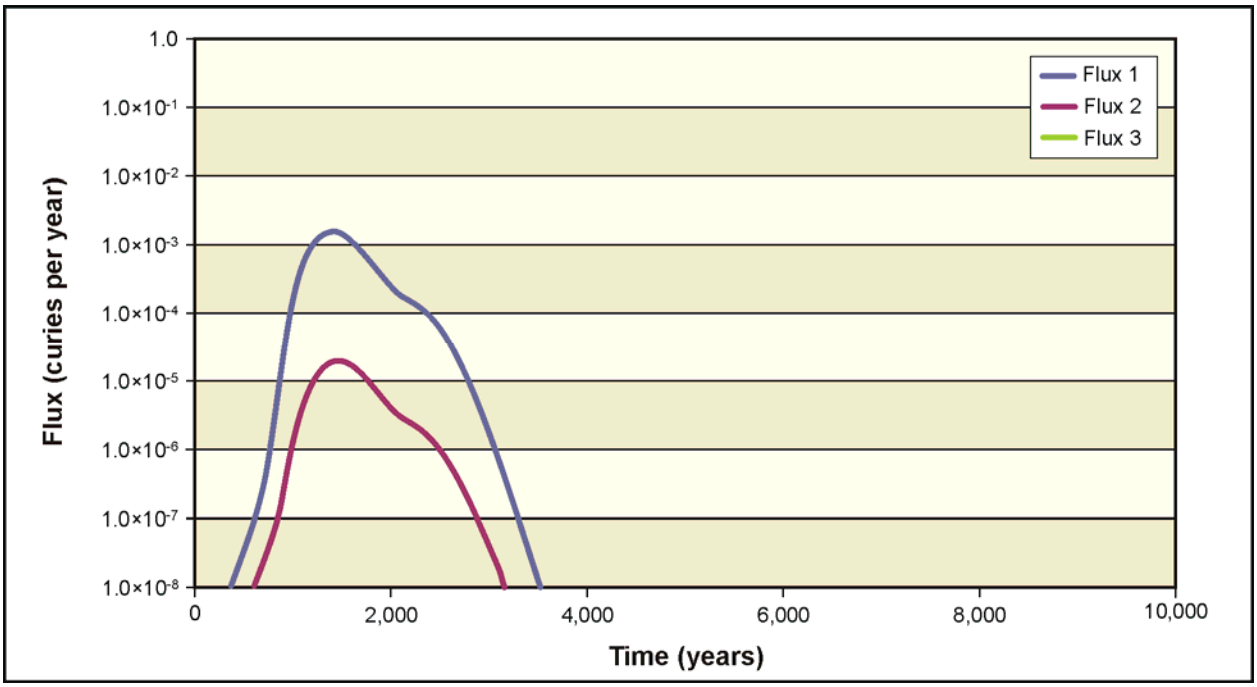

Figure V–25. Base Case Flow Model – Vadose Zone Flux Release over Time, 200-West Area, Trench 31

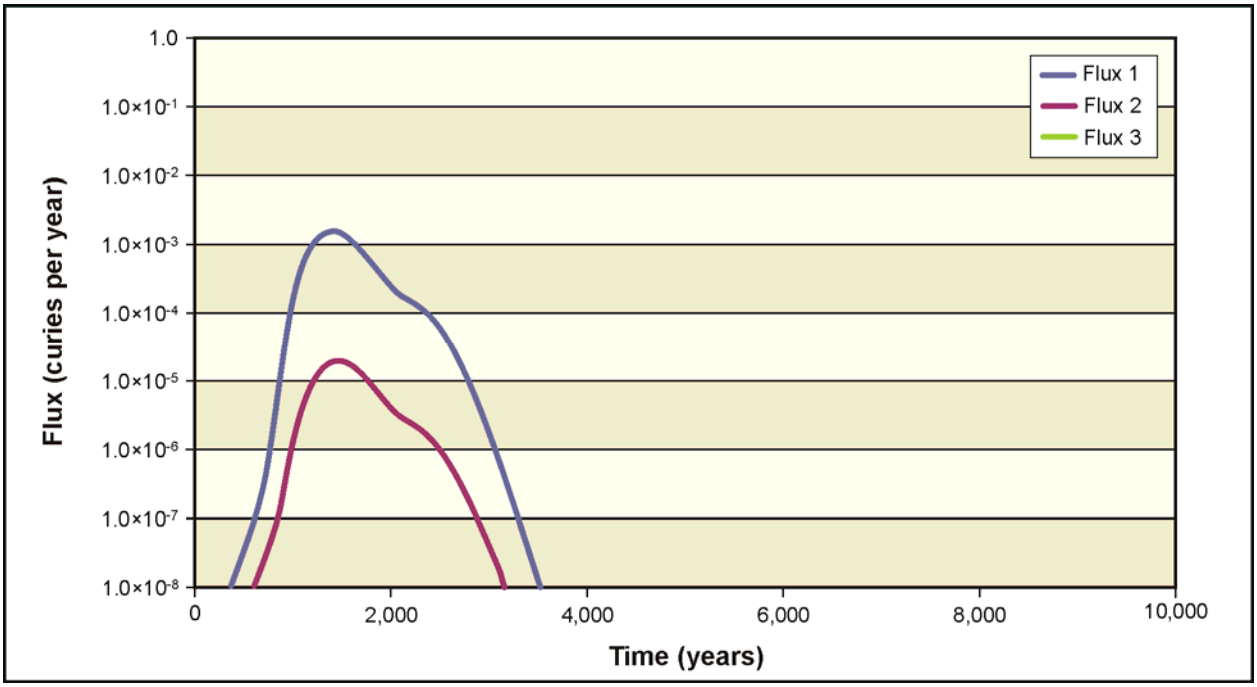

Figure V–26. Black Rock Reservoir Variant Flow Field Model – Vadose Zone Flux Release over Time, 200-West Area, Trench 31

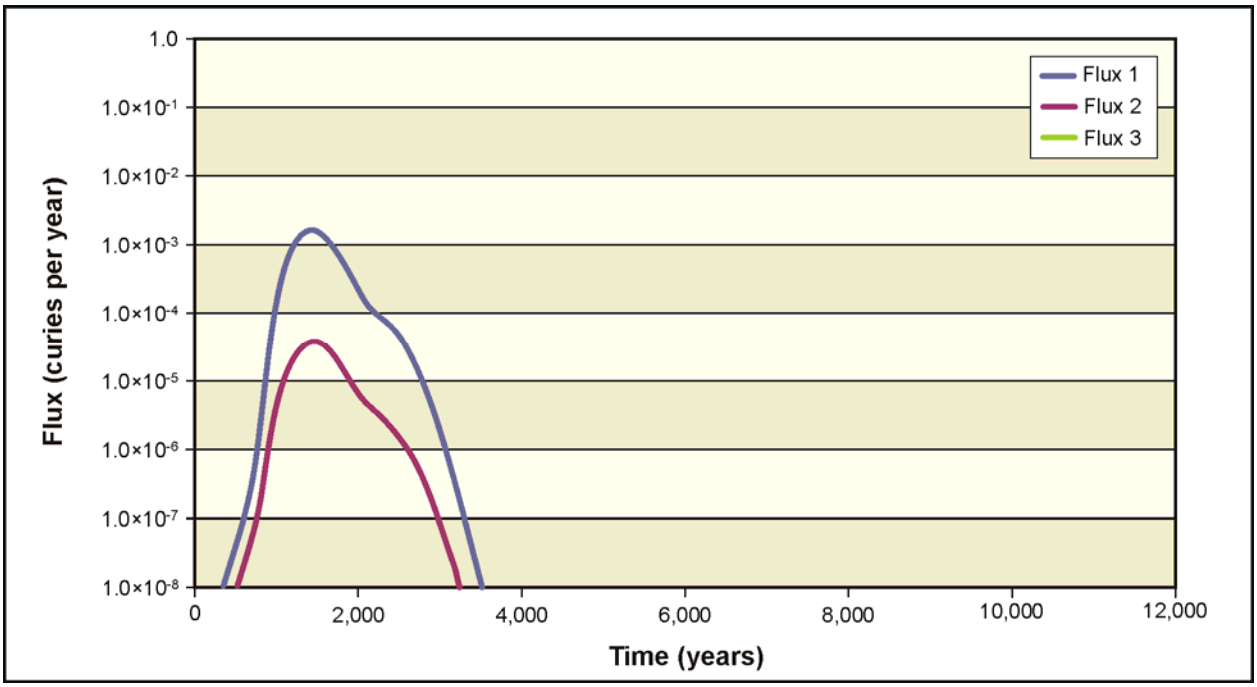

Figure V–27. Base Case Flow Model – Vadose Zone Flux Release over Time, 200-West Area, Trench 34

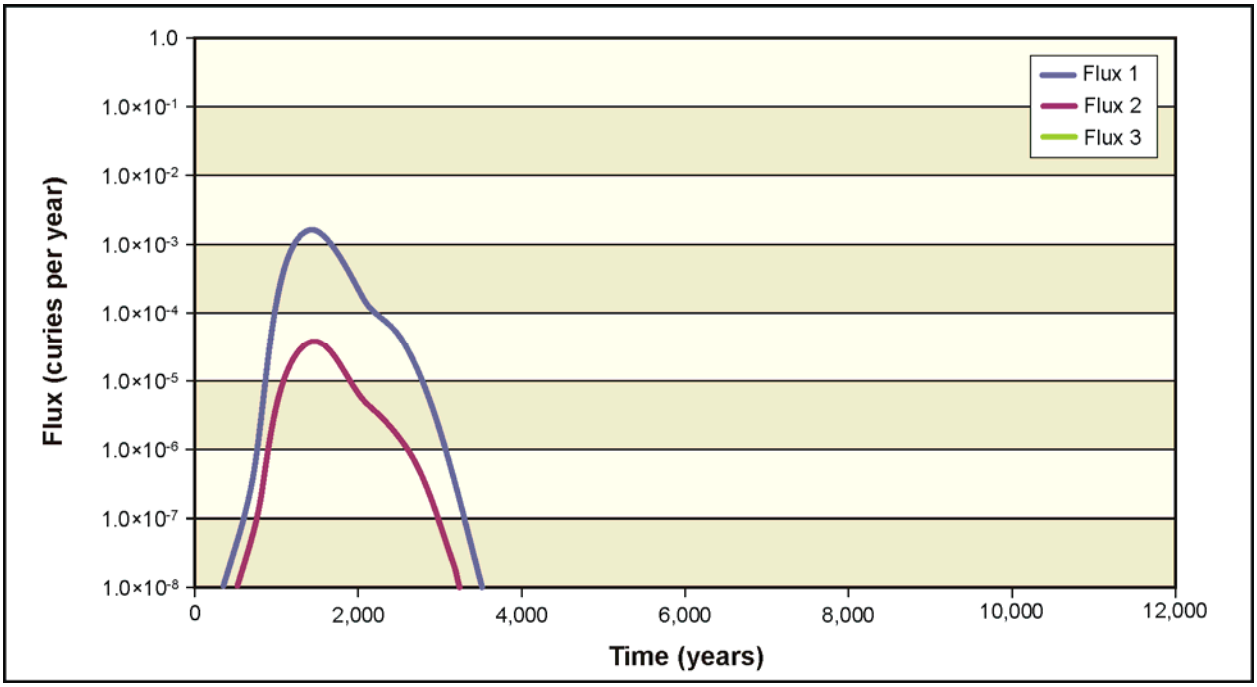

Figure V–28. Black Rock Reservoir Variant Flow Field Model – Vadose Zone Flux Release over Time, 200-West Area, Trench 34

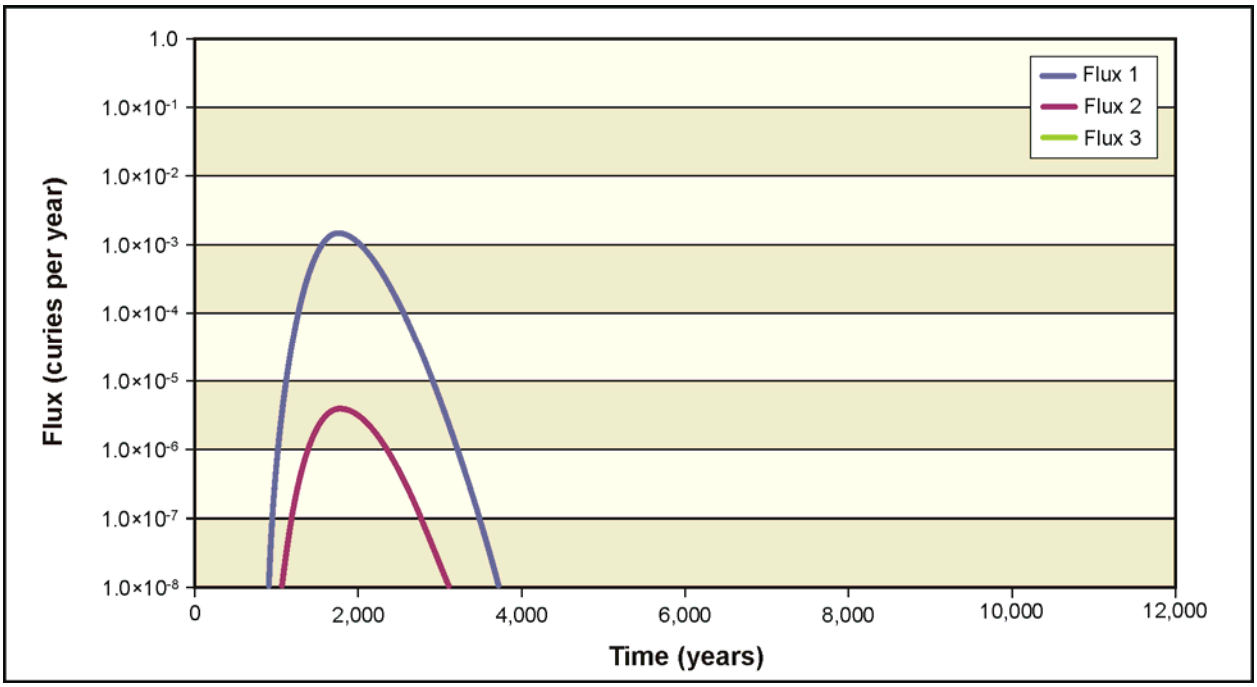

Figure V–29. Base Case Flow Model – Vadose Zone Flux Release over Time, River Protection Project Disposal Facility

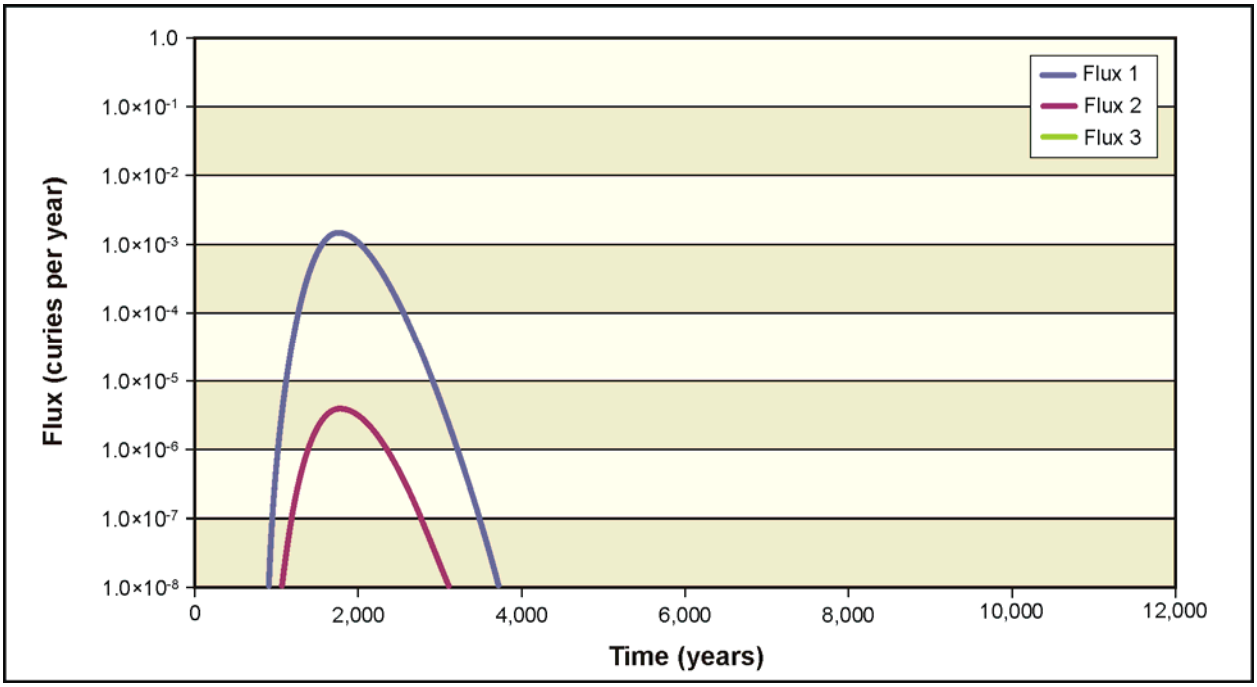

Figure V–30. Black Rock Reservoir Variant Flow Field Model – Vadose Zone Flux Release over Time, River Protection Project Disposal Facility

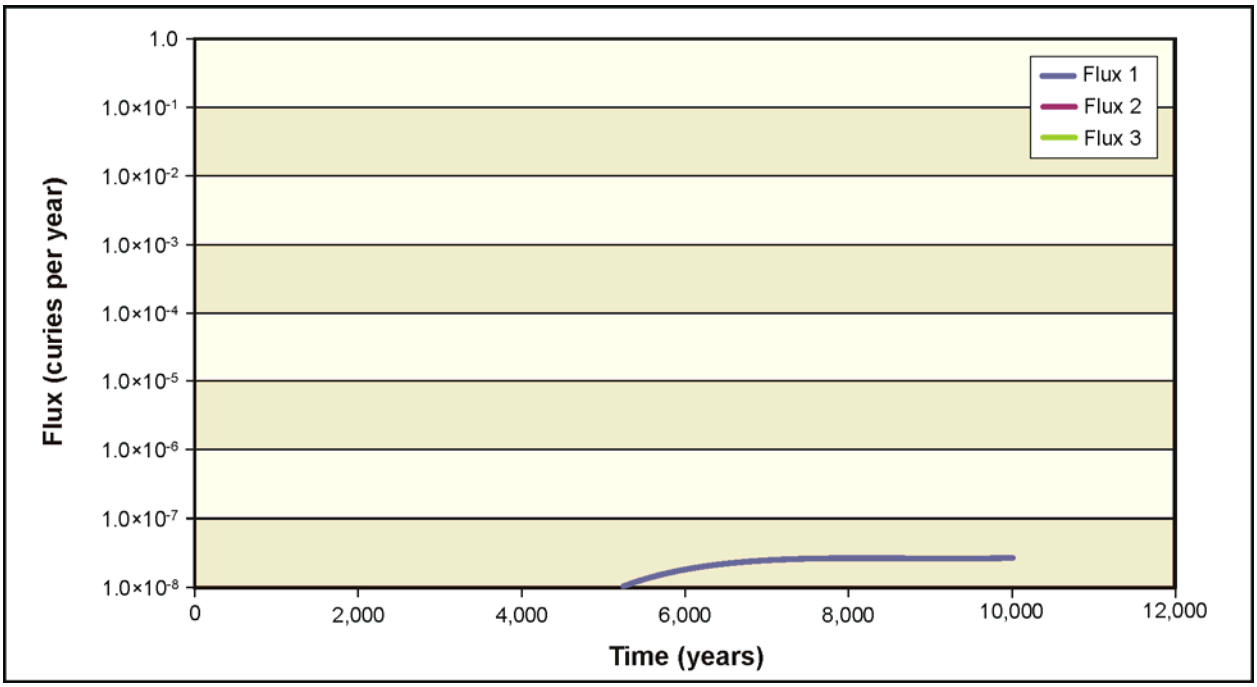

Figure V–31. Base Case Flow Model – Vadose Zone Flux Release over Time, 200-East Area Integrated Disposal Facility

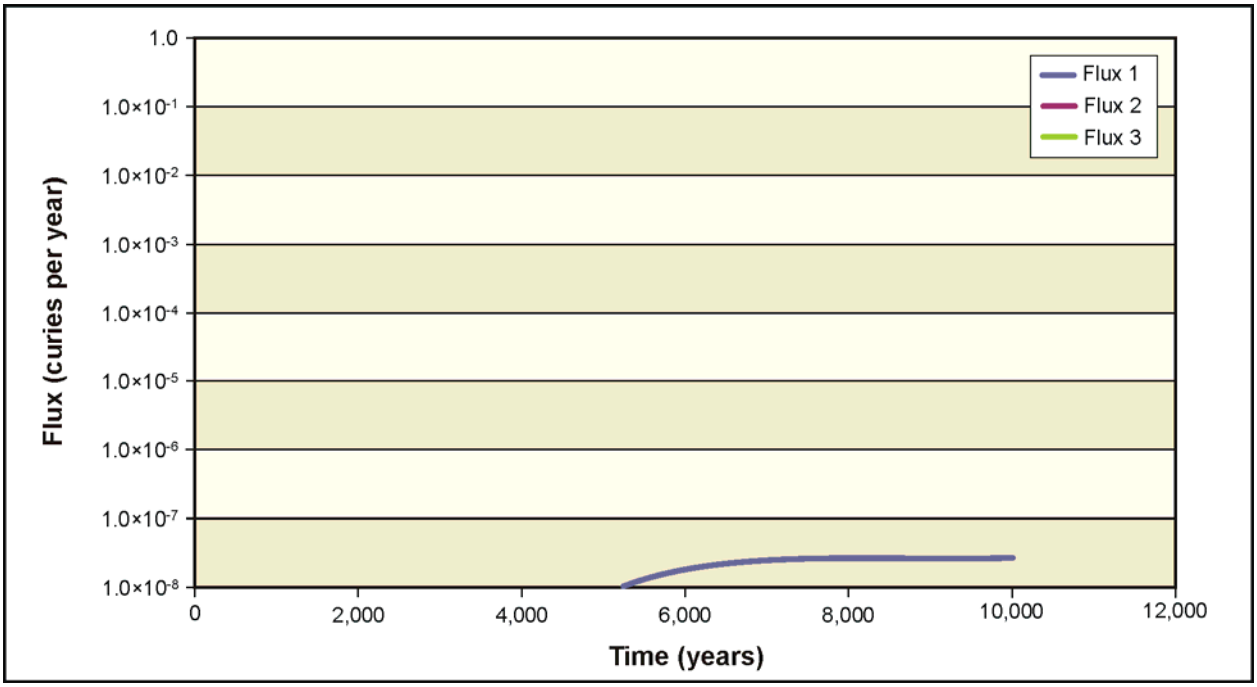

Figure V–32. Black Rock Reservoir Variant Flow Field Model – Vadose Zone Flux Release over Time, 200-East Area Integrated Disposal Facility

Table V–5. STOMP Vadose Zone Waste Management Simulation Summary

Hanford Site Disposal Location	*TC & WM EIS* Waste Management Alternative Description[a]	Solute Modeled (1 Curie)	Vadose Zone Release to Flow Field (Flux/Time) Figure Number	
			TC & WM EIS Base Case Flow Model	BRR Variant Flow Field Model
200-East Area Integrated Disposal Facility	Waste Management Alternative 2, Disposal Group 1 – Offsite waste (waste meeting Hanford Waste Acceptance Criteria, grouted waste form)	Tc-99	Figure V–20	Figure V–21
200-West Area Integrated Disposal Facility	Waste Management Alternative 3, Disposal Group 1 – Offsite waste (waste meeting Hanford Waste Acceptance Criteria, grouted waste form)	Tc-99	Figure V–22	Figure V–23
200-West Area—trench 31	Waste Management Alternative 1, Non-CERCLA Waste – miscellaneous waste meeting Hanford Waste Acceptance Criteria, stored in 55-gallon drums	Tc-99	Figure V–24	Figure V–25
200-West Area—trench 34	Waste Management Alternative 1, Non-CERCLA Waste – miscellaneous waste meeting Hanford Waste Acceptance Criteria, stored in 55-gallon drums	Tc-99	Figure V–26	Figure V–27
Central Plateau—River Protection Project Disposal Facility	Waste Management Alternative 2, Disposal Group 1 – Onsite-generated contaminated soils and decommissioned ancillary equipment	Tc-99	Figure V–28	Figure V–29
200-East Area Integrated Disposal Facility	Waste Management Alternative 2, Disposal Group 1 – immobilized low-activity waste, poured glass in steel canisters	Tc-99	Figure V–30	Figure V–31

[a] Additional details regarding the Waste Management alternatives are included in Chapter 2 of this *TC & WM EIS*.

Key: BRR=Black Rock Reservoir; CERCLA=Comprehensive Environmental Response, Compensation, and Liability Act; STOMP=Subsurface Transport Over Multiple Phases; Tc=technetium; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

In all waste management scenarios examined (see Table V–4), the results of the STOMP modeled long-term vadose zone transport simulations indicate essentially no differences in either timing of the release or the amount released between the BRR variant flow field conditions and the *TC & WM EIS* Base Case conditions.

Additional sensitivity analysis regarding vadose zone transport within this *TC & WM EIS* can be found in Appendix N, Section N.3, "Sensitivity Analysis."

V.4.3 Changes to Timing of Groundwater Peak Concentrations at the Columbia River

Groundwater flow and transport analysis was performed using the BRR variant flow field and the *TC & WM EIS* Base Case flow field to evaluate peak concentration arrival time to the Columbia River from a 1-curie release of technetium-99 at each barrier location. Table V–6 provides the results of this analysis. The year of peak concentration arrival at the Columbia River from all releases is earlier in the BRR variant model. In general, the peak year variances are minimal compared to the overall period of waste release and the length of the *TC & WM EIS* Base Case transport simulation (10,000 years).

Table V–6. Technetium-99 (1-Curie Release) Peak Concentration at Columbia River

Release Location[a]	*TC & WM EIS* Base Case Model		BRR Variant Model		Peak Year Variance[b]
	Peak Concentration (picocuries/liter)	Peak Year	Peak Concentration (picocuries/liter)	Peak Year	
A Barrier	6.44×10^{-1}	2206	6.43×10^{-1}	2190	–16
B Barrier	1.09	2207	1.04	2102	–105
FFTF	9.05×10^{-2}	2171	9.05×10^{-2}	2138	–33
T Barrier	1.02	2211	1.55	2119	–92
U Barrier	7.52×10^{-1}	2242	1.09	2120	–122
S Barrier	5.94×10^{-1}	2373	1.01	2171	–202
IDF-East	3.89	2149	3.62	2151	–2
IDF-West	1.20	2201	8.18×10^{-1}	2127	–74
Trenches 31 and 34	1.30	2238	1.18	2125	–113
RPPDF	1.02	2191	1.64	2101	–90

[a] Particle released (1 curie) in center of location. Particle released in 2090, at a time after which the BRR is expected to have reached steady state equilibrium.

[b] Difference between the peak year of the BRR variant model and that of the *TC & WM EIS* Base Case model.

Key: BRR=Black Rock Reservoir; FFTF=Fast Flux Test Facility; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; RPPDF=River Protection Project Disposal Facility; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

V.5 SUMMARY OF IMPLICATIONS FOR THE *TC & WM EIS* ALTERNATIVES

Comprehensive descriptions of the various Tank Closure, FFTF Decommissioning, and Waste Management alternatives can be found in Chapter 2 of this *TC & WM EIS*. In addition, analysis regarding groundwater constituent of potential concern driver identification and discussion can be found in Chapter 5 and Chapter 6 of this *TC & WM EIS*.

In summary, based on results presented in Section V.4, the following conclusions can be made regarding the BRR variant model:

- Localized changes in the flow field are noted primarily in the northwestern region of Hanford. Groundwater is more likely to flow north (rather than east) through Gable Gap toward the Columbia River. A decrease in vadose zone thickness (due to elevated water table) at various sites is minimal.

- The BRR variant model has no discernible effects on the short-term Tank Closure and associated long-term Waste Management alternatives presented in this *TC & WM EIS*.

- The BRR variant model has no discernible effects on additional mobilization of deep vadose zone contaminants.

V.6 REFERENCES

BOR (U.S. Bureau of Reclamation), 2007, *Modeling Groundwater Hydrologic Impacts of the Potential Black Rock Reservoir: A Component of the Yakima River Basin Water Storage Feasibility Study, Washington Pacific Northwest Region*, Technical Series No. TS-YSS-19, Pacific Northwest Region, Boise, Idaho, September.

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Schmidt, R., 2007, U.S. Department of the Interior, Bureau of Reclamation, Boise, Idaho, personal communication (email) to M. Burandt, U.S. Department of Energy, Office of River Protection, Richland, Washington, "Data Request #279 Related to Hanford *Tank Closure & Waste Management Environmental Impact Statement*," September 6.