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Revision 0

Groundwater Hydraulic Gradient and Velocity Calculations for 200 East Area RCRA Sites in 2011

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

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

CH2MHILL
Plateau Remediation Company
P.O. Box 1600
Richland, Washington 99352

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CH2MHILL
Plateau Remediation Company
P.O. Box 1600
Richland, Washington 99352

APPROVED
By Julia Raymer at 2:56 pm, Oct 02, 2013

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CH2MHILL
Plateau Remediation Company

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Preparer: J.P. McDonald	**Basis of Qualification:** Hydrogeologist
Checker: G.S. Thomas	**Basis of Qualification:** Hydrogeologist
Senior Reviewer: M.J. Hartman	**Basis of Qualification:** Hydrogeologist

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NAME/POSITION
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NAME/POSITION
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Responsible Manager: W.R. Faught
NAME/POSITION
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Contents

Appendices

1 Purpose

This environmental calculation describes the methodology, data, and results of calculating some of the groundwater flow velocities reported in *Hanford Site Groundwater Monitoring for 2011* (DOE/RL-2011-118, Appendix B, Table B-1). The focus of this calculation documentation are waste sites monitored under the *Resource Conservation and Recovery Act of 1976* (RCRA) in the 200 East Area and vicinity, although RCRA sites overlying the 200-UP-1 Operable Unit in the 200 West Area are also included (i.e., 216-S-10 Pond & Ditch, Waste Management Area [WMA] S-SX, and WMA U). Groundwater flow velocity calculations for the remaining RCRA sites at Hanford, as published in DOE/RL-2011-118, are documented in *Hydraulic Gradients and Velocity Calculations for RCRA Sites in 2011* (ECF-HANFORD-12-0048).

The RCRA sites addressed in this calculation documentation include the 216-A-29 Ditch, 216-A-36B Crib, 216-A-37-1 Crib, 216-B-3 Pond, 216-B-63 Trench, 216-S-10 Pond & Ditch, Integrated Disposal Facility (IDF), Liquid Effluent Retention Facility (LERF), Low-Level Waste Management Area 1 (LLWMA-1), LLWMA-2, WMA A-AX Tank Farm, WMA B-BX-BY Tank Farm, WMA C Tank Farm, WMA S-SX Tank Farm, and WMA U Tank Farm.

2 Background

Hydraulic gradients are determined by analysis of water-level elevation differences between monitoring wells. At many of the sites discussed in this calculation, differences in water-level elevations were analyzed by trend-surface analysis in which a plane is fit to a set of water-level measurements by least-squares regression (described below). This process is fairly straightforward in areas where the hydraulic gradient magnitude is large (e.g., in the 200 West Area) because elevation differences between wells are much larger than the variability (or noise) in the measurements themselves. Where the hydraulic gradient magnitude is low, however, it is much harder to resolve the small water-level elevation differences that occur between monitoring wells.

The water table is very flat over much of the 200 East Area. The variability of 200 East Area water-level measurements is typically up to 0.20 m (0.66 ft) (or 20 cm [7.9 in.]) and more in some instances. At the scale of individual waste sites, this is larger than the hydraulic gradient magnitude in which water-level elevations are expected to differ by only a few centimeters. Thus, water-level measurements cannot be used to determine hydraulic gradients at most 200 East Area RCRA sites unless specific measures are taken to reduce measurement variability.

Sources of variability in water-level measurements include deviation of wellbores from vertical, accuracy of casing elevation surveys, accuracy of depth to water measurements, well construction, and fluctuations of barometric pressure. Measures have been taken to reduce measurement variability at five RCRA sites in the 200 East Area: LLWMA-1, LLWMA-2, LERF, and IDF, and the 216-A-36B Crib combined. These measures include gyroscope surveys of borehole paths in three-dimensional space to allow for wellbore deviation corrections, highly accurate resurveys of casing elevations, and careful selection of wells to minimize vertical flow caused by long-open intervals or mud units within the open interval. These measures also ensure that only a single measurement device is used to collect water-level measurements, and uses normalization of the water-level elevations to a constant barometric pressure using the multiple regression/deconvolution technique described in *Identifying and Removing Barometric Pressure Effects in Confined and Unconfined Aquifers* (Rasmussen and Crawford, 1997). The methods, data analysis, and calculation results of this work are described in *Calculations in Support of the Low Hydraulic Gradient Evaluation Study for the 200 East Area Unconfined Aquifer* (ECF-200E-12-0086).

3 Methodology

This section describes the method of trend-surface analysis was adapted from ECF-200E-12-0086.

3.1 Trend-Surface Analyses

In trend-surface analysis, a plane is fit to a set of water-level elevation measurements by least-squares regression. The regression equation used was from *Statistics and Data Analysis in Geology*, Equation 5.84 (Davis, 2002):

$$z = b_0 + b_1 x + b_2 y \qquad \textbf{(Equation 1)}$$

where:

z = predicted water-level elevation (m) at a location x,y, in which x is the easting geographic coordinate (m) and y is the northing geographic coordinate (m)

b_0 = offset (m)

b_1 = slope in the x direction (m/m)

b_2 = slope in the y direction (m/m)

Equation 1 can be rearranged as follows:

$$b_1 x + b_2 y - z + b_0 = 0 \qquad \textbf{(Equation 2)}$$

This equation has the same form as the following:

$$Ax + By + Cz + D = 0 \qquad \textbf{(Equation 3)}$$

where:

C = -1 (which is the familiar equation of a plane in standard form)

The least-squares regression for each set of water-level measurements was performed by solving the following matrix equation for the regression coefficients b_0, b_1, and b_2 (Davis, 2002; Equation 5.86):

$$\begin{bmatrix} k & \sum_{j=1}^{k} x_j & \sum_{j=1}^{k} y_j \\ \sum_{j=1}^{k} x_j & \sum_{j=1}^{k} x_j^2 & \sum_{j=1}^{k} x_j y_j \\ \sum_{j=1}^{k} y_j & \sum_{j=1}^{k} x_j y_j & \sum_{j=1}^{k} y_j^2 \end{bmatrix} \cdot \begin{bmatrix} b_0 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} \sum_{j=1}^{k} z_j \\ \sum_{j=1}^{k} x_j z_j \\ \sum_{j=1}^{k} y_j z_j \end{bmatrix} \qquad \textbf{(Equation 4)}$$

where:

k = number of wells

x_j = easting geographic coordinate of the j^{th} well (m)

y_j = northing geographic coordinate of the j^{th} well (m)

z_j = hydraulic head in the j^{th} well (m)

Equation 4 was solved in a spreadsheet modeled after the spreadsheet in "A Spreadsheet Method of Estimating Best-Fit Hydraulic Gradients Using Head Data from Multiple Wells" (Devlin, 2003) using the matrix math functions in Microsoft[1] Excel®. The spreadsheet used is documented in Appendix A.

The hydraulic gradient magnitude is represented by the slope of the fitted plane. It follows from mathematics that vector $<A,B,C>$ is a normal vector to the plane (i.e., a vector perpendicular to the plane) in Equation 3; therefore, vector $<b_1,b_2,-1>$ is a normal vector to the plane represented in Equation 2 (because $C = -1$ in Equation 2). The slope of the fitted plane, which is the gradient magnitude, was calculated from the deviation of vector $<b_1,b_2,-1>$ from the vertical (i.e., its "tilt") using the Pythagorean theorem as follows:

$$i = \left(b_1^2 + b_2^2\right)^{1/2} \quad \textbf{(Equation 5)}$$

Vector $<b_1,b_2,-1>$ begins at the origin of the coordinate system and points in the negative z direction (i.e., downward), because $C = -1$. Thus, the vector $<-b_1,-b_2,1>$ is also a normal vector to the fitted plane pointing in the positive z direction (i.e., upward). This vector can be projected onto the x,y plane by setting $C = 0$, and the direction of the resulting vector, $< -b_1, -b_2, 0>$, is the direction of the hydraulic gradient. This direction was calculated from $-b_1$ and $-b_2$ using trigonometric functions.

3.2 Statistical Test

The degree to which the fitted plane represented the data (i.e., the goodness of fit) was assessed by an analysis of variance (ANOVA) statistical test. This test identifies whether the data exhibit a true spatially dependent trend to an acceptable probability of error (i.e., the level of significance), which is chosen to be 0.05 (i.e., a 95 percent confidence level). The ANOVA was performed by constructing a standard ANOVA table (Davis, 2002), as shown in Table 1.

Table 1. Standard ANOVA Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	*F*-Test Statistic
Polynomial regression	SS_R	2	MS_R	MS_R / MS_D
Deviation from Polynomial	SS_D	$k - 3$	MS_D	—
Total variation	SS_T	$k - 1$	—	—

In Table 1, SS_R is the sum of squares due to the regression and is given as follows (Davis, 2002; Equation 4.20):

$$SS_R = \sum_{j=1}^{k} (\hat{z}_j - \overline{Z})^2 \quad \textbf{(Equation 6)}$$

where:

$\hat{z}_j$ = predicted water-level elevation in the j[th] well

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1 The Microsoft® products identified in this calculation are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or in other countries.

$\overline{Z}$ = mean of all the water-level elevations (either the actual measurements or the predicted measurements because the mean will be the same for both sets)

SS_D is the sum of squares due to the deviations (i.e., the sum of squares of the residuals) and is given by the following equation (Davis, 2002; Equation 4.22):

$$SS_D = \sum_{j=1}^{k} (\hat{z}_j - z_j)^2 \quad \textbf{(Equation 7)}$$

SS_T is the total sum of squares and is given by the following equation (Davis, 2002; Equation 4.18):

$$SS_T = \sum_{j=1}^{k} (z_j - \overline{Z})^2 \quad \textbf{(Equation 8)}$$

The degrees of freedom associated with the regression is one less than the number of coefficients in the fitted equation (i.e., two degrees of freedom because Equation 1 has three coefficients: b_0, b_1, and b_2). The degrees of freedom associated with the total variation is one less than the number of measurements (k), and the degrees of freedom associated with the deviations is the degrees of freedom for the total variation less the degrees of freedom for the regression (i.e., $[k - 1] - 2$, or $k - 3$). The mean squares, which are estimates of the variance, are the sums of squares divided by the associated degrees of freedom, and the test statistic is the ratio of the mean squares (or variance estimates).

The statistical test was performed using the *F* probability distribution. As stated in Davis (2002, p. 75), this distribution "…is the theoretical distribution of values that would be expected by randomly sampling from a normal population and calculating, for all possible pairs of sample variances, the ratios" of those variances. The ANOVA was performed by comparing the test statistic in Table 1 with the *F*-distribution to determine the probability of obtaining the observed test statistic (or a larger test statistic) by random sampling from the same population. If that probability (i.e., the *p*-value) was small (i.e., less than 0.05), then it was concluded that the two variances are from separate populations (i.e., there is a spatially dependent trend in the water-level measurements).

3.3 Goodness of Fit

Two other parameters were calculated as part of the trend-surface analyses: the goodness of fit coefficient (R^2) and the correlation coefficient (R). The goodness of fit coefficient is the ratio of the sum of squares due to the regression (SS_R, given by Equation 6) to the total sum of squares (SS_T, given by Equation 8), as follows (Davis, 2002; Equation 4.23):

$$R^2 = \frac{SS_R}{SS_T} \quad \textbf{(Equation 9)}$$

If the measurements fit a plane closely, SS_R and SS_T will be approximately equal and their ratio, R^2, will be approximately one. If the measurements do not fit a plane very well, the best fit plane will be nearly horizontal. In this case, SS_R will be small compared to SS_T and their ratio will be near zero. Thus, the more closely an R^2 value is to unity, the better the measurements fit a plane. The correlation coefficient is the square root of the goodness of fit coefficient.

As part of the trend-surface analyses, potential outliers in the hydraulic head measurements were identified using the interquartile range (IQR) approach described in *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance* (EPA 530/R-09-007). With this approach, the 25^{th} and 75^{th} percentiles of the residuals (i.e., the observed hydraulic head less the predicted hydraulic head) are computed. The difference between these values is the IQR, and any residual less than the 25th percentile minus 1.5 times the IQR or greater than the 75th percentile plus 1.5 times the IQR was identified as a potential outlier. Potential outliers were evaluated case-by-case to determine whether they should be included in the analysis.

For some sites, the hydraulic gradient results were summarized as mean values of multiple trend-surface analyses. Uncertainties on these mean values were calculated as 1.65 times the standard error of the results (i.e., a 90 percent confidence interval). The standard error was used rather than the standard deviation, because each trend-surface result is itself a type of mean of the measurements collected on the given date. Thus, the mean of a set of trend-surface results is a mean of means and so the standard error is applicable to estimating confidence intervals (see the "Confidence Intervals" section in Davis, 2002; pp. 66-68). The standard error is given by the following (Davis, 2002; Equation 2.38):

$$s_e = \sigma\sqrt{\frac{1}{n}} \qquad \textbf{(Equation 10)}$$

where:

s_e = standard error, σ is the standard deviation of the trend-surface analyses results (either the magnitude or direction)

n = number of trend-surface analyses used to calculate the mean

Where only three wells were used in the trend-surface analyses (i.e., at LERF), the uncertainty was expressed as 1.65 times the standard deviation of the results. When only three wells were used in the analysis, the fitted plane was considered to be an exact solution and not a type of mean.

3.4 Flow Rate Calculations

Flow rates were calculated using Darcy's Law, as follows (modified from *Applied Hydrogeology* [Fetter, 1988]):

$$v = \frac{K}{n_e} \cdot \frac{\Delta h}{\Delta l} \qquad \textbf{(Equation 11)}$$

where:

v = average linear velocity (m/d)

K = hydraulic conductivity (m/d)

n_e = effective porosity (unitless)

$\Delta h/\Delta l$ = average hydraulic gradient magnitude across the waste site (m/m)

4 Assumptions and Inputs

A trend-surface analysis result represents the mean, linear trend of the hydraulic gradient for the area being analyzed. The result will be most representative if the true hydraulic gradient across the study area is uniform. This is generally a good assumption at the scale of an individual waste site (LERF is one exception discussed in Section 7).

The best flow velocity estimates are obtained from Darcy's Law if the aquifer is homogeneous and isotropic. No aquifer is truly homogeneous and isotropic, but as long as the hydraulic gradient, hydraulic conductivity, and effective porosity are good average values for the site, the calculated flow rate will be representative of an average flow rate.

Input data to these calculations consisted of well location coordinates and water-level measurements. Coordinates were obtained from the Hanford Well Information System (HWIS), and water-level data were obtained from the HydroDat database. Assumptions applicable to the hydraulic gradient and flow velocity determinations at specific RCRA sites are described in Section 7.

5 Software Applications

The HydroDat database is the official repository for Hanford Site manual water-level measurements. HydroDat is a software application maintained in Microsoft SQL Server®, which is controlled under procedure PRC-PRO-IRM-309, *Controlled Software Management*, and is registered on the Hanford Information System Inventory (HISI) as approved for use. The HISI documentation for HydroDat is provided in Appendix D. HydroDat was the correct software for use in this application because it is the official repository for Hanford Site manual groundwater-level measurements. HydroDat was used within its limitations.

Microsoft Excel, which is exempt from the requirements of PRC-PRO-IRM-309, was also used in calculating hydraulic gradients and flow velocities.

6 Calculations

Calculations of the hydraulic gradient for 216-A-36B Crib, IDF, LERF, LLWMA-1, and LLWMA-2 are provided in ECF-200E-12-0086. The results in ECF-200E-12-0086 were also assumed to apply to the 216-A-29 Ditch, 216-A-37-1 Crib, 216-B-63 Trench, WMA A-AX, WMA B-BX-BY, and WMA C, which are also located above the region of the aquifer with the flat water table. Hydraulic gradients for the 216-B-3 Pond, 216-S-10 Pond & Ditch, WMA S-SX, and WMA U were determined by trend-surface analyses documented in Appendix B. Flow rate calculations are documented in Appendix C.

7 Results

Results of the hydraulic gradient and flow velocity determinations are described in this section. Those sites directly addressed by ECF-200E-12-0086 are discussed first, along with other 200 East Area RCRA sites with a very low hydraulic gradient magnitude (i.e., a flat water table). Results are then presented for the remaining RCRA sites not affected by the flat water table.

7.1 RCRA Sites in the Region of Low Hydraulic Gradient Magnitude

7.1.1 Integrated Disposal Facility

The IDF and 216-A-36B Crib are located adjacent to each other and were analyzed by trend-surface analysis as a single site. The wells used in the analysis are part of the low-gradient evaluation network established within the 200 East Area, and all of the measures described in Section 2 to reduce the variability of the data were applied. The trend-surface calculations are documented in ECF-200E-12-0086 and the results are summarized in Table 2. The magnitude and direction of the hydraulic gradient were taken as the average of the specific trend-surface analysis results between June 2008 and December 2011. The uncertainty on the means was calculated as 1.65 times the standard error (Equation 10). The final result was a gradient magnitude of 2.2×10^{-5} m/m ($\pm 0.2 \times 10^{-5}$ m/m) at 71 (±11) degrees azimuth (east-northeast).

Table 2. Results of Trend-Surface Analyses for IDF and 216-A-36B Crib (from ECF-200E-12-0086)

Measurement Date	Gradient Magnitude (m/m)	Gradient Direction (Azimuth)[a]	R^2	*p*-Value[b]	Number of Measurements
6/16/2008	1.8×10^{-5}	58	0.81	0.0064	9
8/1/2008	1.8×10^{-5}	138	0.65	0.0411	9
8/29/2008	2.3×10^{-5}	63	0.78	0.0047	10
9/10/2008	No valid result				
10/23/2008	2.5×10^{-5}	52	0.81	0.0065	9
11/26/2008	1.2×10^{-5}	55	0.91	0.0283	6
12/22/2008	1.7×10^{-5}	108	0.92	0.0072	7
1/26/2009	No valid result				
2/5/2009	3.8×10^{-5}	47	0.95	0.0006	8
3/24/2009	1.9×10^{-5}	59	0.89	0.0039	8
6/29/2009	2.2×10^{-5}	36	0.95	0.0108	6
9/22/2009	2.6×10^{-5}	52	0.86	0.0069	8
12/30/2009	2.8×10^{-5}	73	0.88	0.0015	9
3/16/2010	2.0×10^{-5}	49	0.86	0.0071	8
6/30/2010	No valid result				
9/14/2010	1.4×10^{-5}	49	0.99	0.0001	7
3/18/2011	2.2×10^{-5}	57	0.78	0.0110	9
6/20/2011	2.4×10^{-5}	89	0.84	0.0102	8
9/22/2011	2.1×10^{-5}	89	0.99	0.0001	7
12/29/2011	2.7×10^{-5}	104	0.90	0.0009	9
Means for 6/16/2008 through 12/29/2011	*2.2×10^{5} ($\pm 0.2 \times 10^{5}$)*	*71 (±11)*			

a. Degrees clockwise from true north; 90 = east, 180 = south, 270 = west, 0 and/or 360 = north.

b. The probability that the degree of an apparent spatially dependent trend observed in the data (or a trend of even greater degree) would occur solely by random chance. If the *p*-value is less than 0.05, the fitted trend surface is deemed statistically significant.

Flow velocities were calculated using the average gradient magnitude, an assumed effective porosity range of 0.1 to 0.3, and a hydraulic conductivity range of 65 to 75 m/d (PNNL-13652, *Geologic and Wireline Borehole Summary from the Second ILAW Borehole [299-E24-21]*; PNNL-11957, *Immobilized Low-Activity Waste Site Borehole 299-E17-21*). The results were 0.005 to 0.02 m/d.

7.1.2 216-A-36B Crib

The hydraulic gradient for this site was determined to be 2.2×10^{-5} m/m ($\pm 0.2 \times 10^{-5}$ m/m) at 71 (±11) degrees azimuth (east-northeast) (see Table 2 and the IDF section above). Flow velocities were calculated using the average gradient magnitude, an assumed effective porosity range of 0.1 to 0.3, and a hydraulic conductivity range of 18 to 3,000 m/d (PNNL-11523, *Interim-Status RCRA Groundwater Monitoring Plan for the 216-A-10, 216-A-36B, and 216-A-37-1 PUREX Cribs*). The results were 0.001 to 0.66 m/d (the latter reported as 0.6 m/d in DOE/RL-2011-118).

7.1.3 Low-Level Waste Management Area 1

This site is included in the low-gradient evaluation study and has a network of wells established for water-level monitoring in which all of the measures to reduce measurement variability described in Section 2 have been applied. The trend-surface calculations for this site in 2011 are documented in ECF-200E-12-0086 and the results are summarized in Table 3. The hydraulic gradient was indeterminate between January and June 2011, as evidenced by the relatively low goodness of fit coefficients during this time (0.16 to 0.49). Beginning in July, the trend-surface analyses indicated a statistically significant hydraulic gradient toward the south with relatively high goodness of fit coefficients (up to 0.86). Thus, the groundwater flow direction changed during 2011 at this site. Because of this, the gradient magnitude and direction were reported as variable for the year and no flow rate calculations were made.

Table 3. 2011 Results of Trend-Surface Analyses for LLWMA-1 (from ECF-200E-12-0086)

Measurement Date	Gradient Magnitude (m/m)	Gradient Direction (Azimuth)[a]	R^2	*p*-Value[b]	Statistically Significant?
1/4/2011	1.1×10^{-5}	358	0.26	0.1841	No
2/11/2011	1.1×10^{-5}	339	0.48	0.0288	Yes
3/21/2011	8.1×10^{-6}	311	0.29	0.1573	No
4/25/2011	7.3×10^{-6}	326	0.49	0.0362	Yes
5/25/2011	4.7×10^{-6}	18	0.29	0.2147	No
6/20/2011	3.3×10^{-6}	191	0.16	0.4179	No
7/14/2011	1.2×10^{-5}	192	0.51	0.0278	Yes
8/15/2011	2.0×10^{-5}	161	0.79	0.0045	Yes
8/29/2011	2.8×10^{-5}	176	0.86	0.0001	Yes
11/30/2011	3.2×10^{-5}	171	0.83	0.0001	Yes
12/29/2011	2.6×10^{-5}	172	0.77	0.0006	Yes

a. Degrees clockwise from true north; 90 = east, 180 = south, 270 = west, 0 and/or 360 = north.

b. The probability that the degree of an apparent spatially dependent trend observed in the data (or a trend of even greater degree) would occur solely by random chance. If the *p*-value is less than 0.05, the fitted trend surface is deemed statistically significant.

7.1.4 Low-Level Waste Management Area 2

This site is included in the low-gradient evaluation study and has a network of wells established for water-level monitoring in which all of the measures to reduce measurement variability described in Section 2 have been applied. The trend-surface calculations for this site in 2011 are documented in ECF-200E-12-0086 and the results are summarized in Table 4. Statistically significant results were achieved for only 6 of the 11 data sets analyzed. Those that were significant yielded results indicating a hydraulic gradient direction toward the north-northeast straight toward a basalt subcrop above the water table. A complication in the trend-surface analyses is that many of the wells are located along a line parallel to the southern boundary of LLWMA-2, which is a poor geometry for trend-surface analyses.

Table 4. 2011 Results of Trend-Surface Analyses for LLWMA-2 (from ECF-200E-12-0086)

Measurement Date	Gradient Magnitude (m/m)	Gradient Direction (Azimuth)[a]	R^2	*p*-Value[b]	Number of Measurements
1/4/2011	2.1×10^{-5}	16	0.74	0.0348	8
2/11/2011	4.8×10^{-5}	33	0.94	0.0145	6
3/21/2011	No valid result				
4/25/2011	2.6×10^{-5}	23	0.92	0.0063	7
5/25/2011	1.5×10^{-5}	15	0.99	0.0001	7
6/20/2011	No valid result				
7/14/2011	2.7×10^{-5}	20	0.97	0.0043	6
8/15/2011	No valid result				
9/26/2011	No valid result				
11/30/2011	1.4×10^{-5}	38	0.80	0.0414	7
12/29/2011	No valid result				

a. Degrees clockwise from true north; 90 = east, 180 = south, 270 = west, 0 and/or 360 = north.

b. The probability that the degree of an apparent spatially dependent trend observed in the data (or a trend of even greater degree) would occur solely by random chance. If the *p*-value is less than 0.05, the fitted trend surface is deemed statistically significant.

Because of this and the difficulty obtaining statistically significant results at this site, it was concluded that the hydraulic gradient was too low to measure. The hydraulic gradient magnitude and direction were reported as indeterminate in DOE/RL-2011-118 and the flow rate was not calculated.

7.1.5 Liquid Effluent Retention Facility

Due to an oversight, the hydraulic gradient and flow velocity results for LERF published in DOE/RL-2011-118 were actually the values for 2010 and not for 2011. This calculation documentation provides the hydraulic gradient and flow velocity results for 2011.

The trend-surface analysis results for 2011 are shown in Table 5 (the calculations are documented in ECF-200E-12-0086). This site is included in the low-gradient evaluation study and has a network of wells established for water-level monitoring in which all of the measures to reduce measurement variability described in Section 2 have been applied. The network consisted of three wells (299-E26-10, 299-E26-77, and 299-E26-79) until a newly drilled fourth well (299-E26-14) was added to the network in December 2011. The average trend surface result for the three-well network in 2011 was a gradient magnitude of 1.1×10^{-4} m/m ($\pm 0.7 \times 10^{-4}$ m/m) at 199 (±19) degrees azimuth (south-southwest) (see Table 5). With well 299-E26-14 in the network, the result for December 2011 was 2.8×10^{-4} m/m at 195 degrees azimuth (south-southwest).

Table 5. 2011 Results of Trend-Surface Analyses for LERF (from ECF-200E-12-0086)

Measurement Date	Gradient Magnitude (m/m)	Gradient Direction (Azimuth)[a]	R^2	*p*-Value[b]	Statistically Significant?
Three-Well Network (not including 299-E26-14)					
1/4/2011	8.1×10^{-5}	198	N/A	N/A	N/A
2/11/2011	1.6×10^{-4}	182	N/A	N/A	N/A
3/21/2011	1.7×10^{-4}	196	N/A	N/A	N/A
4/25/2011	1.5×10^{-4}	205	N/A	N/A	N/A
5/25/2011	6.7×10^{-5}	221	N/A	N/A	N/A
7/14/2011	4.8×10^{-5}	343	N/A	N/A	N/A
9/26/2011	8.1×10^{-5}	198	N/A	N/A	N/A
11/30/2011	9.0×10^{-5}	195	N/A	N/A	N/A
2011 Mean for the Three-Well Network (excluding 7/14/2011 result)	*1.1×10^{-4} ($\pm 0.7 \times 10^{-4}$)*	*199 (±19)*			
Four-Well Network (including 299-E26-14)					
12/29/2011	2.8×10^{-4}	195	0.92	0.2858	No

a. Degrees clockwise from true north; 90 = east, 180 = south, 270 = west, 0 and/or 360 = north.

b. The probability that the degree of an apparent spatially dependent trend observed in the data (or a trend of even greater degree) would occur solely by random chance. If the *p*-value is less than 0.05, the fitted trend surface is deemed statistically significant.

N/A = not applicable

The larger gradient magnitude for December 2011 indicates that the gradient magnitude changes spatially in the LERF vicinity. For instance, the trend-surface analysis result for December 2011 using the three-well network yielded a gradient magnitude of 6.7×10^{-5} m/m (the direction was 207 degrees), which is within the range of results for the three-well network from January through November 2011 (Table 5). Well 299-E26-14 is to the north of LERF, whereas the other wells are to the west and south. So, the hydraulic gradient magnitude is larger in the north portion of the well network. Although the December 2011 trend-surface result was not statistically significant, it is interpreted as being the most representative hydraulic gradient for the LERF because the fitted plane represents the spatially averaged hydraulic gradient beneath the site. The December 2011 result was used in the flow velocity calculations. Note that there was no appreciable change in the direction of the gradient when including well 299-E26-14 (199 and 195 degrees azimuth before and after inclusion of the new well, respectively). An additional well to the northwest, as proposed for the nearby Trench 94, may provide additional understanding of the flow direction in this area.

The flow velocity for LERF was calculated using a gradient magnitude of 2.8×10^{-4} m/m, an assumed effective porosity of 0.1, and using either 36.2 m/d or 39.8 m/d for the hydraulic conductivity (PNNL-14804, *Results of Detailed Hydrologic Characterization Tests - Fiscal Year 2003*), the flow rate was calculated at 0.1 m/d.

7.1.6 216-A-29 Ditch

The water table beneath the 216-A-29 Ditch is very flat and this site is not part of the low-gradient evaluation network for the 200 East Area. It was assumed that the hydraulic gradient magnitude of 2.2×10^{-5} m/m calculated for the IDF/216-A-36B Crib was also representative for the water table beneath the 216-A-29 Ditch. The flow rate was calculated using a hydraulic conductivity of 18 m/d (WHC-SD-EN-DP-047, *Borehole Completion Data Package for the 216-A-29 RCRA Facility Monitoring Wells, Calendar Year 1991*) and an effective porosity range of 0.1 to 0.3 (assumed). This resulted in an estimated flow rate of 0.001 to 0.004 m/d. The southeast flow direction was interpreted based on contaminant plume maps.

7.1.7 216-A-37-1 Crib

The water table beneath the 216-A-37-1 Crib is very flat and this site is not part of the low-gradient evaluation network for the 200 East Area. However, it is located near the 21-A-36B Crib, so it was assumed that the hydraulic gradient magnitude of 2.2×10^{-5} m/m calculated for the IDF/216-A-36B Crib was also representative for the water table beneath the 216-A-37-1 Crib. The flow velocity was calculated using a hydraulic conductivity range of 18 to 3,000 m/d (PNNL-11523) and an effective porosity range of 0.1 to 0.3 (assumed). This resulted in an estimated flow rate of 0.001 to 0.66 m/d. The southeast flow direction was interpreted based on contaminant plume maps. (Note: Due to an oversight, the values given in Table B-1 of DOE/RL-2011-118 were not correct, but the values in the text [Section 3.5.9.3] were correct.)

7.1.8 216-B-63 Trench

This site is located along the south side of LLWMA-2. While not directly part of the low-gradient evaluation network, some of the wells at the 216-B-63 Trench are used in the network for LLWMA-2. As explained above, the water table was deemed too flat to measure at LLWMA-2. This conclusion also applies to the 216-B-63 Trench. The hydraulic gradient magnitude and direction were reported as indeterminate in DOE/RL-2011-118 and the flow rate was not calculated.

7.1.9 Waste Management Area A-AX Tank Farms

The water table beneath WMA A-AX is very flat and this site is not part of the low-gradient evaluation network for the 200 East Area. No assumptions were made regarding the magnitude of the hydraulic gradient. The gradient magnitude and flow rate were reported as indeterminate in DOE/RL-2011-118 and no flow rate calculations were performed. The flow direction is southeast based on interpretations from plume maps.

7.1.10 Waste Management Area B-BX-BY Tank Farms

This site is located adjacent to LLWMA-1, and two of the wells at WMA B-BX-BY are included in the low-gradient evaluation network for LLWMA-1. Thus, groundwater flow at LLWMA-1 is also assumed to be representative of flow at WMA B-BX-BY. As explained above for LLWMA-1, the groundwater flow direction changed during the year. Because of this, the gradient magnitude and direction for both LLWMA-1 and WMA B-BX-BY was reported in DOE/RL-2011-118 as variable for the year and no flow rate calculations were made.

7.1.11 Waste Management Area C Tank Farm

The water table beneath WMA C is very flat, and this site is not part of the low-gradient evaluation network for the 200 East Area. No assumptions were made regarding the magnitude of the hydraulic gradient. The gradient magnitude and flow rate were reported as indeterminate in DOE/RL-2011-118 and no flow rate calculations were performed. The flow direction is south based on interpretations from plume maps.

7.2 Other RCRA Sites

This section addresses the 216-B-3 Pond, which is east of the 200 East Area and outside the region of low hydraulic gradient magnitude. It also addresses the RCRA sites associated with the 200-UP-1 Operable Unit in the 200 West Area. Trend-surface analyses for these sites are documented in Appendix B.

7.2.1 216-B-3 Pond

Due to an oversight, the hydraulic gradient and flow velocity results for 216-B-3 Pond published in DOE/RL-2011-118 were actually the values for 2010 and not for 2011. This calculation documentation provides the hydraulic gradient and flow velocity results for 2011.

The hydraulic gradient for this site was determined by trend-surface analysis of the water-level measurements collected on March 18, 2011. The result was 1.3×10^{-3} m/m at 259 degrees azimuth (west) ($R^2 = 0.98$, $R = 0.99$, p-value = 0.0005). Using a hydraulic conductivity 1.0 m/d (WHC-SD-EN-EV-002, *Interim Hydrogeologic Characterization Report for the 216-B-3 Pond*; PNL-10195, *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System: FY 1994 Status Report*) and an effective porosity of 0.25 (assumed), the flow rate is 0.0052 m/d.

7.2.2 216-S-10 Pond & Ditch

The hydraulic gradient for this site was determined by trend-surface analysis of the water-level measurements collected on March 31, 2011. The result was 2.5×10^{-3} m/m at 108 degrees azimuth (east-southeast) ($R^2 = 0.91$, $R = 0.95$, p-value = 0.0267). Using a hydraulic conductivity range of 2 to 42.7 m/d (range of 10 hydraulic test results in the 216-S-10 vicinity for the upper portion of the unconfined aquifer, after excluding the low and high values from the 12 available test results; the 2 m/d value is from *Summary and Evaluation of Available Hydraulic Property Data for Hanford Site Unconfined Aquifer* (PNL-8337), well 299-W26-8; the 42.7 m/d value is the midpoint of the reported range for well 699-32-77 in PNL-8337) and an assumed effective porosity range of 0.1 to 0.2, the flow rate ranges between 0.025 and 1.1 m/d. Using best values of 10.4 m/d for hydraulic conductivity (from the constant-rate discharge test result [well 299-W27-2] closest to the median of the 10 test results used for the range [WHC-SD-EN-DP-052, *Borehole Completion Data Package for the 216-S-10 Facility, CY 1992*]) and an assumed effective porosity of 0.15, the best estimate of the flow rate is 0.17 m/d.

7.2.3 Waste Management Area S-SX Tank Farms

The hydraulic gradient for this site was determined by trend-surface analysis of the water-level measurements collected on March 31, 2011. The result was 2.0×10^{-3} m/m (rounded from 1.96×10^{-3} m/m) at 90 degrees azimuth (east) ($R^2 = 0.94$, $R = 0.97$, p-value = 0.0000). Using a hydraulic conductivity range of 1.33 to 14.4 m/d (range of seven constant-rate discharge test results in the WMA S-SX wells reported in PNNL-13514, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2000*; PNNL-14113, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2001*; and PNNL-14186, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2002*; lower bound from PNNL-14186, well 299-W22-84; upper bound from PNNL-14113, well 299-W22-80) and an assumed effective porosity range of 0.09 to 0.2 (lower value is the lowest specific yield determined from the seven constant-rate pump tests; upper value assumed), the flow rate ranges between 0.013 and 0.31 m/d. Using best values of 6.1 m/d for hydraulic conductivity (average of the constant-rate pump tests) and an effective porosity of 0.12 (PNNL-13514; PNNL-14113), the best estimate of the flow rate is 0.10 m/d.

7.2.4 Waste Management Area U Tank Farm

The hydraulic gradient for this site was determined as the average of two trend-surface analyses: one for water-level measurements collected on March 30, 2011, and another for measurements collected between

July 18 and July 27, 2011. The results for March 30, 2011, were 1.99×10^{-3} m/m at 80.9 degrees azimuth (east-northeast) ($R^2 = 0.72$, $R = 0.85$, p-value = 0.0231). The results for July 2011 were 2.26×10^{-3} m/m at 78.4 degrees azimuth (east-northeast) ($R^2 = 0.98$, $R = 0.99$, p-value = 0.0001). The average gradient magnitude was 2.13×10^{-3} m/m. Using a hydraulic conductivity range of 1.69 to 9.5 m/d (range of three hydraulic test results in the WMA U wells reported in PNNL-13378, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 1999*) and an effective porosity range of 0.1 to 0.2 (assumed), the flow rate ranges between 0.018 and 0.20 m/d. Using best values of 6.1 m/d for hydraulic conductivity and an effective porosity of 0.17 (both from the constant-rate pump test in well 299-W19-42 [PNNL-13378]), the best estimate of the flow rate is 0.076 m/d.

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Appendix A

Trend-Surface Analysis Spreadsheet

The spreadsheet used for the trend-surface analyses, with formulas displayed, is shown on Figure A-1. The input data, consisting of the easting and northing well coordinates and the calculated hydraulic heads, are entered into columns C, D, and E. Intermediate computations needed to solve the matrix equation (i.e., Equation 4) are in the block from L23 through L36. The matrix equation is displayed in the block from K46 to O48, and it is solved using Microsoft Excel matrix functions in rows 46 to 54. The matrix functions are entered as array formulas (to enter an array formula in Microsoft Excel, hold down the control and shift keys at the same time and press enter). The coefficients of the fitted plane are in L52 to L54. The normal vector to the fitted plane (pointing upward) is determined in cells L58 and L59. The gradient magnitude is calculated in L64 (Equation 5), and the gradient direction is determined in the block of cells from L69 to M77. To determine the gradient direction, the coefficients of the fitted plane are examined in a logic block from L69 to L77 so only one of the series of "IF" functions will be true. The conditions being tested are listed in K69 to K77, and this is mainly to determine within which quadrant the fitted plane dips. The "IF" functions in column M identify which of the conditions is true, and then computes the dip direction of the fitted plane using the arctangent function in the appropriate manner for that quadrant. The gradient magnitude and direction are then echoed in L10 and L11 so the user can easily find the result.

Remaining calculations consist of the predicted hydraulic heads, identification of potential outliers, and the ANOVA statistical test. The coefficients of the fitted plane are used to calculate the predicted hydraulic heads for each well in column G. The difference of the predicted heads from their mean is computed in column H, and the residuals are calculated in column I. The predicted range of the measurements, using the IQR, is determined from the 25^{th} and 75^{th} percentiles in cells O23 to O30. The cells showing the residuals (i.e., in column I) are conditionally formatted to highlight yellow if a value is outside the range determined by the IQR, which allows for easy identification of the potential outliers. The ANOVA table is in the block of cells from N14 to S17. The test statistic is in R15 and the *p*-value is determined using the "FDIST" function in S15. The results of the statistics are in cells L15 to L19. In L19, the *p*-value (cell L18) is compared to the level of significance specified in L17 to determine if the trend surface is statistically significant.

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Figure A-1. Spreadsheet Used for the Trend-Surface Analysis with Formulas Displayed

	A	B	C	D	E	F	G	H	I	J
1	**Trend Surface Analysis of Hydraulic Gradient**									
2	(Least Squares Regression of a Plane to Points in 3-D Space)									
3	Reference: Davis, J. C. 2002. Statistics and Data Analysis in Geology, John Wiley & Sons									
4	Prepared by JP McDonald									
5										
6										
7		Input Data					Computed Data			
8		Well Name	Easting (x-coord)	Northing (y-coord)	Observed Hydraulic Head (z-coord)		Predicted Hydraulic Head	Predicted Diff from Mean	Residuals (Observed - Predicted)	
9		1					=IF(ISBLANK(E9),"",$L$52+$L$53*C9+$L$54*D9)	=IF(ISBLANK(E9),"",G9-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E9),"",E9-G9)	
10		2					=IF(ISBLANK(E10),"",$L$52+$L$53*C10+$L$54*D10)	=IF(ISBLANK(E10),"",G10-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E10),"",E10-G10)	
11		3					=IF(ISBLANK(E11),"",$L$52+$L$53*C11+$L$54*D11)	=IF(ISBLANK(E11),"",G11-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E11),"",E11-G11)	
12		4					=IF(ISBLANK(E12),"",$L$52+$L$53*C12+$L$54*D12)	=IF(ISBLANK(E12),"",G12-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E12),"",E12-G12)	
13		5					=IF(ISBLANK(E13),"",$L$52+$L$53*C13+$L$54*D13)	=IF(ISBLANK(E13),"",G13-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E13),"",E13-G13)	
14		6					=IF(ISBLANK(E14),"",$L$52+$L$53*C14+$L$54*D14)	=IF(ISBLANK(E14),"",G14-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E14),"",E14-G14)	
15		7					=IF(ISBLANK(E15),"",$L$52+$L$53*C15+$L$54*D15)	=IF(ISBLANK(E15),"",G15-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E15),"",E15-G15)	
16		8					=IF(ISBLANK(E16),"",$L$52+$L$53*C16+$L$54*D16)	=IF(ISBLANK(E16),"",G16-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E16),"",E16-G16)	
17		9					=IF(ISBLANK(E17),"",$L$52+$L$53*C17+$L$54*D17)	=IF(ISBLANK(E17),"",G17-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E17),"",E17-G17)	
18		10					=IF(ISBLANK(E18),"",$L$52+$L$53*C18+$L$54*D18)	=IF(ISBLANK(E18),"",G18-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E18),"",E18-G18)	
19		11					=IF(ISBLANK(E19),"",$L$52+$L$53*C19+$L$54*D19)	=IF(ISBLANK(E19),"",G19-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E19),"",E19-G19)	
20		12					=IF(ISBLANK(E20),"",$L$52+$L$53*C20+$L$54*D20)	=IF(ISBLANK(E20),"",G20-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E20),"",E20-G20)	
21		13					=IF(ISBLANK(E21),"",$L$52+$L$53*C21+$L$54*D21)	=IF(ISBLANK(E21),"",G21-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E21),"",E21-G21)	
22		14					=IF(ISBLANK(E22),"",$L$52+$L$53*C22+$L$54*D22)	=IF(ISBLANK(E22),"",G22-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E22),"",E22-G22)	
23		15					=IF(ISBLANK(E23),"",$L$52+$L$53*C23+$L$54*D23)	=IF(ISBLANK(E23),"",G23-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E23),"",E23-G23)	
24		16					=IF(ISBLANK(E24),"",$L$52+$L$53*C24+$L$54*D24)	=IF(ISBLANK(E24),"",G24-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E24),"",E24-G24)	
25		17					=IF(ISBLANK(E25),"",$L$52+$L$53*C25+$L$54*D25)	=IF(ISBLANK(E25),"",G25-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E25),"",E25-G25)	
26		18					=IF(ISBLANK(E26),"",$L$52+$L$53*C26+$L$54*D26)	=IF(ISBLANK(E26),"",G26-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E26),"",E26-G26)	
27		19					=IF(ISBLANK(E27),"",$L$52+$L$53*C27+$L$54*D27)	=IF(ISBLANK(E27),"",G27-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E27),"",E27-G27)	
28		20					=IF(ISBLANK(E28),"",$L$52+$L$53*C28+$L$54*D28)	=IF(ISBLANK(E28),"",G28-SUM($G$9:$G$28)/$L$23)	=IF(ISBLANK(E28),"",E28-G28)	
29										
30										

Figure A-1. Spreadsheet Used for the Trend-Surface Analysis with Formulas Displayed

	K	L	M	N	O	P	Q	R	S
8	**Hydraulic Gradient**								
9									
10	Gradient Magnitude:	=L64							
11	Gradient Direction (azimuth):	=INDEX(M69:M77,MATCH("Yes",L69:L77,0))							
12									
13	**Statistics**			**ANOVA**					
14				Var Source	Sum of Squares	Df	Mean Squares	F-Test	P-Value
15	Goodness of Fit (R^2):	=L36/L35		Regression	=SUMSQ(H9:H28)	2	=O15/P15	=Q15/Q16	=FDIST(R15,P15,P16)
16	Correlation Coefficient (R):	=SQRT(L15)		Deviation	=SUMSQ(I9:I28)	=L23-3	=O16/P16		
17	Level of Significance:	0.05		Total	=O15+O16	=L23-1			
18	P-Value:	=ROUND(S15,4)							
19	Statistically Significant Trend?:	=IF(L23=3,"N/A - 3 pts",IF(L18<=L17,"Yes","No"))							
20									
21	Intermediate Computations			Potential Outlier Range (on the Residuals):					
22									
23	# of Observations:	=COUNT(C9:C28)		25th Percentile:	=PERCENTILE(INDIRECT("I9:I"&L23+8),0.25)				
24	Sum of Easting:	=SUM(C9:C28)		75th Percentile:	=PERCENTILE(INDIRECT("I9:I"&L23+8),0.75)				
25	Sum of Northing:	=SUM(D9:D28)		Interquartile Range (IQR):	=$O$24-$O$23				
26	Sum of Easting*Northing:	=SUMPRODUCT(C9:C28,D9:D28)							
27	Sum of Easting^2:	=SUMSQ(C9:C28)		IQR Factor:	1.5				
28	Sum of Northing^2:	=SUMSQ(D9:D28)							
29	Sum of Observed Heads:	=SUM(E9:E28)		Lower Value:	=ROUND($O$23-$O$27*$O$25,3)				
30	Sum of Easting*Observed Heads:	=SUMPRODUCT(C9:C28,E9:E28)		Upper Value:	=ROUND($O$24+$O$27*$O$25,3)				
31	Sum of Northing*Observed Heads:	=SUMPRODUCT(D9:D28,E9:E28)							
32	Sum of Observed Heads^2:	=SUMSQ(E9:E28)							
33	Sum of Predicted Heads:	=SUM(G9:G28)							
34	Sum of Predicted Heads^2:	=SUMSQ(G9:G28)							
35	SSt:	=L32-(L29^2)/L23							
36	SSr:	=L34-(L33^2)/L23							
37									
38	Matrix Equation (Equation 5.86 in Davis, 2002)								
39									
40	=L23	=L24	=L25	b0	=L29				
41	=L24	=L27	=L26	b1	=L30				
42	=L25	=L26	=L28	b2	=L31				
43									
44	Inverse Matrix								
45									
46	=MINVERSE(K40:M42)	=MINVERSE(K40:M42)	=MINVERSE(K40:M42)						
47	=MINVERSE(K40:M42)	=MINVERSE(K40:M42)	=MINVERSE(K40:M42)						
48	=MINVERSE(K40:M42)	=MINVERSE(K40:M42)	=MINVERSE(K40:M42)						
49									
50	Coefficients of the Fitted Plane (z = b0 + b1x + b2y)								
51									
52	b0=	=MMULT(K46:M48,O40:O42)							
53	b1=	=MMULT(K46:M48,O40:O42)							
54	b2=	=MMULT(K46:M48,O40:O42)							
55									
56	Normal Vector to the Fitted Plane (<a,b,c> where a = -b1, b = -b2, c = 1)								
57									
58	a:	=$L$53*(-1)							
59	b:	=$L$54*(-1)							
60	c:	1							
61									
62	Gradient Magnitude								
63									
64		=SQRT(L58^2+L59^2)							
65									
66	Gradient Direction								
67									
68			Azimuth:						
69	Horizontal Plane?:	=IF(AND($L$58=0,$L$59=0),"Yes","No")	n/a						
70	Due North?:	=IF(AND($L$58=0,$L$59>0),"Yes","No")	=IF(L70="Yes",0,"n/a")						
71	Due East?:	=IF(AND($L$58>0,$L$59=0),"Yes","No")	=IF(L71="Yes",90,"n/a")						
72	Due South?:	=IF(AND($L$58=0,$L$59<0),"Yes","No")	=IF(L72="Yes",180,"n/a")						
73	Due West?:	=IF(AND($L$58<0,$L$59=0),"Yes","No")	=IF(L73="Yes",270,"n/a")						
74	First Quadrant?:	=IF(AND($L$58>0,$L$59>0),"Yes","No")	=IF(L74="Yes",ATAN($L$58/$L$59)*180/PI(),"n/a")						
75	Second Quadrant?:	=IF(AND($L$58>0,$L$59<0),"Yes","No")	=IF(L75="Yes",90+ATAN(ABS($L$59)/$L$58)*180/PI(),"n/a")						
76	Third Quadrant?:	=IF(AND($L$58<0,$L$59<0),"Yes","No")	=IF(L76="Yes",180+ATAN($L$58/$L$59)*180/PI(),"n/a")						
77	Fourth Quadrant?:	=IF(AND($L$58<0,$L$59>0),"Yes","No")	=IF(L77="Yes",270+ATAN($L$59/ABS($L$58))*180/PI(),"n/a")						

Appendix B

Trend-Surface Analyses

The appendix contains the trend-surface analysis spreadsheets for 216-B-3 Pond, 216-S-10 Pond & Ditch, WMA S-SX, and WMA U. Each spreadsheet documents the wells and hydraulic heads used in the analysis. The trend-surface analysis spreadsheet itself is documented in Appendix A.

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Figure B-1. Trend-Surface Analysis Spreadsheet for 216-B-3 Pond

Input Data				Computed Data		
Well Name	Easting (x-coord)	Northing (y-coord)	Observed Hydraulic Head (z-coord)	Predicted Hydraulic Head	Predicted Diff from Mean	Residuals (Observed - Predicted)
299-E25-32P	576382.422	136044.335	121.636	121.638	-0.875	-0.002
699-41-40	577613.886	135995.881	123.263	123.185	0.672	0.078
699-41-42	577122.035	136067.945	122.519	122.580	0.066	-0.061
699-42-42B	576998.097	136433.923	122.406	122.510	-0.004	-0.104
699-43-44	576744.713	136652.854	122.08	122.241	-0.272	-0.161
699-43-45	576283.815	136585.729	121.835	121.642	-0.871	0.193
699-44-39B	577960.618	136727.386	123.855	123.798	1.284	0.057
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Measurements collected on 3/18/2011

Hydraulic Gradient

Gradient Magnitude:	1.29E-03
Gradient Direction (azimuth):	259.4

Statistics

Goodness of Fit (R^2):	0.98
Correlation Coefficient (R):	0.99
Level of Significance:	0.05
P-Value:	0.0005
Statistically Significant Trend?:	Yes

ANOVA

Var Source	Sum of Squares	Df	Mean Squares	F-Test	P-Value
Regression	3.704166483	2	1.852083241	85.07186511	0.000527599
Deviation	0.087083232	4	0.021770808		
Total	3.791249715	6			

Potential Outlier Range (on the Residuals):

25th Percentile:	-0.082384044
75th Percentile:	0.067600614
Interquartile Range (IQR):	0.149984658
IQR Factor:	1.5
Lower Value:	-0.307
Upper Value:	0.293

Intermediate Computations

# of Observations:	7
Sum of Easting:	4039105.586
Sum of Northing:	954508.053
Sum of Easting*Northing:	5.50766E+11
Sum of Easting^2:	2.33063E+12
Sum of Northing^2:	1.30156E+11
Sum of Observed Heads:	857.594
Sum of Easting*Observed Heads:	494847561.9
Sum of Northing*Observed Heads:	116940261.4
Sum of Observed Heads^2:	105070.5725
Sum of Predicted Heads:	857.5940001
Sum of Predicted Heads^2:	105070.4855
SSt:	3.791249714
SSr:	3.704166483

Matrix Equation (Equation 5.86 in Davis, 2002)

7	4039105.586	954508.1	b0	857.594
4039105.586	2.33063E+12	5.51E+11	b1	494847561.9
954508.053	5.50766E+11	1.3E+11	b2	116940261.4

Inverse Matrix

172039.5155	-0.249144538	-0.20739
-0.249144538	4.40948E-07	-3.9E-08
-0.207389047	-3.87894E-08	1.69E-06

Coefficients of the Fitted Plane (z = b0 + b1x + b2y)

b0=	-640.0479473
b1=	0.001265499
b2=	0.000237237

Normal Vector to the Fitted Plane (<a,b,c> where a = -b1, b = -b2, c = 1)

a:	-0.001265499
b:	-0.000237237
c:	1

Gradient Magnitude

0.001287544

Gradient Direction

		Azimuth:
Horizontal Plane?:	No	n/a
Due North?:	No	n/a
Due East?:	No	n/a
Due South?:	No	n/a
Due West?:	No	n/a
First Quadrant?:	No	n/a
Second Quadrant?:	No	n/a
Third Quadrant?:	Yes	259.3823
Fourth Quadrant?:	No	n/a

Figure B-2. Trend-Surface Analysis Spreadsheet for 216-S-10 Pond & Ditch

Input Data				Computed Data		
Well Name	Easting (x-coord)	Northing (y-coord)	Observed Hydraulic Head (z-coord)	Predicted Hydraulic Head	Predicted Diff from Mean	Residuals (Observed - Predicted)
299-W26-13	566424.387	133293.598	134.859	134.877	0.395	-0.018
299-W26-14	566682.69	133539.21	134.415	134.446	-0.036	-0.031
699-32-76	566683.94	133137.73	134.026	134.134	-0.348	-0.108
699-32-77	566416.794	133152.488	134.922	134.787	0.305	0.145
699-33-75	566904.78	133662.48	134.13	134.008	-0.475	0.122
699-33-76	566621.21	133600.43	134.531	134.641	0.159	-0.110
7						
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19						
20						

Measurements collected on 3/31/2011

Hydraulic Gradient

Gradient Magnitude:	2.52E-03
Gradient Direction (azimuth):	107.8

Statistics

Goodness of Fit (R^2):	0.91
Correlation Coefficient (R):	0.95
Level of Significance:	0.05
P-Value:	0.0267
Statistically Significant Trend?:	Yes

ANOVA

Var Source	Sum of Squares	Df	Mean Squares	F-Test	P-Value
Regression	0.622301005	2	0.311150502	15.28798919	0.026707846
Deviation	0.061057834	3	0.020352611		
Total	0.683358839	5			

Intermediate Computations

# of Observations:	6
Sum of Easting:	3399733.801
Sum of Northing:	800385.936
Sum of Easting*Northing:	4.53517E+11
Sum of Easting^2:	1.92637E+12
Sum of Northing^2:	1.0677E+11
Sum of Observed Heads:	806.883
Sum of Easting*Observed Heads:	457203268.9
Sum of Northing*Observed Heads:	107637511
Sum of Observed Heads^2:	108513.4023
Sum of Predicted Heads:	806.8829964
Sum of Predicted Heads^2:	108513.3402
SSt:	0.683358833
SSr:	0.622301005

Potential Outlier Range (on the Residuals):

25th Percentile:	-0.088562234
75th Percentile:	0.087160008
Interquartile Range (IQR):	0.175722241
IQR Factor:	1.5
Lower Value:	-0.352
Upper Value:	0.351

Matrix Equation (Equation 5.86 in Davis, 2002)

6	3399733.801	800385.9	b0	806.883
3399733.801	1.92637E+12	4.54E+11	b1	457203268.9
800385.936	4.53517E+11	1.07E+11	b2	107637511

Inverse Matrix

2601074.14	-5.087101008	2.109414
-5.087101008	1.02081E-05	-5.2E-06
2.109414125	-5.22506E-06	6.28E-06

Coefficients of the Fitted Plane (z = b0 + b1x + b2y)

b0=	1393.022292
b1=	-0.002402625
b2=	0.000770935

Normal Vector to the Fitted Plane (<a,b,c> where a = -b1, b = -b2, c = 1)

a:	0.002402625
b:	-0.000770935
c:	1

Gradient Magnitude

0.002523281

Gradient Direction

		Azimuth:
Horizontal Plane?:	No	n/a
Due North?:	No	n/a
Due East?:	No	n/a
Due South?:	No	n/a
Due West?:	No	n/a
First Quadrant?:	No	n/a
Second Quadrant?:	Yes	107.79
Third Quadrant?:	No	n/a
Fourth Quadrant?:	No	n/a

Figure B-3. Trend-Surface Analysis Spreadsheet for WMA S-SX Tank Farms

Input Data				Computed Data		
Well Name	Easting (x-coord)	Northing (y-coord)	Observed Hydraulic Head (z-coord)	Predicted Hydraulic Head	Predicted Diff from Mean	Residuals (Observed - Predicted)
299-W22-44	566955.99	134484.42	134.291	134.304	-0.098	-0.013
299-W22-45	566945.16	134292.51	134.372	134.324	-0.078	0.048
299-W22-47	566908.74	134076.28	134.458	134.395	-0.008	0.063
299-W22-48	566996.641	134425.096	134.199	134.224	-0.178	-0.025
299-W22-49	566904.383	134201.625	134.418	134.404	0.001	0.014
299-W22-50	566904.261	134139.756	134.418	134.404	0.001	0.014
299-W22-80	566842.851	134125.649	134.492	134.524	0.121	-0.032
299-W22-81	567000.263	134354.189	134.215	134.217	-0.186	-0.002
299-W22-82	567004.731	134167.07	134.23	134.207	-0.196	0.023
299-W22-83	567009.082	134092.546	134.145	134.198	-0.204	-0.053
299-W22-84	566978.76	134547.62	134.29	134.260	-0.143	0.030
299-W22-89	566906.77	134031.67	134.306	134.398	-0.004	-0.092
299-W23-15	566794	134127.23	134.686	134.619	0.217	0.067
299-W23-20	566717.669	134446.189	134.702	134.771	0.368	-0.069
299-W23-21	566707.737	134293.994	134.816	134.789	0.387	0.027
16						
17						
18						
19						
20						

Measurements collected on 3/31/2011

Hydraulic Gradient

Gradient Magnitude:	1.96E-03
Gradient Direction (azimuth):	90.2

Statistics

Goodness of Fit (R^2):	0.94
Correlation Coefficient (R):	0.97
Level of Significance:	0.05
P-Value:	0
Statistically Significant Trend?:	Yes

ANOVA

Var Source	Sum of Squares	Df	Mean Squares	F-Test	P-Value
Regression	0.529456486	2	0.264728243	102.0434664	2.93303E-08
Deviation	0.031131233	12	0.002594269		
Total	0.560587718	14			

Intermediate Computations

# of Observations:	15
Sum of Easting:	8503577.038
Sum of Northing:	2013805.844
Sum of Easting*Northing:	1.14164E+12
Sum of Easting^2:	4.82072E+12
Sum of Northing^2:	2.70361E+11
Sum of Observed Heads:	2016.038
Sum of Easting*Observed Heads:	1142902026
Sum of Northing*Observed Heads:	270660585.8
Sum of Observed Heads^2:	270961.1751
Sum of Predicted Heads:	2016.038025
Sum of Predicted Heads^2:	270961.1507
SSt:	0.560587733
SSr:	0.529456486

Potential Outlier Range (on the Residuals):

25th Percentile:	-0.028541173
75th Percentile:	0.028351428
Interquartile Range (IQR):	0.056892601
IQR Factor:	1.5
Lower Value:	-0.114
Upper Value:	0.114

Matrix Equation (Equation 5.86 in Davis, 2002)

15	8503577.038	2013806	b0	2016.038
8503577.038	4.82072E+12	1.14E+12	b1	1142902026
2013805.844	1.14164E+12	2.7E+11	b2	270660585.8

Inverse Matrix

2346085.167	-4.085309252	-0.22422
-4.085309252	7.26003E-06	-2.3E-07
-0.224219511	-2.26732E-07	2.63E-06

Coefficients of the Fitted Plane (z = b0 + b1x + b2y)

b0=	1243.867443
b1=	-0.001958387
b2=	5.4713E-06

Normal Vector to the Fitted Plane (<a,b,c> where a = -b1, b = -b2, c = 1)

a:	0.001958387
b:	-5.4713E-06
c:	1

Gradient Magnitude

0.001958394

Gradient Direction

		Azimuth:
Horizontal Plane?:	No	n/a
Due North?:	No	n/a
Due East?:	No	n/a
Due South?:	No	n/a
Due West?:	No	n/a
First Quadrant?:	No	n/a
Second Quadrant?:	Yes	90.16007
Third Quadrant?:	No	n/a
Fourth Quadrant?:	No	n/a

Figure B-4. Trend-Surface Analysis Spreadsheet for WMA U Tank Farm (3/30/2011)

Input Data				Computed Data		
Well Name	Easting (x-coord)	Northing (y-coord)	Observed Hydraulic Head (z-coord)	Predicted Hydraulic Head	Predicted Diff from Mean	Residuals (Observed - Predicted)
299-W18-30	566870.755	135193.619	134.357	134.450	-0.065	-0.093
299-W18-31	566721.541	135075.178	134.794	134.780	0.265	0.014
299-W18-40	566723.29	134996.41	134.802	134.802	0.286	0.000
299-W19-12	566897.131	135059.446	134.357	134.441	-0.075	-0.084
299-W19-41	566896.532	135004.51	134.455	134.459	-0.057	-0.004
299-W19-42	566896.812	135122.901	134.352	134.421	-0.094	-0.069
299-W19-44	566896.95	135041.97	134.38	134.446	-0.069	-0.066
299-W19-45	566897.65	135087.65	134.642	134.431	-0.085	0.211
299-W19-47	566895.31	135161.86	134.504	134.412	-0.104	0.092
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Measurements collected on 3/30/2011

Note: The observed hydraulic head for 299-W18-40 measured on 3/30/2011 is currently calculated to be 134.820 m instead of the 134.802 m value used in this trend-surface analysis. This well is deviated from vertical and the method of calculating the correction value in the database changed during May 2013. The former correction value was 1.22 ft (0.372 m) while the new correction value is 1.28 ft (0.390 m) which accounts for the difference in the observed hydraulic heads. Using 134.820 m for 299-W18-40 results in only a slight change in the results: 2.04E-3 m/m at 80.4 degrees azimuth.

Hydraulic Gradient

Gradient Magnitude:	1.99E-03
Gradient Direction (azimuth):	80.9

Statistics

Goodness of Fit (R^2):	0.72
Correlation Coefficient (R):	0.85
Level of Significance:	0.05
P-Value:	0.0231
Statistically Significant Trend?:	Yes

ANOVA

Var Source	Sum of Squares	Df	Mean Squares	F-Test	P-Value
Regression	0.196573074	2	0.098286537	7.540991225	0.023052573
Deviation	0.078201816	6	0.013033636		
Total	0.274774891	8			

Intermediate Computations

# of Observations:	9
Sum of Easting:	5101695.971
Sum of Northing:	1215743.544
Sum of Easting*Northing:	6.8915E+11
Sum of Easting^2:	2.89192E+12
Sum of Northing^2:	1.64226E+11
Sum of Observed Heads:	1210.643
Sum of Easting*Observed Heads:	686259074.2
Sum of Northing*Observed Heads:	163536786.2
Sum of Observed Heads^2:	162850.994
Sum of Predicted Heads:	1210.643009
Sum of Predicted Heads^2:	162850.9182
SSt:	0.274774889
SSr:	0.196573074

Potential Outlier Range (on the Residuals):

25th Percentile:	-0.069405299
75th Percentile:	0.013571912
Interquartile Range (IQR):	0.082977211
IQR Factor:	1.5
Lower Value:	-0.194
Upper Value:	0.138

Matrix Equation (Equation 5.86 in Davis, 2002)

9	5101695.971	1215744	b0	1210.643
5101695.971	2.89192E+12	6.89E+11	b1	686259074.2
1215743.544	6.8915E+11	1.64E+11	b2	163536786.2

Inverse Matrix

7032717.935	-12.62029176	0.896925
-12.62029176	2.44049E-06	-9E-06
0.896925374	-8.98654E-06	3.11E-05

Coefficients of the Fitted Plane (z = b0 + b1x + b2y)

b0=	1289.623296
b1=	-0.001963131
b2=	-0.000313117

Normal Vector to the Fitted Plane (<a,b,c> where a = -b1, b = -b2, c = 1)

a:	0.001963131
b:	0.000313117
c:	1

Gradient Magnitude

0.001987945

Gradient Direction

		Azimuth:
Horizontal Plane?:	No	n/a
Due North?:	No	n/a
Due East?:	No	n/a
Due South?:	No	n/a
Due West?:	No	n/a
First Quadrant?:	Yes	80.93772
Second Quadrant?:	No	n/a
Third Quadrant?:	No	n/a
Fourth Quadrant?:	No	n/a

Figure B-5. Trend-Surface Analysis Spreadsheet for WMA U Tank Farm (July 2011)

Input Data				Computed Data		
Well Name	Easting (x-coord)	Northing (y-coord)	Observed Hydraulic Head (z-coord)	Predicted Hydraulic Head	Predicted Diff from Mean	Residuals (Observed - Predicted)
299-W18-30	566870.755	135193.619	134.278	134.319	-0.044	-0.041
299-W18-31	566721.541	135075.178	134.709	134.703	0.341	0.006
299-W19-12	566897.131	135059.446	134.315	134.321	-0.041	-0.006
299-W19-41	566896.532	135004.51	134.332	134.347	-0.015	-0.015
299-W19-42	566896.812	135122.901	134.306	134.293	-0.069	0.013
299-W19-44	566896.95	135041.97	134.33	134.329	-0.033	0.001
299-W19-45	566897.65	135087.65	134.316	134.307	-0.055	0.009
299-W19-47	566895.31	135161.86	134.312	134.279	-0.084	0.033
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Measurements collected between 7/18/2011 and 7/27/2011

Hydraulic Gradient

Gradient Magnitude:	2.26E-03
Gradient Direction (azimuth):	78.4

Statistics

Goodness of Fit (R^2):	0.98
Correlation Coefficient (R):	0.99
Level of Significance:	0.05
P-Value:	0.0001
Statistically Significant Trend?:	Yes

ANOVA

Var Source	Sum of Squares	Df	Mean Squares	F-Test	P-Value
Regression	0.136029067	2	0.068014534	102.4184169	8.76437E-05
Deviation	0.003320425	5	0.000664085		
Total	0.139349492	7			

Intermediate Computations

# of Observations:	8
Sum of Easting:	4534972.681
Sum of Northing:	1080747.124
Sum of Easting*Northing:	6.12645E+11
Sum of Easting^2:	2.57075E+12
Sum of Northing^2:	1.46002E+11
Sum of Observed Heads:	1074.898
Sum of Easting*Observed Heads:	609329074.6
Sum of Northing*Observed Heads:	145211603
Sum of Observed Heads^2:	144425.8532
Sum of Predicted Heads:	1074.897993
Sum of Predicted Heads^2:	144425.8478
SSt:	0.1393495
SSr:	0.136029067

Potential Outlier Range (on the Residuals):

25th Percentile:	-0.008371091
75th Percentile:	0.009973339
Interquartile Range (IQR):	0.018344431
IQR Factor:	1.5
Lower Value:	-0.036
Upper Value:	0.037

Matrix Equation (Equation 5.86 in Davis, 2002)

8	4534972.681	1080747	b0	1074.898
4534972.681	2.57075E+12	6.13E+11	b1	609329074.6
1080747.124	6.12645E+11	1.46E+11	b2	145211603

Inverse Matrix

12776040.22	-21.46283776	-4.51071
-21.46283777	3.80191E-05	-6.6E-07
-4.510710865	-6.59683E-07	3.62E-05

Coefficients of the Fitted Plane (z = b0 + b1x + b2y)

b0=	1452.645319
b1=	-0.00221718
b2=	-0.000454697

Normal Vector to the Fitted Plane (<a,b,c> where a = -b1, b = -b2, c = 1)

a:	0.00221718
b:	0.000454697
c:	1

Gradient Magnitude

0.002263325

Gradient Direction

		Azimuth:
Horizontal Plane?:	No	n/a
Due North?:	No	n/a
Due East?:	No	n/a
Due South?:	No	n/a
Due West?:	No	n/a
First Quadrant?:	Yes	78.41054
Second Quadrant?:	No	n/a
Third Quadrant?:	No	n/a
Fourth Quadrant?:	No	n/a

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Appendix C

Flow Rate Calculations

This appendix documents the flow rate calculations. The spreadsheet used for the calculations can determine minimum and maximum flow rates using minimum/maximum hydraulic conductivity values and minimum/maximum effective porosity values. Where only one flow rate is calculated, the minimum and maximum values in the spreadsheet are the same.

Figure C-1 shows the spreadsheet used for the calculations with formulas displayed. The RCRA site name is in column B and the hydraulic gradient magnitude is in column C. The minimum and maximum hydraulic conductivity values are in columns D and E, respectively. The minimum and maximum effective porosity values are in columns F and G, respectively. If an effective porosity was not provided for a given site, a range of 0.1 to 0.3 was assumed. The flow rate calculations, using Equation 11, are performed in columns H and I. In column H, a minimum flow rate is determined using the minimum hydraulic conductivity and the maximum effective porosity. In column I, a maximum flow rate is determined using the maximum hydraulic conductivity and the minimum effective porosity.

Figure C-2 shows the spreadsheet with calculation results displayed.

Figure C-1. Spreadsheet for Flow Rate Calculations (with Formulas Displayed)

Flow Rate Calculations								
	Site	Gradient (m/m)	K minimum (m/d)	K maximum (m/d)	ne minimum	ne maximum	v minimum (m/d)	v maximum (m/d)
	216-A-29 Ditch	0.000022	18	18	0.1	0.3	=D4*(C4)/G4	=E4*C4/F4
	216-A-36B Crib	0.000022	18	3000	0.1	0.3	=D5*(C5)/G5	=E5*C5/F5
	216-A-37-1 Crib	0.000022	18	3000	0.1	0.3	=D6*(C6)/G6	=E6*C6/F6
	216-B-3 Pond	0.0013	1	1	0.25	0.25	=D7*(C7)/G7	=E7*C7/F7
	216-S-10 Pond & Ditch (best)	0.0025	10.4	10.4	0.15	0.15	=D8*(C8)/G8	=E8*C8/F8
	216-S-10 Pond & Ditch (range)	0.0025	2	42.7	0.1	0.2	=D9*(C9)/G9	=E9*C9/F9
	IDF	0.000022	65	75	0.1	0.3	=D10*(C10)/G10	=E10*C10/F10
	LERF	0.00028	36.2	39.8	0.1	0.1	=D11*(C11)/G11	=E11*C11/F11
	WMA S-SX (best)	0.00196	6.1	6.1	0.12	0.12	=D12*(C12)/G12	=E12*C12/F12
	WMA S-SX (range)	0.00196	1.33	14.4	0.09	0.2	=D13*(C13)/G13	=E13*C13/F13
	WMA U (best)	0.00213	6.1	6.1	0.17	0.17	=D14*(C14)/G14	=E14*C14/F14
	WMA U (range)	0.00213	1.69	9.5	0.1	0.2	=D15*(C15)/G15	=E15*C15/F15

Figure C-2. Spreadsheet for Flow Rate Calculations (with Results Displayed)

Flow Rate Calculations								
	Site	Gradient (m/m)	K minimum (m/d)	K maximum (m/d)	ne minimum	ne maximum	v minimum (m/d)	v maximum (m/d)
	216-A-29 Ditch	2.20E-05	18	18	0.1	0.3	0.001	0.004
	216-A-36B Crib	2.20E-05	18	3000	0.1	0.3	0.001	0.66
	216-A-37-1 Crib	2.20E-05	18	3000	0.1	0.3	0.001	0.66
	216-B-3 Pond	1.30E-03	1	1	0.25	0.25	0.0052	0.0052
	216-S-10 Pond & Ditch (best)	2.50E-03	10.4	10.4	0.15	0.15	0.17	0.17
	216-S-10 Pond & Ditch (range)	2.50E-03	2	42.7	0.1	0.2	0.025	1.1
	IDF	2.20E-05	65	75	0.1	0.3	0.005	0.02
	LERF	2.80E-04	36.2	39.8	0.1	0.1	0.1	0.1
	WMA S-SX (best)	1.96E-03	6.1	6.1	0.12	0.12	0.10	0.10
	WMA S-SX (range)	1.96E-03	1.33	14.4	0.09	0.2	0.013	0.31
	WMA U (best)	2.13E-03	6.1	6.1	0.17	0.17	0.076	0.076
	WMA U (range)	2.13E-03	1.69	9.5	0.1	0.2	0.018	0.20

Appendix D

Hanford Information Systems Inventory Information for the HydroDat Database

This appendix contains the Hanford Information System Inventory (HISI) documentation for the HydroDat database.

HISI ID: 2009 Acronym: HYDRODAT

Last Updated: 05/07/2013	Core Information		
Acronym:	HYDRODAT	Title:	HYDRODAT
Purpose/Scope:	HydroDat is a database of discrete hydraulic head measurements collected on the Hanford Site and in selected offsite areas. The information in HydroDat dates from 1948 to the present, and is the most comprehensive source of manual hydraulic head measurements for the Hanford Site.		
Operational Date:	12/01/1999	Status: Operational	Support Level:
Owning Company:	CH2M HILL PLATEAU REMEDIATION COMPANY	Non Hanford?: No	
Base:	Network - HLAN	Type:	Custom Developed Software
Date Owner Reviewed: (Connell, Carl W)	04/15/2013	Breadth Of Usage:	Sitewide
Date CIO Approved Use:	Not Required	Number of Users:	50
Date SME Approved Use: (Schatz, Aaron L)		Uses Database?:	Yes
Comments:			
Configuration Mgt Path:	\\sieroot\HEIS\HYDRODAT\HYDRODAT.PJ	Configuration Mgt Approach:	MKS
Home Page:			
Project ID for SCRs:	HYDRODAT		

Contacts (Hanford)			
Type	Primary?	Name/Organization/Phone	Email?
Owner Manager	Yes	CONNELL, CARL W / FFS - ENVIRONMENTAL DATA INTEGRATION 376-3920	Yes
Owner Manager	No	WEBBER, WILLIAM D / CHPRC - ENVIRONMENTAL DATA INTEGRATION 376-4744	Yes
Project Lead	Yes	BROWN, WARREN L / LMSI - IS - BUSINESS & PENSION SYSTEM 376-2883	Yes
Project Lead	Yes	CARR, JENNIFER S / CHPRC - ENVIRONMENTAL DATA INTEGRATION 376-4196	Yes
System Analyst	No	MANGANO, COLLEEN P / CHPRC - ENVIRONMENTAL DATA INTEGRATION 373-5597	Yes
System Analyst	No	SCHATZ, AARON L / FFS - ENVIRONMENTAL DATA INTEGRATION 376-2628	Yes
System Analyst	Yes	WEBBER, WILLIAM D / CHPRC - ENVIRONMENTAL DATA INTEGRATION 376-4744	Yes
Technical Lead	Yes	MCDONALD, JOHN P / CHPRC - GROUNDWATER SCIENCE 373-3727	Yes
Technical Support Manager	Yes	CONNELL, CARL W / FFS - ENVIRONMENTAL DATA INTEGRATION 376-3920	Yes

Business Categories
Environmental

Hanford Interfaces		
Input/Output	Interface	Frequency
Outputs to	DATACAP - Data Capture Application	Real-time
Receives from	DATACAP - Data Capture Application	Real-time
Outputs to	DaVE - Data Viewer and Evaluator	Real-time
Outputs to	EDA - Environmental Dashboard Application	Daily
Outputs to	HEIS - Hanford Environmental Information System	Daily
Receives from	HEIS - Hanford Environmental Information System	Real-time
Outputs to	RDR - Request For Data Review	Real-time
Receives from	RDR - Request For Data Review	Real-time
Outputs to	VL - Virtual Library	Daily

External Interfaces to non-Hanford Applications (i.e., for other contracts, other networks, non-HLAN)

Hosts					
Host	Host Function	Host Environment	Host OS	Item Type	Item Name Item Description
SQL-DEV2\D2	Database Server	Development	W2K8	Database	HYDRODAT_P
SQL-3\P3	Database Server	Production	W2K8	Database	HYDRODAT_P
SQL-TST2\T2	Database Server	Test	W2K8	Database	HYDRODAT_P

Software					
Software Name	Version	Status	Environment	Software Type	Location
MICROSOFT SQL SERVER 10 (2008 R2)			Development	DBMS	Host
MICROSOFT SQL SERVER 10 (2008 R2)			Production	DBMS	Host
MICROSOFT SQL SERVER 10 (2008 R2)			Test	DBMS	Host

Non-Hanford Contacts

Version Description	
Version Update Number:	1.0.3
Software Number:	
Change Summary:	Fix to Gyroscopic Correction Rounding
Change Description Detail:	The Gyroscopic Correction needs to be rounded to two places prior to performing the calculations. The field CORRECTION in tbl_HydraulicHead also needs to be rounded to two places.

Affected Change Requests:	SCR # 10
Impact Of Change:	No impact to current users.
Minimum Client Resource Requirements:	N/A
Minimum Host Resource Requirements:	N/A
System Components:	WatLvSched.mdb, tbl_StandardCorrection, tbl_StandardCorrection_J, GYROSCOPIC_CORRECTION
Backup and Recovery Procedure:	Recover from backups and MKS
Implementation Start Date / Time:	03/11/2011 / 8:00 am
Implementation End Date / Time:	03/11/2011 / 8:30 am
Communication Plan:	The users will be notified via email.
Version Type:	Minor - User Interface/Report changes, Limited number of users, bug fix, etc.
Version Comments / Additional Information:	

Referenced Documents	
Functional Requirements Definition	Legacy system. Existing documentation in: sieroot/HEIS/HYDRODAT/Documentation folder in MKS
Alternatives Analysis	
Software Management Plan	HNF-28242 EIS Software Management Plan (HEIS/309_GEN_DOCS/SMP folder in MKS)
Software Configuration Management Plan	HNF-28242 EIS Software Management Plan (HEIS/309_GEN_DOCS/SMP folder in MKS)
Acquisition Documents	N/A
Software Requirements Specification	Legacy system. Existing documentation in: sieroot/HEIS/HYDRODAT/Documentation folder in MKS

Software Design Description	Legacy system. Existing documentation in: sieroot/HEIS/HYDRODAT/Documentation folder in MKS
Requirements Traceability Matrix	
Code Walkthrough	Located in sieroot/HEIS/HYDRODAT/Documention/QA folder in MKS
User Documents	N/A
Unit Testing	
Test Plan And Cases	
Acceptance Test Report	Located in sieroot/HEIS/HYDRODAT/Documention/QA folder in MKS
Contingency Plan	
Software Installation Plan	N/A
User Qualification	
User Training	N/A
Operational Testing	
Change Request / Problem Report	SCR #10
Retirement Plan Checklist	
Other Documents	

Version Submittal/Approval Status

Action	Date	By	Version	Previous Date	Previous By	Previous Version
Saved	08/24/2012	Connell, Carl W	1.0.3	03/02/2011	Carr, Jennifer S	1.0.3
Submitted				03/02/2011	Carr, Jennifer S	1.0.3
Approved By Owner				03/02/2011	Connell, Carl W	1.0.3
Approved By SME				03/02/2011	Schatz, Aaron L	1.0.3
Approved By CIO	N/A			N/A		
Approved By PRRB				03/03/2011	Ibsen, Thomas G	1.0.3
Implemented				03/06/2011	Carr, Jennifer S	1.0.3

Software Grading Checklist

Software Grading Checklist

Question #	Question	Yes	No
	Is the Software Safety Software?		
S1.	Is the software Safety System Software? Software for a nuclear facility that performs a safety function as part of an system, structure, or component (SSC) and is cited in	☐	☑

	either (1) a DOE approved documented safety analysis or (2) an approved hazard analysis per DOE P 450.4, "Safety Management System Policy" dated 10-15-96, and the DEAR Clause.		
S2.	Is the software Safety and Hazard Analysis Software and Design Software? Software that is used to classify, design, or analyze nuclear facilities. This software is not part of an SSC but helps to ensure the proper accident or hazards analysis of nuclear facilities or an SSC that performs a safety function.	☐	☑
S3.	Is the software Safety Management and Administrative Controls Software? Software that performs a hazard control function in support of nuclear facility or radiological safety management programs or Technical Safety Requirements or other software that performs a control function necessary to provide adequate protection from nuclear facility or radiological hazards. This software supports eliminating, limiting, or mitigating nuclear hazards to workers, the public, or the environment as addressed in 10 CFR 830, 10 CFR 835, and the DEAR ISMS clause.	☐	☑
	Detailed Information		
1.	Could software failure compromise a limiting condition of operation?	☐	☑
2.	Could software failure cause a reduction in the safety margin for a safety SSC that is cited in DOE approved documented safety analysis (DSA)?	☐	☑
3.	Could software failure cause a reduction in the safety margin for other systems such as toxic or chemical protection systems that are cited in either (a) a DOE approved documented safety analysis or (b) an approved hazard analysis per DOE P 450.1, "Environment, Safety, and Health Policy for the Department of Energy Complex" and the DEAR ISMS clause?	☐	☑
4.	Could software failure result in non-conservative safety analysis, design, or misclassification of facilities or SSCs?	☐	☑
5.	Is the software a safety management database used to aid in decision making whose failure could impact safety SSC operation?	☐	☑
6.	Could software failure result in incorrect analysis, design, monitoring, alarming, or recording of hazardous exposures to workers or public?	☐	☑
7.	Could software failure compromise the defense in depth capability of a nuclear facility?	☐	☑
8.	Could software failure cause a potential violation of regulatory permitting requirements?	☐	☑
9.	Could software failure affect environment, safety, health monitoring or alarming systems?	☐	☑
10.	Could software failure affect the safe operation of a SSC?	☐	☑
11.	Is this software used to support facility protection (i.e., security, fire, etc.) or determine, display, or implement emergency actions?	☐	☑
12.	Does the software perform nuclear material, hazardous chemical, or waste inventory tracking and/or accountability?	☐	☑
13.	Is the software used in support of a quality assurance program that implements a contractual requirement?	☑	☐
14.	Is the software used to support a legal, regulatory, or external milestone?	☑	☐
15.	Is the software used to engineer, analyze, or calculate general service facility equipment designs and/or configurations?	☐	☑
16.	Is this software used to determine, select, or evaluate remedial actions for cleanup of contaminated sites or facilities?	☐	☑
17.	Would a disruption of service, or software error or failure, result in costs greater than $100K to resolve?	☑	☐
18.	Is software lifecycle cost through the first year of maintenance greater than $250K?		

		[x]	[ ]
19.	Does the software/system contain information that may be considered "controlled use"?	[ ]	[x]
	Controlled Use Exemptions		
E3.	<u>Exemption 3 - Statutory Exemption</u> Definition: Exemption 3 is for information that is explicitly prohibited from disclosure, generally by federal law. Basing an OUO determination on Exemption 3 is very complex. Therefore, use of this exemption for Export Controlled Information (ECI) must be reviewed by an ECI Reviewer; all other Exemption 3 information should be reviewed by Legal Services.	[ ]	[x]
E4.	<u>Exemption 4 - Commercial/Proprietary</u> Definition: Exemption 4 addresses trade secrets and commercial or financial information that the Federal government has obtained from persons or commercial entities and that is privileged or confidential. This exemption is intended to protect both the interests of the government and persons submitting information to the government.	[ ]	[x]
E5.	<u>Exemption 5 - Privileged Information</u> Definition: Federal Government-generated information that would not be available by law other than through litigation, including letters, evaluations, plans, trade secrets, etc. are covered by Exemption 5. This exemption protects "intra-agency" and "inter-agency" communications, which has been interpreted by courts to include contractor privileged communications prepared under government direction or initiative (e.g., government funded).	[ ]	[x]
E6.	<u>Exemption 6 - Personal Privacy</u> Definition: Exemption 6 protects personal information related to a specific individual that, if disclosed, might cause personal distress or embarrassment.	[ ]	[x]
E7.	<u>Exemption 7 - Law Enforcement</u> Definition: Exemption 7 protects information compiled by an agency with the authority to enforce the law. It covers information compiled for law enforcement purposes regardless of the format of the information or how and where the information may be filed.	[ ]	[x]
	Key Systems – Critical/Essential		
KC.	<u>Key Critical Software</u>. Is the application, data storage location (share area), or telecommunication service necessary to manage, monitor, and control during emergency and response situations including natural disasters, onsite unsafe conditions, re-establishing the safe work environment, avoiding imminent violation of safety and environmental requirements, or restore security systems when an alternate is not available? Requires immediate restore within 24 hours.	[ ]	[x]
KE.	<u>Key Essential Software</u>. Is the application, data storage location (share area), or telecommunication service required for ensuring area, facility, business, or plant safety and those actions necessary for continuing productive operation supporting the Hanford site mission? Requires attention and restore within 48-72 hours.	[ ]	[x]
	Nuclear Facilities		
NF1	Identify the specific nuclear facility or facilities where the application is used. If "Other" is selected, describe in the "Comments" section.		
Comments:			

SGC Concurrence

SME Concurrence Date:	03/20/2012 SME: Schatz, Aaron L
CIO Concurrence Date:	03/20/2012 Concurrence: Nelson, Ronald L
Reported As CPIC Investment:	
Comments or Additional Concurrences:	

Software Level/Risk	

Measure	Rating
Business Category:	**Environmental**
Software Type:	**Custom Developed Software**
Safety Software:	**No**
Safety Software Classification:	**N/A**
Grading Level:	**D**
Key System:	**N/A**
Controlled Use:	**No**
Controlled Use Exemptions:	

Authorized Users

Usage Log

Cyber Security Information	
Local Admin Privileges Required To Install?	
Local Admin Privileges Required To Operate?	
Risk Assessment Number (CSRM-ID):	
Accreditation Boundary:	