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Hydraulic Gradients and Velocity Calculations for RCRA Sites in 2016

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

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P.O. Box 1600
Richland, Washington 99352

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By Lana Perry at 6:21 am, Feb 08, 2017

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Terms

DOE	United States Department of Energy
m/d	Meters per day
LLWMA	Low-Level Waste Management Area
NAVD88	North American Vertical Datum of 1988
NRDWL	Nonradioactive Dangerous Waste Landfill
P&T	Pump and Treat
RCRA	*Resource Conservation and Recovery Act of 1976*
WMA	Waste Management Area

1 Purpose

The purpose of this environmental calculation is to estimate hydraulic gradients and groundwater flow velocities at Hanford Site *Resource Conservation and Recovery Act* (RCRA) facilities in 2016.

2 Methodology

Water-level data were analyzed by trend-surface analysis calculations in a Microsoft Excel 2007®[1] spreadsheet created by J.P. McDonald. The method was described by Davis (2002, *Statistics and Data Analysis in Geology*). A first-order, linear trend surface (i.e., a plane) was fitted to the water-level elevation data using least squares regression. The slope of the fitted surface represented the hydraulic gradient magnitude, and the dip direction represented the hydraulic gradient direction. To determine if the fitted planes were valid for determining the hydraulic gradient, statistical tests were used to evaluate the goodness of fit of the planes to the water-level data.

For some sites, gradients were estimated using a digital grid. The water table in the 200 East Area is very flat (i.e., a low hydraulic gradient magnitude), and water level measurements typically exhibit a variability that is larger than the local change in the water table elevation (i.e., a low signal to noise ratio). Thus, it is difficult to use water level measurements in the local vicinity of a 200 East Area RCRA site to determine the gradient. Groundwater flow directions in the 200 East Area were determined by preparing a digital grid of the water table across most of the 200 East Area based on average water level measurements[2]. In some cases, the grid nodes from the local area around a RCRA site were then extracted from the larger grid and a trend surface was fitted to the grid node values to determine the gradient. In other cases, the contoured grid (i.e. the water table map) was used to estimate the gradient magnitude and direction at a RCRA site by inspection.

Methods of trend-surface analysis, digital gridding, and statistical testing were described in ECF-Hanford-16-0013 and will not be repeated here. Methods of correcting water level data for barometric effects and borehole deviation from vertical are described in SGW-54165.

3 Assumptions and Inputs

For the conventional calculations (i.e., all except the low gradient sites in 200 East Area), water-level data were retrieved from the "Environmental Monitoring" module of the Hanford Site's Virtual Library for wells screened across the water table near RCRA WMAs. Calculations were performed for March 2016 and, in many cases, for additional time periods. For the Liquid Effluent Treatment Facility (LERF) site, data were corrected for barometric effects using the methods of SGW-54165. Well coordinates (northing and easting) were retrieved from the Hanford Site "Environmental Dashboard Application" (http://environet.rl.gov/EDA), rounded to the nearest hundredth of a meter. The data are provided in the electronic spreadsheet files that accompany this calculation.

For the 200 East Area sites the gradient was determined using the digital grid, which is based on annual average water level elevations for October 2015 through September 2016 (to be documented in an upcoming environmental calculation). This time period, is used to represent 2016 conditions because the last quarter of 2016 data were not ready for analysis at the time of this calculation. Gradients based on this digital grid are referred to herein as 2016 gradients.

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[1] Microsoft Excel is a registered product of the Microsoft Corporation.

[2] Method described in SGW-58828

The hydraulic gradient calculation assumes that the water table is planar. This is of course a simplification, because water table contours form a varied "topography." Thus, the hydraulic gradient calculation provides an average result.

As applied here, the Darcy equation assumes that flow is horizontal (vertical gradients are insignificant) and the aquifer is homogeneous. Table 1 lists hydraulic parameters and their sources.

4 Software Applications

A Microsoft Excel 2013® spreadsheet was used to perform calculations described in Section 2, using the default calculation formulae available in that software. The hydraulic gradient spreadsheet previously was validated by comparison of results with a commercial software (personal communication, e-mail from Dennis Weier, Pacific Northwest National laboratory, to John McDonald, Fluor Hanford, Inc., "Spreadsheet verification," April 7, 2008).

5 Calculations

Table 1 of ECF-Hanford-16-0013 illustrates the Excel spreadsheet and its formulae. The same formulae were used for the 2016 calculations, and they are included in the electronic spreadsheet that accompany this calculation.

6 Results

Table 1 and the following paragraphs summarize results of the hydraulic gradient and velocity calculations.

6.1 1301-N Liquid Waste Disposal Facility

This facility is located near the Columbia River in 100-N Area. Groundwater typically flows to the northwest toward the river. However, the water table map for March 2016 indicates a reversed gradient (toward the southeast) was present adjacent to the river. Farther inland at the 1301-N network, however, the gradient dipped to the north-northwest (azimuth 343°) at 9.04×10^{-4} m/m. Statistical tests indicated a good fit. Estimated groundwater flow rates ranged from 0.018 to 0.33 m/d.

Data from September 2016, when river stage was low, were also evaluated. An initial attempt using the five network wells had a P value >0.05. Adding two nearby wells improved the fit. The gradient had a magnitude of 2.51×10^{-3} m/m and dipped to the northwest (azimuth 324°). Estimated groundwater flow rates ranged from 0.051 to 0.93 m/d.

6.2 1324-N Surface Impoundment and 1324-NA Percolation Pond

The 1324-N Surface Impoundment and 1324-NA Percolation Pond (1324-N/NA Facilities) are located in southern 100-N Area. The KX pump and treat (P&T) system includes injection wells located approximately 200 to 300 meters west and south of 1324-N/NA. No water-level data are available between these injection wells and the 1324-N/NA monitoring network, and it is likely that the water table beneath 1324-N/NA is not truly planar. Thus the gradient estimated by trend surface analysis has more uncertainty here than at other locations.

Based on March 2016 water-level data, the gradient was 8.93×10^{-4} m/m, and dipping toward the north-northeast (azimuth 21°). Statistical parameters show a good fit and acceptably low P value. Estimated groundwater flow rates ranged from 0.018 to 0.33 m/d.

The gradient in September 2016 was 8.45×10^{-4} m/m dipping toward the north (azimuth 4°). Statistical parameters show a good fit and acceptably low P value. Estimated groundwater flow rates ranged from 0.017 to 0.31 m/d.

6.3 1325-N Liquid Waste Disposal Facility

This facility is located in the 100-N Area and is farther from the river than the 1301-N facility. The data set includes the five wells in the RCRA network plus three nearby wells. The gradient in March 2016 was 9.35×10^{-4} m/m dipping to the north (azimuth 357°). Statistical tests indicated a good fit. Estimated groundwater flow rates ranged from 0.02 to 0.35 m/d.

In September 2016 (low river stage) the some wells were removed from the data set through trial and error to achieve a better fit. The gradient was 7.76×10^{-4} m/m, dipping to the north (9°). Statistical tests indicated a good fit. Estimated groundwater flow rates ranged from 0.02 to 0.29 m/d.

6.4 183-H Basins

This unit is located in 100-H Area. The HX P&T system affects groundwater flow in this region with extraction wells located north and east of 183-H, and injection wells located to the west. The natural groundwater gradient dips toward the east (toward the Columbia River). In March 2016, however, the gradient was reversed, dipping to the west-southwest (240°) with a magnitude 2.53×10^{-3} m/m. Statistical tests indicated a good fit. Estimated groundwater flow rates ranged from 0.13 to 3.5 m/d.

In November 2016 the gradient was 1.45×10^{-3} m/m to the south-southeast (153°). The P value was 0.19, well above the 0.05 level of significance. Estimated flow rates ranged from 0.07 to 2.0 m/d.

6.5 216-A-29 Ditch

This unit is located east of the 200 East Area. The hydraulic gradient was determined by extracting head values from the 200 East Area water table digital grid and performing a trend surface analysis, as described in Sections 2 and 3. The calculated gradient magnitude was 6.11×10^{-6} m/m, sloping to the southeast (143°). The estimated groundwater flow rate is 0.0011 m/d.

6.6 216-A-36B Crib

This crib is located in the southeast part of the 200 East Area south of the Plutonium-Uranium Extraction (PUREX) Plant. The hydraulic gradient was determined by extracting head values from the 200 East Area water table digital grid as described in Sections 3 and 4. The calculated gradient was 3.48×10^{-6} m/m, dipping to the southeast (136°). Estimated groundwater flow rates ranged from 0.0006 to 0.10 m/d.

6.7 216-A-37-1 Crib

This crib is located east of the southern part of the 200 East Area. The hydraulic gradient was determined by extracting head values from the 200 East Area water table digital grid as described in Sections 2 and 3. The calculated gradient magnitude was 6.35×10^{-6} m/m, with a direction of southeast (142°). Estimated groundwater flow rates range from 0.0004 to 0.19 m/d.

6.8 216-B-3 Pond

This pond is located east of the 200 East Area. The hydraulic gradient was determined using water level measurements collected during January, March, and July 2016, with consistent results for the three periods. The average gradient was 1.40×10^{-3} m/m, dipping to the southwest (228°). Statistical indicators showed a good fit. The estimated groundwater flow rate is 0.0056 m/d.

6.9 216-B-63 Trench

This facility is located in the northern part of the 200 East Area and is adjacent to LLWMA 2. The hydraulic gradient was determined jointly for this site and the adjacent LLWMA-2 by extracting head values from the 200 East Area water table digital grid as described in Sections 2 and 3. The average gradient was 2.12×10^{-6} m/m dipping to the southeast (130°). The groundwater flow rate was estimated to be 0.18 m/d.

Revised estimates of the hydraulic gradient and flow rate were based on (a) low-gradient water table map, and (b) inferred radius of influence associated with local groundwater pumping from October 2015 to September 2016, as reflected by modeling results from the treatability test report and review of groundwater chemistry. The resulting groundwater gradient was 1.06×10^{-6} m/m, dipping to the southeast. Estimated flow rate was 0.09 m/day.

6.10 216-S-10 Pond and Ditch

This unit is located in southern 200 West Area. Gradients were calculated for 3 data sets from March, May, and November 2016. The average gradient was 3.04×10^{-3} m/m dipping to the east (103°). Statistical indicators showed a good fit. Groundwater flow velocity estimates ranged from 0.03 to 1.3 m/d.

6.11 300 Area Process Trenches

This unit is located near the Columbia River in the 300 Area. The gradient in March 2016 was 2.42×10^{-4} m/m dipping to the south-southeast (163°). Statistical indicators showed a good fit. Groundwater flow velocity was estimated at 13 m/d.

The gradient in June 2016 had a magnitude of 2.88×10^{-4} m/m dipping to the south (170°). Statistical indicators showed a good fit. Groundwater flow velocity was estimated at 15 m/d.

6.12 Integrated Disposal Facility

This facility is located in the southeast part of the 200 East Area. The hydraulic gradient was determined by extracting head values from the 200 East Area water table digital grid as described in Sections 2 and 3. The calculated gradient magnitude was 3.11×10^{-6} m/m, with a direction of east-southeast (110°). The estimated groundwater flow rate is between 0.0021 and 0.0023 m/d.

6.13 Liquid Effluent Retention Facility

This facility is located just outside the northeast corner of the 200 East Area. The hydraulic gradient was determined by trend surface analysis of monthly water level measurements between May and October 2016. Due to the low gradient magnitude in this area, all wells used have been resurveyed for casing elevation and have had gyroscope surveys performed to control for deviation error. The water level data were corrected for barometric effects before performing the calculations. The average hydraulic gradient was 2.79×10^{-4} m/m toward the south (183 degrees) and the estimated groundwater flow rate is 0.11 m/d.

6.14 Low-Level Waste Management Area (LLWMA) 1

This unit is located in the northwest corner of the 200 East Area. The hydraulic gradient was determined by extracting head values from the 200 East Area water table digital grid as described in Sections 2 and 3. The calculated gradient was 3.07×10^{-6} m/m dipping to the southeast (137°). The groundwater flow rate was estimated to be 0.26 m/d.

Revised estimates of the hydraulic gradient and flow rate were based on (a) low-gradient water table map, (b) inferred radius of influence associated with local groundwater pumping from October 2015 to September 2016, as reflected by modeling results from the treatability test report and review of groundwater chemistry. The derived gradient in the northeast corner was 4.7×10^{-6} m/m dipping southeast. The gradient in the south part of LLWMA-1 was 1.8×10^{-6} m/m dipping to the east. The average groundwater flow rate ranged from 0.15 to 0.40 m/d.

6.15 LLWMA 2

This unit is located in the northern part of the 200 East Area and is adjacent to the 216-B-63 Trench. The hydraulic gradient was determined by extracting head values from the 200 East Area water table digital grid as described in Sections 2 and 3. The calculated gradient was 2.12×10^{-6} m/m dipping to the southeast (130°). Estimates of groundwater flow rates range from 0.016 to 0.071 m/d.

Revised estimates of the hydraulic gradient and flow rate were based on a local interpretation of the low-gradient water table map. Flow directions are interpreted to be to the south and southeast with a gradient of 5.6×10^{-6} m/m. Estimates of groundwater flow rates range from 0.04 to 0.19 m/d.

6.16 LLWMA 3

This unit is located in the northern 200 West Area. Two injection wells for the 200 West P&T system are located within the boundaries of LLMWA-3 and the water table cannot be approximated by a single plane. Therefore, flow calculations are based on data from wells east of the injection wells. In March 2016 the hydraulic gradient was 7.01×10^{-3} m/m dipping toward the east (96°). Statistical indicators showed a good fit but large residuals. Groundwater velocity was estimated to range from 0.18 to 0.70 m/d.

6.17 LLWMA 4

This unit is located in southwestern 200 West Area where the natural direction of groundwater flow is to the east. Injection wells for the 200 West P&T system are located west of LLWMA-4, creating a groundwater mound. In March 2016 the gradient was 5.03×10^{-3} m/m dipping to the east (82°). Statistical tests indicated a good fit. Groundwater velocity was estimated to range from 0.13 to 0.50 m/d.

6.18 Nonradioactive Dangerous Waste Landfill

This landfill is located southeast of the 200 East Area. The hydraulic gradient was determined using water level measurements collected during January, March, April, and October 2016. Due to the low gradient magnitude in this area, all wells used have been resurveyed for casing elevation and have had gyroscope surveys performed to control for deviation error. The calculated average gradient was 3.14×10^{-5} m/m, dipping to the east-southeast (123°). Statistical indicators showed only a moderately good fit. Average groundwater flow rates were between 0.16 and 0.48 m/d.

6.19 Waste Management Area (WMA) A-AX

These tank farms are located in the eastern part of the 200 East Area south of WMA C. The hydraulic gradient was determined by extracting head values from the 200 East Area water table digital grid as described in Sections 2 and 3. The calculated gradient was 4.61×10^{-6} m/m, dipping to the south-southeast (150°). The groundwater flow rate is estimated to be 0.091 m/d.

6.20 WMA B-BX-BY

These tank farms are located in the northwestern part of the 200 East Area east of LLWMA 1. The hydraulic gradient was determined by extracting head values from the 200 East Area water table digital grid as described in Sections 2 and 3. The calculated gradient was 1.68×10^{-6} m/m, dipping to the east (93°). The groundwater flow rate is estimated to be 0.14 to 0.16 m/d.

Revised estimates of the hydraulic gradient and flow rate were based on (a) low-gradient water table map, (b) inferred radius of influence associated with local groundwater pumping from October 2015 to September 2016, as reflected by modeling results from the treatability test report and review of groundwater chemistry. The gradient ranged from 1.10×10^{-6} to 3.9×10^{-6} m/m and flow directions ranged from northwest to southeast. The estimated groundwater flow rate ranged from 0.09 to 0.37 m/d.

6.21 WMA C

This tank farm is located in the eastern part of the 200 East Area north of WMA A-AX. The hydraulic gradient was determined by extracting head values from the 200 East Area water table digital grid as described in Sections 2 and 3. The calculated gradient was 3.67×10^{-6} m/m dipping to the south-southeast (154°). The groundwater flow rate is estimated to be 0.31 m/d.

Revised estimates of the hydraulic gradient and flow rate were based on the low-gradient water table network. Quarterly calculations were completed during 2016 using 12-month rolling average to verify consistency. The hydraulic gradient declined from 2.6×10^{-5} m/m in January to 4.13×10^{-6} in September 2016. Flow rate ranged from 2.2 m/d in January to 0.35 m/d in September. The flow direction was estimated to be between 160° and 170°.

6.22 WMA S-SX

These tank farms are located in the southern 200 West Area. Two extraction wells for the 200 West P&T system operate immediately east of the WMA. Gradients were calculated for monthly data sets from January to October 2016; results were consistent. The average gradient was 3.50×10^{-3} m/m dipping toward the east (86°). Statistical indicators showed a good fit. Groundwater flow velocity estimates ranged from 0.020 to 0.56 m/d.

6.23 WMA T

This tank farm is located in northern 200 West Area. An extraction well for the 200 West P&T is located east of the site. Using March 2016 data, the gradient was 6.63×10^{-3} m/m dipping toward the east-southeast (108°). Statistical indicators showed a good fit. Estimated groundwater velocity ranged from 0.41 to 0.64 m/d.

6.24 WMA TX-TY

These tank farms are located in central 200 West Area. 200 West P&T system extraction wells are located on the east and west sides of the WMA. Consequently, a plane could not be fit to the data. Instead, flow directions and gradient magnitude were estimated from the water table contours. In the northern part of the WMA the flow direction in March 2016 was to the east-southeast with a gradient of 8.4×10^{-3} m/m. In the southern part of the WMA the flow direction was to the east-northeast with a gradient of 7.7×10^{-3} m/m. Estimated flow rates ranged from 0.0031 to 0.89 m/d.

6.25 WMA U

The tank farm is located in southern 200 West Area. Gradients were calculated for March, June, and September 2016 with consistent results. Statistical tests indicate a good fit. The average gradient was 4.97×10^{-3} m/m dipping to the east (89°). Groundwater velocity estimates ranged from 0.04 to 0.47 m/d.

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Table 1. Results of Gradient and Velocity Calculations

WMA	Date (2016)	v min (m/d)	v max (m/d)	Gradient (m/m)	Direction (degrees east of north)	Goodness of Fit (R^2)	Correlation Coefficient (R):	P Value	Hydrologic Properties (references)	Comments
Gradients Estimated from Measured Data										
1301-N	Mar	0.018	0.33	9.04E-04	343	0.98	0.99	0.021	K = 6.1 to 37 m/d (PNL-8335); n_e = 0.10 to 0.30	
	Sep	0.051	0.93	2.51E-03	324	0.94	0.97	0.0031		
1324-N/NA	Mar	0.018	0.33	8.93E-04	21	0.98	0.99	0.021	K = 6.1 to 37 m/d (PNL-8335); n_e = 0.10 to 0.30	Influenced by 100-K injection wells.
	Sep	0.017	0.31	8.45E-04	4	0.96	0.98	0.038		
1325-N	Mar	0.02	0.35	9.35E-04	357	0.97	0.98	0.0002	K = 6.1 to 37 m/d (PNL-8335); n_e = 0.10 to 0.30	
	Sep	0.02	0.29	7.76E-04	9	0.99	0.99	0.012		
183-H	Mar	0.13	3.5	2.53E-03	240	0.97	0.98	0.031	K = 15 to 140 m/d (PNL-6728); n_e = 0.10 to 0.30	Extraction wells to east, injection wells to west
	Nov	0.07	2.0	1.45E-03	153	0.96	0.98	**0.19**		Used AWLN daily average data
216-B-3	Jan, Mar, Jul	0.0056	0.0056	1.34 E-03 to 1.49E-03 Av 1.40E-03	227 to 229 Av 228	0.97 to 0.99	0.99	0.024 to **0.11**	K = 1 m/d (WHC-SD-EN-EV-002; PNL-10195); n_e = 0.25 (assumed)	Average of 3 months
216-S-10	Mar, May, Nov	0.030	1.3	2.98E-03 to 3.14E-03 Av 3.04E-03	101 to 104 Av 103	0.98 to 1.0	0.99 to 1.0	0.004 to 0.04	K = 2 to 42.7 m/d (PNL-8337); n_e = 0.1 to 0.2 (assumed)	Average of 3 months

Table 1. Results of Gradient and Velocity Calculations

WMA	Date (2016)	v min (m/d)	v max (m/d)	Gradient (m/m)	Direction (degrees east of north)	Goodness of Fit (R^2)	Correlation Coefficient (R):	P Value	Hydrologic Properties (references)	Comments
300 APT	Mar	13	13	2.42E-04	163	0.92	0.96	0.0002	K = 9,000 m/d; n_e = 0.17 (PNL-17708)	
	Jun	15	15	2.88E-04	170	0.95	0.97	0.000		
LERF	May-Oct	0.11	0.11	2.62E-04 to 2.96E-04 Av 2.79E-04	177 to 186 Av 183	0.95	0.95 to 1.0	0.004 to 0.053	K = 39.5 m/d (DOE/RL-2013-46); n_e =0.1 (assumed)	Average of 11 months*
LLWMA-3	Mar	0.18	0.70	7.01E-03	96	0.98	0.99	0.0003	K= 2.5 to 10 m/d; n_e = 0.10 (PNNL-14753)	200 West P&T injection wells in WMA. Gradient calculated east of injection wells
LLWMA-4	Mar	0.13	0.50	5.03E-03	82	0.99	0.99	0.0015	K= 2.5 to 10 m/d; n_e = 0.10 (PNNL-14753)	P&T injection wells west of WMA
NRDWL	Jan, Mar, Apr, Oct	0.16	0.48	1.93E-05 to 5.37E-05 Av 3.14E-05	105 to 147 Av 123	0.62 to 0.92	0.79 to 0.96	0.001 to 0.022	K = 518 to 1,524 (WHC-EP-0021); n_e = 0.1 (assumed)	Average of 4 months
WMA S-SX	Jan-Oct	0.02	0.56	3.39E-03 to 3.68E-03 Av 3.50E-03	82 to 91 Av 86	0.89 to 0.93	0.94 to 0.97	0.000 to 0.0011	K = 1.33 to 14.4 m/d (PNNL 14113 and PNNL-14186); n_e = 0.09 to 0.2 (assumed)	Average of 10 months
WMA T	Mar	0.41	0.64	6.63E-03	108	0.97	0.99	0.0001	K = 6 to 10 m/d; n_e = 0.10 (PNNL-17732)	P&T extraction well east of WMA. Excluded 2 wells with large residuals

Table 1. Results of Gradient and Velocity Calculations

WMA	Date (2016)	v min (m/d)	v max (m/d)	Gradient (m/m)	Direction (degrees east of north)	Goodness of Fit (R^2)	Correlation Coefficient (R):	P Value	Hydrologic Properties (references)	Comments
WMA TX-TY (north)	Mar	0.0031	0.89	8.4E-03	ESE	N/A	N/A	N/A	K= 0.07 to 19.9 (PNNL-18279); n_e = 0.18 (DOE/RL- 2009-38)	Directions and gradient estimated from water table contours. Flow rate based on average gradient 8.0E-04.
WMA TX-TY (south)	Mar			7.7E-03	ENE					
WMA U	Mar, Jun, Sep	0.04	0.47	4.97E-03	89	0.99 to 1.00	1.00	0.000	K = 1.69 to 9.5 m/d (PNNL-13378); n_e = 0.1 to 0.2 (assumed)	Average of 3 months
Gradients Estimated from Digital Grid of Low Gradient Region, October 2015 through September 2016										
216-A-29	FY 2016	0.0011	0.0011	6.11E-06	143	0.99	0.99	0.000	K = 18 m/d (WHC-SD-EN-DP-047); n_e = 0.1 (assumed)	Based on digital grid
216-A-36B	FY 2016	0.0006	0.10	3.48E-06	136	0.93	0.97	0.000	K = 18 to 3,000 m/d (PNNL-11523); n_e = 0.1 (assumed)	Based on digital grid
216-A-37-1	FY 2016	0.0004	0.19	6.35E-06	142	1.00	1.00	0.000	K = 18 to 300 m/d (PNNL-11523); n_e n = 0.1 to 0.3 (assumed)	Based on digital grid
216-B-63	FY 2016	0.18	0.18	2.12E-06	130	0.94	0.97	0.000	K = 17,000; n_e = 0.2 (CP-57037)	Also see "gradients estimated by other methods"

Table 1. Results of Gradient and Velocity Calculations

WMA	Date (2016)	v min (m/d)	v max (m/d)	Gradient (m/m)	Direction (degrees east of north)	Goodness of Fit (R^2)	Correlation Coefficient (R):	P Value	Hydrologic Properties (references)	Comments
IDF	FY 2016	0.0021	0.0023	3.11E-06	110	0.92	0.96	0.000	K = 68 to 75 m/d (PNNL-13652, PNNL-11957); n_e = 0.1 (assumed)	Based on digital grid
LLWMA-1	FY 2016	0.26	0.26	3.07E-06	137	0.92	0.96	0.000	K = 17,000; n_e = 0.2 (CP-57037)	Also see "gradients estimated by other methods"
LLWMA-2	FY 2016	0.016	0.071	2.12E-06	130	0.94	0.97	0.000	K = 1,500 to 6,700 m/d (PNL-6820); n_e = 0.2 (CP-57037)	Also see "gradients estimated by other methods"
WMA A-AX	FY 2016	0.091	0.091	4.61E-06	150	0.97	0.99	0.000	K = 1,981 m/d (PNL-8337, WHC-SD-EN-TI-019); n_e = 0.1 (assumed)	Based on digital grid
WMA B-BX-BY	FY 2016	0.14	0.16	1.68E-06	93	0.81	0.90	0.000	K = 17,000 (200-BP-5 treatability test results) to 18,800 m/d (CP-57037); n_e = 0.2 (CP-57037)	Also see "gradients estimated by other methods"
WMA C	FY 2016	0.31	0.31	3.67E-06	154	0.98	0.99	0.000	K = 17,000; n_e = 0.2 (CP-57037)	Also see "gradients estimated by other methods"

Table 1. Results of Gradient and Velocity Calculations

WMA	Date (2016)	v min (m/d)	v max (m/d)	Gradient (m/m)	Direction (degrees east of north)	Goodness of Fit (R^2)	Correlation Coefficient (R):	P Value	Hydrologic Properties (references)	Comments
Gradients Estimated by Other Methods										
216-B-63	FY 2016	0.09	0.09	1.06E-06	SE	N/A	N/A	N/A	K = 17,000; n_e = 0.2 (CP-57037)	Interpreted from water table map and inferred radius of influence of local groundwater extraction
LLWMA-1 (north part)	FY 2016	0.15	0.40	4.7E-06	SE	N/A	N/A	N/A	K = 17,000; n_e = 0.2 (CP-57037)	Interpreted from water table map and inferred radius of influence of local groundwater extraction
LLWMA-1 (south part)				1.8E-06	E	N/A	N/A	N/A		
LLWMA-2	FY 2016	0.04	0.19	5.6E-06	S and SE	N/A	N/A	N/A	K = 1,500 to 6,700 m/d (PNL-6820); n_e = 0.2 (CP-57037)	Interpreted from water table map
WMA B-BX-BY	FY 2016	0.09	0.37	1.1E-06 to 3.9E-06	NW to SE	N/A	N/A	N/A	K = 17,000 (200-BP-5 treatability test results) to 18,800 m/d (CP-57037); n_e = 0.2 (CP-57037)	Interpreted from water table map and inferred radius of influence of local groundwater extraction
WMA C	FY 2016	2.2	0.35	4.13E-06 to 2.6E-05	160° to 170°	N/A	N/A	N/A	K = 17,000; n_e = 0.2 (CP-57037)	Interpreted from water table map

Terms:

AWLN = Automated Water Level Network

Table 1. Results of Gradient and Velocity Calculations

WMA	Date (2016)	v min (m/d)	v max (m/d)	Gradient (m/m)	Direction (degrees east of north)	Goodness of Fit (R^2)	Correlation Coefficient (R):	P Value	Hydrologic Properties (references)	Comments

IDF = integrated disposal facility

LERF = Liquid Effluent Treatment Facility

LLWMA = low-level waste management area

K = horizontal hydraulic conductivity

N/A = not applicable

n_e = effective porosity

P&T = pump and treat

v = average linear velocity

WMA = waste management area