Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&D Project

Prepared for:

Westinghouse Electric Company
Hematite Facility
Festus, Missouri 63028

September 15, 2003

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Site-Specific Soil Parameters
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RESRAD Parameter Table for ^{99}Tc

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	179	W(i)	pCi/L	24.9	1590	7	Lognormal	1
Area of Contaminated Zone	6432	AREA	m^2	5146	7718	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.00005	VCZ	m/yr	0.00004	0.00006	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	562	UW	m^3/yr	450	674	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{99}Tc

1 ^{99}Tc ground-water concentration data were taken from piezometer GWE-6, which was sampled by Gateway Environmental and analyzed by ABB in September 1996. This information was referenced in Table 3-3, "*Investigation to Determine the Source of ^{99}TC in Groundwater Monitoring Wells 17 and 17B.*" Figure 1 shows the former location of GWE-6 and Appendix A contains a copy of Table 3-3. The low and high values of the uncertainty range correspond to concentrations from WS-14 and GWE-4, respectively.

2 ^{99}Tc data does not exist for soil. Therefore, LBG assumes the contaminated zone is based on operations where ^{99}Tc may have been stored or disposed. This includes the former ring storage area and the evaporation ponds, located immediately south of the existing structures. This assumption is based on information provided on page 15 of the "*Remedial Investigation/Feasibility Study (RI/FS) Work Plan, Revision 0,*" dated May 9, 2003. Figure 2 shows the Area of Contamination boundary for ^{99}Tc and Appendix B contains a copy of page 15. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a lack of soil data for ^{99}Tc, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993, was used as a starting point. Since approximately 95 percent of the area of contamination is covered with impervious material, the default value was multiplied by .05 to give a value of 0.00005 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended

value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for NSSSC and DSCC as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG

in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSCC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing*," prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (1.59 acres) were used for pastureland, approximately 4 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended

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RESRAD Parameter Table for ^{235}U

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	13.4	W(i)	pCi/L	0	60.6	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{235}U

1 ^{235}U ground-water concentration data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in August 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (November 1998).

2 Only sparse ^{235}U data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving ^{235}U occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{235}U. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{235}U, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

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5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

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13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

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15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

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Controlled Grazing" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

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RESRAD Parameter Table for ^{228}Ac

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	29.3	W(i)	pCi/L	0	41.8	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
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Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{228}Ac

1 ^{228}Ac ground-water concentration data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in May 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (August 1999).

2 Only sparse ^{228}Ac data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving radioactive materials occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{228}Ac. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{228}Ac, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing,*" prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of*

Controlled Grazing" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{212}Bi

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	1.49	W(i)	pCi/L	0	1.49	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{212}Bi

1 ^{212}Bi ground-water concentration data was taken from piezometer MW-23, which was sampled by Leggette, Brashears & Graham, Inc. in May 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-23 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to the recommended value (1.49; May 1999).

2 Only sparse ^{212}Bi data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving radioactive materials occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{212}Bi. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{212}Bi, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing,*" prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of*

Controlled Grazing" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{212}Pb

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	31.8	W(i)	pCi/L	0	78.4	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{212}Pb

1 ^{212}Pb ground-water concentration data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in February 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-23 (February 1999).

2 Only sparse ^{212}Pb data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving radioactive materials occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{212}Pb. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{212}Pb, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

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8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

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13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

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Controlled Grazing" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{208}Tl

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	8.3	W(i)	pCi/L	0	12.3	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{208}Tl

1 ^{208}Tl ground-water concentration data was taken from piezometer MW-17B, which was sampled by Leggette, Brashears & Graham, Inc. in February 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-17B and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-22 (August 1999).

2 Only sparse ^{208}Tl data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving radioactive materials occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{208}Tl. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{208}Tl, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

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10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

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15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

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Controlled Grazing" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{234}U

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	213	W(i)	pCi/L	0	238	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{234}U

1 ^{234}U ground-water concentration data does not exist. However ^{234}Th (a Parent isotope of ^{234}U) ground-water data does exist. If we assume that ^{234}U is in 100% equilibrium with ^{234}Th we can use the same data. ^{234}Th data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in August 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (February 1999).

2 Only sparse ^{234}U data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving ^{234}U occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{234}U. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

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Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{238}U

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	213	W(i)	pCi/L	0	238	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
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scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{237}Np

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
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Groundwater Concentration	0	W(i)	pCi/L	0	1.00E+20	NA	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
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Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
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Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{237}Np

1 ^{237}Np ground-water data does not exist, and it is not in a decay series where known concentrations can be used in equilibrium. Therefore, the RESRAD default value (0 pci/L) will be used. Low and high values will also correspond to default values.

2 No ^{237}Np data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving U occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{237}Np. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Since no soil data exists for ^{237}Np, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was

multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing*," prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

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Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{239}Pu

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	0	W(i)	pCi/L	0	1.00E+20	NA	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{239}Pu

1 ^{239}Pu ground-water data does not exist, and it is not in a decay series where known concentrations can be used in equilibrium. Therefore, the RESRAD default value (0 pci/L) will be used. Low and high values will also correspond to default values.

2 No ^{239}Pu data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving U occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{239}Pu. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Since no soil data exists for ^{239}Pu, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993, was used as a starting point. Since approximately 70 percent of the

area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

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12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table

3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing*," prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{232}Th

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	29.3	W(i)	pCi/L	0	41.8	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{232}Th

1 ^{232}Th ground-water concentration data does not exist. However ^{228}Ac (a daughter of ^{232}Th) ground-water data does exist. If we assume that ^{232}Th is in 100% equilibrium with ^{228}Ac, we can use the same data. ^{228}Ac data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in May 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (August 1999).

2 Only sparse ^{232}Th data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving ^{232}Th occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{232}Th. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{235}U, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

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data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

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8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

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11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

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13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

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15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

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Controlled Grazing" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{228}Ra

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	29.3	W(i)	pCi/L	0	41.8	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{228}Ra

1 ^{228}Ra ground-water concentration data does not exist. However ^{228}Ac (a daughter of ^{228}Ra) ground-water data does exist. If we assume that ^{228}Ra is in 100% equilibrium with ^{228}Ac, we can use the same data. ^{228}Ac data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in May 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (August 1999).

2 Only sparse ^{228}Ra data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving ^{228}Ra occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{228}Ra. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{235}U, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference

data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing,*" prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The

example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{228}Th

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	29.3	W(i)	pCi/L	0	41.8	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
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Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{228}Th

1 ^{228}Th ground-water concentration data does not exist. However ^{228}Ac (a parent of ^{228}Th) ground-water data does exist. If we assume that ^{228}Th is in 100% equilibrium with ^{228}Ac, we can use the same data. ^{228}Ac data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in May 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (August 1999).

2 Only sparse ^{228}Th data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving ^{228}Th occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{228}Th. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{235}U, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

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data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

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11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

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15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing,*" prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The

example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{224}Ra

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	29.3	W(i)	pCi/L	0	41.8	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
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Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
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Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
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Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
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REFERENCE FOOTNOTES for ^{224}Ra

1 ^{224}Ra ground-water concentration data does not exist. However ^{228}Ac (a parent of ^{224}Ra) ground-water data does exist. If we assume that ^{224}Ra is in 100% equilibrium with ^{228}Ac, we can use the same data. ^{228}Ac data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in May 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (August 1999).

2 Only sparse ^{224}Ra data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving ^{224}Ra occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{224}Ra. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{235}U, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

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7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

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11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

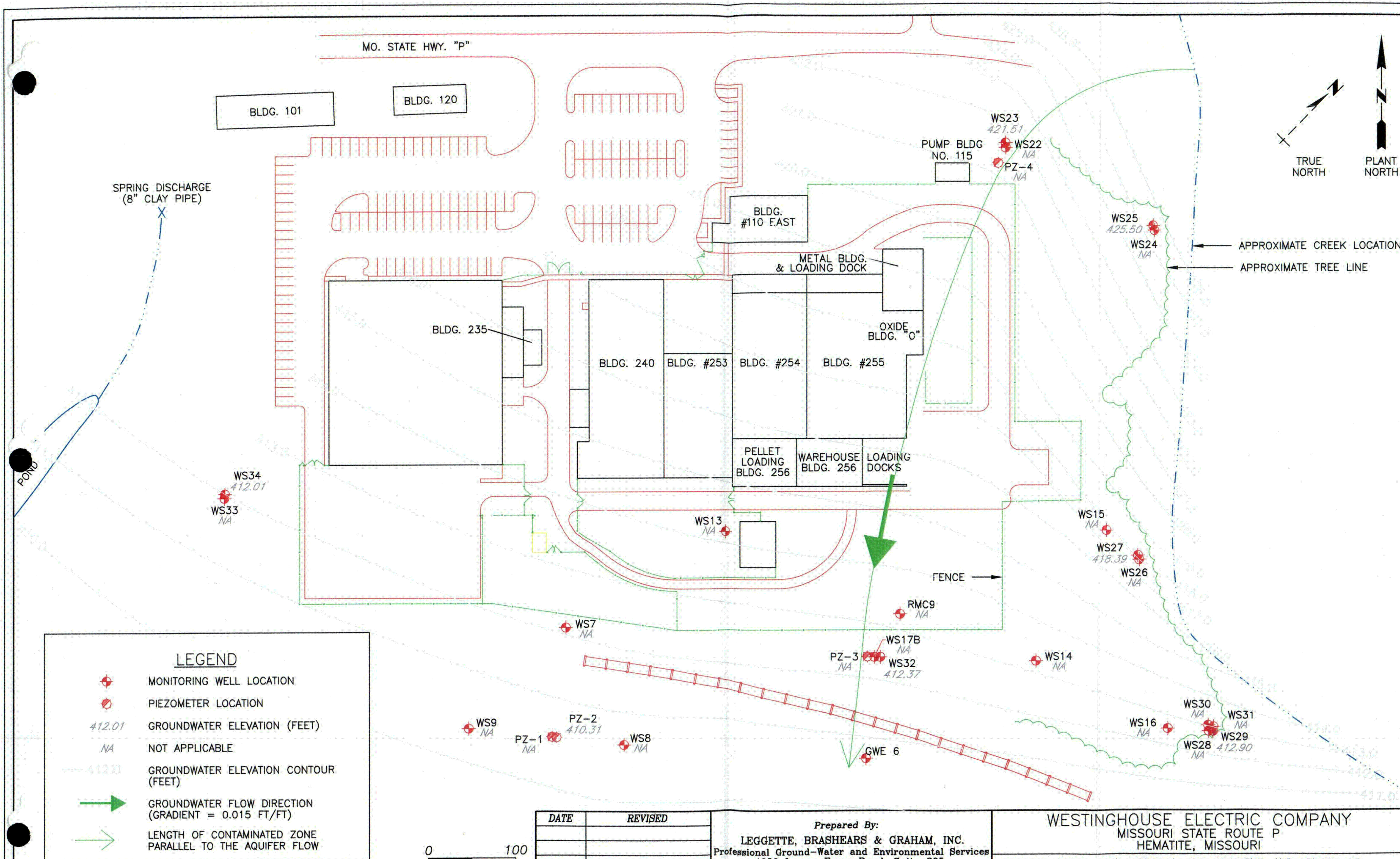
16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing*," prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The

example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

FIGURES

LEGGETTE, BRASHEARS & GRAHAM, INC.



SOURCE: FOURTH SAMPLING EVENT REPORT IN CONJUNCTION WITH THE HYDROGEOLOGIC AND GROUNDWATER, SOIL AND STREAM CHARACTERIZATION, LBG, NOVEMBER 1999

DATE	REVISED

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WESTINGHOUSE ELECTRIC COMPANY
MISSOURI STATE ROUTE P
HEMATITE, MISSOURI

GROUND-WATER FLOW DIRECTION AND GRADIENT, AND LENGTH OF CONTAMINATED ZONE PARALLEL TO THE AQUIFER FLOW IN THE DSCC

FILE: RESRAD contam zone parallel to aquifer flow.dwg | DATE: AUGUST 2003 | FIGURE: 1

C19

APPROXIMATE PROPERTY BOUNDARY
PERENNIAL STREAM
INTERMITTENT STREAM
10-FOOT CONTOUR LINE
FENCE LINE
AREA OF CONTAMINATED ZONE

N

0 150
FEET

SOURCES:

DIGITAL ORTHOPHOTO: USGS, MARCH 1996
DIGITAL ELEVATION MODEL: USGS, JANUARY, 1964
BORING LOCATIONS: BURDINE, 1998-1999
PROPERTY BOUNDARY: ZAHNER & ASSOC., MAY, 2000

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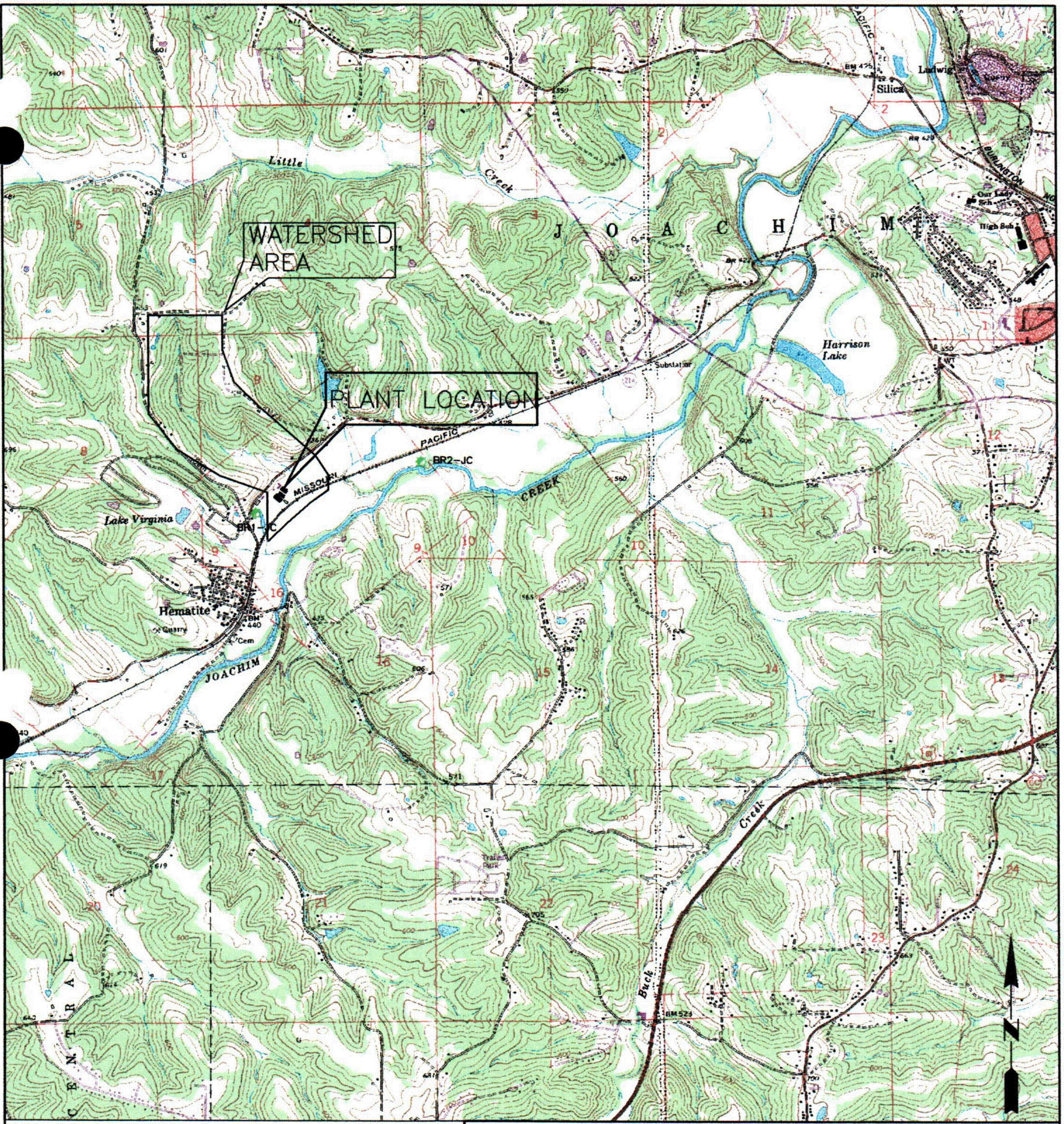
HEMATITE, MISSOURI

AREA OF CONTAMINATED ZONE -- TC-99

FILE: Area of Contaminated Zone -- TC-99.dwg | **DATE:** AUGUST 2003 | **FIGURE:** 2

C20



0 3281

SCALE IN FEET

SOURCE:
U.S.G.S. TOPOGRAPHIC MAP
FESTUS, MISSOURI
7.5 MINUTE QUADRANGLE

WESTINGHOUSE ELECTRIC COMPANY
HEMATITE, MISSOURI FACILITY
HEMATITE, MISSOURI

WATERSHED AREA

DATE	REVISED

Prepared By:

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FILE: WATERSHED AREA.dwg DATE: AUGUST 2003 FIGURE: 3

C21

APPROXIMATE PROPERTY BOUNDARY
PERENNIAL STREAM
INTERMITTENT STREAM
10-FOOT CONTOUR LINE
FENCE LINE
AREA OF CONTAMINATED ZONE

N

0 150
FEET

SOURCES:

DIGITAL ORTHOPHOTO: USGS, MARCH 1996
DIGITAL ELEVATION MODEL: USGS, JANUARY, 1964
BORING LOCATIONS: BURDINE, 1998-1999
PROPERTY BOUNDARY: ZAHNER & ASSOC., MAY, 2000

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HEMATITE, MISSOURI FACILITY
HEMATITE, MISSOURI

AREA OF CONTAMINATED ZONE -- U-235, Ac-228, Bi-212, Pb-212, Tl-208, Np-237, Pu-239, Th-232, Ra-228, Th-228, Ra-224

FILE: Area of Contaminated Zone -- U-235.dwg	DATE: AUGUST 2003	FIGURE: 4

C22

APPENDICES

LEGGETTE, BRASHEARS & GRAHAM, INC.

APPENDIX A

Ground-Water Concentration Supporting Documentation

LEGGETTE, BRASHEARS & GRAHAM, INC.

TABLE 3-3
^{99}Tc Concentration (pCi/L) in Selected Groundwater Monitoring Wells
CE COMBUSTION ENGINEERING
HEMATITE, MISSOURI

Groundwater Monitoring Well Identity	^{99}Tc Concentration (pCi/L) Aug.27, 1996
WS-14	24.9
GWE-2	260
GWE-3	142
GWE-4	1590
GWE-5	874
GWE-6	179
GWE-8	317

COMBUST IGINEERING
MISSOUR. TE ROUTE P
HEMATITE, MISSOURI

FILTERED GAMMA RADIOACTIVE GROUND-WATER AND STREAM SURFACE WATER ANALYTICAL DATA
USEPA METHODS 900.0 AND 901.1M
PICOCURIES PER LITER (pCi/L)

WELL	DATE	K-40 Potassium		Tl-208 Thallium		Pb-212 Lead		Bi-212 Bismuth		Bi-214 Bismuth		Pb-214 Lead		Radium-226*		Ac-228 Actinium		Th-234** Thorium		U-235 Uranium	
		CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL
SW-1	Nov-98	BDL	83.6	BDL	7.9	BDL	12.8			BDL	14.5	ND	ND			BDL	26.4	BDL	91.7	BDL	9.3
(Surface Water)	Feb-99	BDL	173	BDL	12.6	BDL	18.8	BDL	83.6	BDL	24.9	BDL	21.5	BDL	24.9	BDL	43.2	BDL	101.0	BDL	54
	May-99	BDL	137	BDL	11.1	BDL	21.1	BDL	66.5	BDL	19.8	BDL	16.7	BDL	152	BDL	35.3	BDL	101	BDL	9.23
	Aug-99	BDL	156	BDL	19.9	BDL	18.7	BDL	73.4	BDL	26	BDL	23.4	BDL	201	BDL	36.9	BDL	192	BDL	12.2
SW-2	Nov-98	BDL	62.8	BDL	6.3	BDL	15.6			BDL	11.6	BDL	14.3			BDL	20.8	BDL	105.0	BDL	10.0
(Surface Water)	Feb-99	BDL	92	BDL	7.0	BDL	10.1	BDL	45.7	BDL	13.4	BDL	14.7	BDL	13.4	BDL	21.3	BDL	78.5	BDL	31.9
	May-99	BDL	103	BDL	6.90	BDL	14.3	BDL	55.2	BDL	15.0	BDL	12.0	128 +/- 37.1	104	BDL	25.3	BDL	134	17.7 +/- 7.41	9.87
	Aug-99	BDL	159	BDL	10.20	22.9 +/- 3.97	12.8	BDL	59	BDL	19.2	BDL	22.7	BDL	168	BDL	29.9	BDL	120	BDL	7.10
SW-3	Nov-98	BDL	6.1	BDL	6.1	BDL	13.0			3.8 +/- 11.3	10.4	BDL	13.3			BDL	18.2	BDL	9.0	58 +/- 75	76.0
(Surface Water)	Feb-99	BDL	69	BDL	5.1	BDL	7.6	BDL	36.9	BDL	10.2	BDL	11.0	BDL	10.2	BDL	17.2	BDL	86.4	BDL	29.0
	May-99	277 +/- 44.0	98.4	BDL	13.5	25.6 +/- 10.8	21.1	23.3 +/- 118	16.4	BDL	23.4	BDL	23.2	165 +/- 25.3	142	BDL	43.5	BDL	129	BDL	12.8
	Aug-99	182 +/- 46.8	128	BDL	14.6	BDL	32.8	BDL	46.4	BDL	71.6	BDL	61	428 +/- 111	350	BDL	69.2	379 +/- 43.3	153	26.0 +/- 6.77	21.3
SW-4	Nov-98	BDL	4.6	BDL	4.0	BDL	10.2			BDL	8.0	ND	ND			BDL	14.4	8.1 +/- 5.0	7.3	104 +/- 53.6	80.4
(Surface Water)	Feb-99	BDL	124	BDL	8.9	BDL	13.4	BDL	56.7	BDL	16.2	BDL	15.1	BDL	16.2	BDL	28.9	BDL	70.2	BDL	35.0
	May-99	BDL	96.7	BDL	6.24	BDL	9.72	BDL	57.0	BDL	15.4	BDL	16.1	189 +/- 45.7	120	BDL	27.4	BDL	160	BDL	10.5
	Aug-99	130 +/- 35.1	100	BDL	7.88	16.9 +/- 4.09	16.2	BDL	61.8	BDL	37.9	13.1 +/- 2.40	12.4	BDL	163	22.4 +/- 3.57	16.1	BDL	93	BDL	9.91
SW-5	May-99	BDL	93.3	BDL	8.94	12.1 +/- 4.39	13.9	BDL	57.6	18.0 +/- 5.46	18.4	BDL	14.5	200 +/- 41.0	94.3	14.8 +/- 10.1	22.4	BDL	147	BDL	9.49
(BD of SW-3)	Aug-99	BDL	207.0	BDL	28.50	BDL	27.6	BDL	46.4	BDL	22.1	BDL	35.8	50.3 +/- 145	483.0	BDL	65.1	BDL	192	BDL	29.40
WS17B	Nov-98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
(NSSSC)	Feb-99	153 +/- 18.5	50.1	8.3 +/- 0.8	4.4	BDL	10.2	BDL	42.8	22.4 +/- 3.3	10.6	12.0 +/- 3.2	10.3	18.1 +/- 3.6	12.8	23.9 +/- 5.7	19.8	BDL	73.0	BDL	31.9
	May-99	279 +/- 43.4	94.3	BDL	11.9	BDL	22.7	BDL	16.4	BDL	21.0	BDL	23.3	BDL	158	BDL	38.9	BDL	119	BDL	13.5
	Aug-99	BDL	164	BDL	15.8	BDL	29.3	BDL	81.9	59.2 +/- 6.84	25.8	72.2 +/- 7.78	24.1	BDL	403	BDL	40.5	BDL	189	BDL	24.5
WS22	Nov-98	BDL	56.3	BDL	7.1	BDL	8.9			BDL	7.9	BDL	9.9			BDL	16.1	BDL	91.0	BDL	12.2
(NSSSC)	Feb-99	85.8 +/- 22.5	85.0	BDL	5.3	11.0 +/- 1.4	80.6	BDL	41.2	9.2 +/- 2.4	7.5	7.4 +/- 2.3	7.2	BDL	10.8	BDL	17.9	180 +/- 32.9	101	BDL	30.8
	May-99	BDL	75.1	BDL	5.70	BDL	7.83	BDL	39.4	25.8 +/- 4.33	14.9	28.0 +/- 3.52	12.8	151 +/- 31.9	78.5	BDL	21.2	BDL	120	14.4 +/- 4.69	8.67
	Aug-99	BDL	160	12.3 +/- 2.72	8.19	BDL	17.4	BDL	32.4	40.9 +/- 5.85	19.8	26.8 +/- 4.03	17.1	BDL	199	30.4 +/- 7.43	26.5	BDL	88.9	BDL	12.1
WS23	Nov-98	BDL	87.1	BDL	8.7	BDL	21.0			BDL	14.2	ND	ND			BDL	28.4	8.8 +/- 10.9	17.6	38.1 +/- 105	173.0
(DSCC)	Feb-99	BDL	160	BDL	17.1	78.4 +/- 83.7	13.4	BDL	55.4	BDL	32.9	BDL	27.9	23.0 +/- 4.6	15.8	BDL	48.0	BDL	232	BDL	34.7
	May-99	BDL	120	BDL	6.92	27.9 +/- 3.34	18.2	1.49 +/- 66.4	8.22	43.6 +/- 5.82	18.8	36.1 +/- 5.26	21.7	BDL	232	BDL	32.1	BDL	91.6	BDL	16.8
	Aug-99	BDL	266	BDL	18.3	36.5 +/- 4.77	31.2	BDL	30.2	44.1 +/- 11.9	41.5	BDL	37.4	BDL	453	BDL	64.4	199 +/- 48.2	186	BDL	27.5
WS24	Nov-98	BDL	52.6	BDL	6.0	8.3 +/- 12.0	12.2			2.6 +/- 12.0	12.4	4.4 +/- 12.0	12.7			BDL	21.6	3.9 +/- 9.4	12.2	22.3 +/- 95.5	126.0
(NSSSC)	Feb-99	140 +/- 17.7	44.4	10.3 +/- 1.6	4.7	40.2 +/- 3.7	10.1	BDL	42.8	16.7 +/- 3.3	10.0	13.4 +/- 1.5	9.0	13.5 +/- 3.0	12.2	24.9 +/- 2.5	13.3	BDL	70.2	BDL	31.6
	May-99	BDL	90.8	BDL	10.0	BDL	12.9	BDL	47.7	BDL	12.3	BDL	11.6	BDL	213	BDL	23.1	BDL	118	BDL	12.0
	Aug-99	140 +/- 33.0	87.0	BDL	9.7	32.0 +/- 4.03	16.6	BDL	66.8	BDL	32.8	BDL	23.1	BDL	160	28.7 +/- 3.98	18.9	BDL	134	BDL	9.8
WS25	Nov-98	BDL	69.6	BDL	6.7	BDL	15.5			BDL	12.8	BDL	15.0			BDL	20.3	BDL	111	BDL	12.7
(DSCC)	Feb-99	58.7 +/- 17.2	50.2	2.9 +/- 1.8	5.9	5.9 +/- 2.2	75.7	BDL	39.5	8.6 +/- 2.8	8.8	5.0 +/- 1.2	6.4	BDL	10.4	10.8 +/- 3.5	13.8	179.0 +/- 33.1	94.5	BDL	29.2
	May-99	BDL	157	BDL	10.1	BDL	24.2	BDL +/- 69.0	16.4	69.9 +/- 25.3	25.5	BDL	29.3	BDL	177	BDL	38.5	BDL	102	BDL	14.3
	Aug-99	BDL	172	BDL	10.8	BDL	28.8	BDL	75	BDL	30.0	BDL	22.9	BDL	241	BDL	34.7	BDL	200	BDL	14.7
WS26	Nov-98	Dry	Dry	Dry	Dry	Dry	Dry			Dry	Dry	Dry	Dry			Dry	Dry	Dry	Dry	Dry	Dry
	Feb-99	174.0 +/- 26.7	61.6	9.0 +/- 1.8	5.3	BDL	97.7	BDL	45.4	11.2 +/- 2.9	9.9	1.1 +/- 4.8	16.0	14.7 +/- 3.0	11.7	23.6 +/- 3.6	13.3	BDL	84.1	BDL	31.2
	May-99	BDL	145	BDL	9.45	BDL	21.9	BDL	16.4	14.9 +/- 16.3	21.0	BDL	22.1	BDL	197	BDL	39.3	BDL	131	BDL	15.2
	Aug-99	BDL	286	BDL	15.0	BDL	31.5	BDL	30.2	BDL	29.4	BDL	36.9	BDL	501	BDL	36.2	BDL	191	BDL	30.5
WS27	Nov-98	BDL	44.7	BDL	3.6	BDL	12.8			BDL	7.3	ND	ND			BDL	14.3	6.6 +/- 5.5	8.6	60.6 +/- 52.8	84.3
(DSCC)	Feb-99	84.1 +/- 17.8	46.2	BDL	5.0	BDL	76.7	BDL	37.5	BDL	12.5	BDL	12.5	BDL	10.7	BDL	17.1	238.0 +/- 24.1	71.6	BDL	29.4
	May-99	BDL	159	BDL	8.48	BDL	27.4	BDL	16.4	BDL	18.5	BDL	30.6	BDL	237	BDL	44.9	BDL	142	4.10 +/- 18.8	17.2
	Aug-99	128 +/- 32.0	89.6	9.50 +/- 1.41	6.57	BDL	20.2	BDL	166	BDL	36.1	BDL	22.5	BDL	194	41.8 +/- 6.27	18.3	BDL	125	BDL	11.8

BDL=BELOW DETECTION LIMIT
ND=NOT DETECTED
NA=NOT ANALYZED
BD=BLIND DUPLICATE
SD=SPIKE DUPLICATE INCLUDING ALPHA CONCENTRATION OF $9x10^{-4}$ pCi/L AND BETA CONCENTRATION OF $1X10^{-4}$ pCi/L
*=RADIUM-226 REPORTED VALUE HAS NOT BEEN CORRECTED FOR POSSIBLE U-235 INTERFERENCES
**=Th-234 RESULTS MAY NOT BE RELIABLE SINCE THEY WERE RUN ON A "P-TYPE" DETECTOR

COMBUS[illegible] [illegible]NGINEERING
MISSOU[illegible] [illegible]ATE ROUTE P
HEMATITE, MISSOURI

FILTERED GAMMA RADIOACTIVE GROUND-WATER AND STREAM SURFACE WATER ANALYTICAL DATA
USEPA METHODS 900.0 AND 901.1M
PICOCURIES PER LITER (pCi/L)

WELL	DATE	K-40 Potassium		Tl-208 Thallium		Pb-212 Lead		Bi-212 Bismuth		Bi-214 Bismuth		Pb-214 Lead		Radium-226*		Ac-228 Actinium		Th-234** Thorium		U-235 Uranium	
		CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL	CONCENTRATION	MDL
WS28	Nov-98	BDL	65.8	BDL	6.2	BDL	13.5			BDL	10.9	BDL	9.2			BDL	20.3	BDL	110.0	BDL	11.0
(NSSSC)	Feb-99	BDL	151.0	BDL	16.4	BDL	13.1	BDL	58.1	BDL	33.3	BDL	24.9	BDL	15.7	BDL	51.4	BDL	224.0	BDL	34.9
	May-99	BDL	161	6.91 +/- 2.22	8.19	BDL	24.7	BDL +/- 22.6	16.4	BDL	19.1	BDL	27.1	BDL	234	BDL	38.7	BDL	106	BDL +/- 5.11	17.1
	Aug-99	BDL	183	BDL	12.0	BDL	13.6	BDL	16.5	26.0 +/- 6.05	18.1	BDL	17.7	BDL	262	BDL	38.2	BDL	179	BDL	15.9
WS29	Nov-98	BDL	88.1	BDL	7.7	BDL	16.6			BDL	14.8	ND				BDL	27.6	BDL	89.6	BDL	10.1
(DSCC)	Feb-99	BDL	155.0	BDL	15.7	56.4 +/- 17.3	13.1	BDL	56.4	BDL	33.3	BDL	25.5	BDL	15.9	BDL	48.0	BDL	222.0	BDL	34.8
	May-99	BDL	121	BDL	12.2	BDL	19.5	BDL	62.2	BDL	20.8	12.2 +/- 2.26	11.6	BDL	111	BDL	34.3	BDL	105	BDL	6.72
	Aug-99	BDL	129	BDL	7.33	BDL	11.1	BDL	50.0	BDL	17.5	BDL	22.4	BDL	140	BDL	22.9	BDL	107	BDL	8.53
WS30	Nov-98	BDL	100.0	BDL	8.4	BDL	9.6			BDL	18.3	BDL	13.4			BDL	30.0	BDL	99	BDL	9.8
(Bed.)	Feb-99	162.0 +/- 25.9	61.5	9.4 +/- 1.0	4.1	BDL	99.5	BDL	44.0	14.2 +/- 3.3	11.5	10.2 +/- 1.6	8.0	BDL	12.1	24.1 +/- 4.4	16.2	BDL	34.1	BDL	31.4
	May-99	96.8 +/- 40.3	127	BDL	11.4	9.83 +/- 8.27	16.0	BDL	79.2	BDL	22.2	15.6 +/- 2.44	15.8	BDL	179	BDL	33.3	BDL	108	BDL	10.9
	Aug-99	BDL	178	BDL	7.33	BDL	20.9	BDL	76.1	20.0 +/- 5.48	17.6	BDL	22.3	BDL	278	BDL	22.4	BDL	238	BDL	16.9
WS31	Nov-98	BDL	59.9	BDL	6.7	BDL	14.6			BDL	12.5	BDL	15.0			BDL	20.7	BDL	96.1	BDL	11.3
(Bed.)	Feb-99	65.9 +/- 16.6	46.1	BDL	3.7	BDL	75.2	BDL	38.5	BDL	12.4	BDL	9.3	BDL	10.8	BDL	14.8	185.0 +/- 34.5	92.8	BDL	30.1
	May-99	BDL	146	BDL	10.7	27.6 +/- 4.71	22.4	BDL	16.4	BDL	19.1	BDL	22.9	145 +/- 32.0	102	BDL	38.8	BDL	108	BDL	11.3
	Aug-99	150 +/- 22.2	63.8	12.5 +/- 1.32	6.57	17.2 +/- 3.74	11.7	BDL	65.9	BDL	37.2	BDL	22.6	BDL	74.8	BDL	28	BDL	105	BDL	4.54
WS32	Nov-98	BDL	107.0	ND	ND	BDL	14.7			BDL	16.3	ND				BDL	33.4	BDL	98.2	BDL	10.4
(DSCC)	Feb-99	BDL	154.0	BDL	15.6	31.8 +/- 13.6	13.1	BDL	57.1	BDL	32.6	BDL	24.0	24.6 +/- 14.9	15.4	BDL	53.3	BDL	222.0	BDL	35.0
	May-99	BDL	142	BDL	12.9	BDL	16.2	BDL	89.5	BDL	21.5	7.25 +/- 5.56	8.60	BDL	188	29.3 +/- 10.7	33.0	BDL	108	10.9 +/- 3.66	11.4
	Aug-99	BDL	78.9	BDL	9.89	BDL	14.1	BDL	80.1	BDL	48.9	BDL	34.80	BDL	208	BDL	35.1	213 +/- 42.5	137	13.4 +/- 3.97	12.6
WS33	Nov-98	BDL	68.1	BDL	6.4	BDL	14.2			BDL	12.6	BDL	17.7			BDL	20.4	BDL	97.0	BDL	10.2
(NSSSC)	Feb-99	124.0 +/- 16.5	52.0	BDL	9.3	BDL	10.1	BDL	46.7	12.8 +/- 3.7	11.7	BDL	12.1	BDL	12.3	27.9 +/- 3.3	14.3	BDL	77.5	BDL	31.6
	May-99	BDL	164	BDL	9.47	BDL	20.9	BDL	16.4	BDL	20.9	BDL	23.3	BDL	216	BDL	39.2	BDL	121	BDL	16.2
	Aug-99	BDL	202	BDL	14.4	BDL	19.4	BDL	16.5	19.0 +/- 5.67	18.2	BDL	18.5	BDL	312	BDL	36.7	BDL	156	BDL	19.0
WS34	Nov-98	BDL	99.2	ND	ND	BDL	14.1			BDL	15.3	ND				BDL	34.0	BDL	98.0	BDL	10.9
(DSCC)	Feb-99	113.0 +/- 19.1	43.5	BDL	3.5	BDL	77.2	BDL	39.1	BDL	10.6	BDL	12.5	BDL	10.6	BDL	12.0	178.0 +/- 31.7	87.3	BDL	29.5
	May-99	BDL	125	BDL	6.74	BDL	10.2	BDL	56.2	BDL	17.5	BDL	12.5	266 +/- 62.9	166	BDL	27.8	BDL	155	BDL	12.6
	Aug-99	BDL	262	BDL	22.9	BDL	32.4	BDL	21.4	BDL	43.1	BDL	43.5	BDL	417	BDL	94.2	BDL	175	BDL	25.4
WS35	May-99	BDL	108	BDL	7.57	BDL	11.0	BDL	53.2	BDL	15.2	BDL	15.2	155 +/- 47.9	139	BDL	25.9	BDL	188	BDL	11.3
(BD of WS31)	Aug-99	159 +/- 16.8	75.0	8.85 +/- 2.14	6.32	29.0 +/- 3.87	15.9	BDL	62.9	BDL	36.8	BDL	22.1	BDL	176	28.9 +/- 6.94	25.9	155 +/- 48.1	149	BDL	10.7
WS36	May-99	BDL	94.3	BDL	9.00	BDL	12.5	BDL	53.2	BDL	21.4	BDL	15.5	220 +/- 37.1	99.5	BDL	24.5	BDL	124	BDL	9.68
(Deionized Water)	Aug-99	BDL	126	BDL	7.03	BDL	11.6	BDL	51.3	BDL	13.9	42.3 +/- 4.17	12.6	BDL	346	BDL	23.7	BDL	155	BDL	21.1
WS37 SD	May-99	437 +/- 52.8	83.5	BDL	12.1	BDL	25.8	20.6 +/- 22.3	16.4	BDL	26.8	BDL	23.3	2390 +/- 171	262	BDL	43.1	193 +/- 29.4	129	140 +/- 9.63	18.5
	Aug-99	BDL	150	BDL	10.4	34.3 +/- 5.00	16.2	BDL	61.8	BDL	18.7	BDL	22.9	BDL	178	BDL	31.3	BDL	109	BDL	10.8
WS38	May-99	91.7 +/- 41.9	133	BDL	11.0	BDL	17.9	BDL	71.9	31.8 +/- 20.1	22.0	21.7 +/- 2.87	16.3	358 +/- 58.4	146	26.3 +/- 9.97	33.0	BDL	116	21.9 +/- 3.50	8.87
(BD of WS17B)	Aug-99	BDL	91.8	BDL	7.57	BDL	11.2	BDL	37.8	BDL	13.9	40.7 +/- 4.32	12.9	BDL	113	BDL	24.1	BDL	91.6	BDL	6.87

BDL=BELOW DETECTION LIMIT
ND=NOT DETECTED
NA=NOT ANALYZED
BD=BLIND DUPLICATE
SD=SPIKE DUPLICATE INCLUDING ALPHA CONCENTRATION OF 9×10^{-4} pCi/L AND BETA CONCENTRATION OF 1×10^{-4} pCi/L
*=RADIUM-226 REPORTED VALUE HAS NOT BEEN CORRECTED FOR POSSIBLE U-235 INTERFERENCES
**=Th-234 RESULTS MAY NOT BE RELIABLE SINCE THEY WERE RUN ON A "P-TYPE" DETECTOR

APPENDIX B

Supporting Documentation for ^{99}Tc Area of Contamination Zone

LEGGETTE, BRASHEARS & GRAHAM, INC.

detectable levels above background in the northwest corner of the burial site. RMC determined that these levels were due to sources on-site (most likely UF_6 storage area) at that time rather than buried material. RMC concluded that little or no thorium was present near the ground surface. Results of surface soil sampling revealed low level surface contamination. RMC concluded that the surface contamination may have resulted from burial activities or from past effluent (i.e., stack) releases. Results of subsurface soil sampling showed the highest U-234 activity in the Burial Pits to be approximately 400 pCi/g, and the highest U-234 level estimated for surface soil at approximately 47 pCi/g. These levels were based on an estimated U-234/U-238 activity ratio of about 10 to 1.

2.6.2 Investigation to Determine the Source of Technetium-99 in Groundwater Monitoring Wells WS-17 and WS-17B, September 1996

Gateway Environmental Associates, Inc., conducted an investigation to determine the source of Technetium-99 (^{99}Tc) in monitoring wells WS-17 and WS-17B. (Gateway, 1996a) The investigation was conducted to answer concerns expressed by the NRC regarding the source of ^{99}Tc. Gateway Environmental Associates concluded that the ^{99}Tc may have entered the ground-water system within the former ring storage area and traveled down gradient toward the monitoring wells in question. Historical ^{99}Tc and TCE waste disposal practices at the evaporation ponds, may have been a source for contamination in WS17/17B because a nearby gas pipeline may have created a connection between the evaporation ponds and WS17/17B.

^{99}Tc is a low energy beta emitting byproduct of the nuclear fission of Uranium-235 and has a half-life of 213,000 years. ^{99}Tc has appeared as a contaminant in the fuel cycle from the United States Enrichment Company (USEC) facilities. The ^{99}Tc contaminant was present in commercial UF_6 as a result of US government recycling and re-enrichment activities at the gaseous diffusion plants.

One pathway to the evaporation ponds was through the cylinder wash operations. On site UF_6 cylinder washing was performed intermittently over the operating years of the facility. UF_6 cylinder heels preferentially contain the less volatile compounds including ^{99}Tc. The wash solution removed the technetium that was subsequently

APPENDIX C

RESRAD Default Value Table

TABLE 1.3 Default Values, Lower Bounds, and Upper Bounds for RESRAD Input Parameters

Parameter	Unit	Default Value	Lower[a] Bound	Upper[a] Bound
Soil bulk density				
Cover material	g/cm^3	1.5	0	100
Contaminated zone	g/cm^3	1.5	0	100
Unsaturated zone	g/cm^3	1.5	0	100
Saturated zone	g/cm^3	1.5	0	100
Building foundation material	g/cm^3	2.4	0	100
Total porosity				
Cover material	-[b]	.4	0	1
Contaminated zone	-	.4	0	1
Unsaturated zone	-	.4	0	1
Saturated zone	-	.4	0	1
Building foundation material	-	.1	0	1
Effective porosity				
Contaminated zone	-	.2	0	1
Saturated zone	-	.2	0	1
Unsaturated zone	-	.2	0	1
Hydraulic conductivity				
Contaminated zone	m/yr	10	0	1×10^{10}
Unsaturated zone	m/yr	10	0	1×10^{10}
Saturated zone	m/yr	100	0	1×10^{10}
Volumetric water content				
Cover material	-	0.05	0	1
Building foundation material	-	0.03	0	1
Effective radon diffusion coefficient				
Cover material	m^2/s	2×10^{-6}	c	1
Contaminated zone	m^2/s	2×10^{-6}	c	1
Building foundation material	m^2/s	3×10^{-7}	c	1
Radon emanation coefficient (Rn-222/Rn-220)	-	0.25/0.15	0.01	1
Precipitation rate	m/yr	1	0	10
Runoff coefficient	-	0.2	0	1
Irrigation rate	m/yr	0.2	0	10
Evapotranspiration coefficient	-	0.5	0	0.999
Soil-specific *b* parameter				
Contaminated zone	-	5.3	0	15
Unsaturated zone	-	5.3	0	15
Saturated zone	-	5.3	0	15
Erosion rate				

Cover material	m/yr	0.001	0	5
Contaminated zone	m/yr	0.001	0	5
Hydraulic gradient	-	0.02	0	10
Length of contaminated zone parallel to the aquifer flow	m	100	0	∝

TABLE 1.3 (Cont.)

Parameter	Unit	Default Value	Lower[a] Bound	Upper[a] Bound
Watershed area for nearby stream or pond	m^2	1×10^6	0	∞
Water table drop rate	m/yr	0.001	0	5
Well-pump intake depth	m	10	0	1,000
Radon vertical dimension of mixing	m	2	0	1,000
Average annual wind speed	m/s	2	0	100
Average building air exchange rate	1/h	0.5	0	1,000
Building room height	m	2.5	0	100
Building indoor area factor	-	0	0	100
Thickness of uncontaminated unsaturated zone	m	4	0	10,000
Building foundation thickness	m	0.15	0	10
Foundation depth below ground surface	m	1	0	100
Fraction of time spent indoors on-site	-	0.5	0	1
Fraction of time spent outdoors on-site	-	0.25	0	1
Area of contaminated zone	m^2	10,000	0	∞
Cover depth	m	0	0	100
Distribution coefficients	cm^3/g	d	0	1×10^{10}
Fractions of annular areas within contaminated area	-	0	0	1
Radionuclide concentration in groundwater	pCi/L	0	0	1×10^{20}
Leach rate	1/yr	0	0	1×10^{10}
Livestock fodder intake				
Meat	kg/d	68	0	300
Milk	kg/d	55	0	300
Mass loading for inhalation	g/m^3	2×10^{-4}	0	2
Milk consumption rate	L/yr	92	0	1,000

Shielding factor for inhalation	-	0.4	0	1
Depth of roots	m	0.9	0	100
Soil ingestion rate	g/yr	36.5	0	10,000

TABLE 1.3 (Cont.)

Parameter	Unit	Default Value	Lower[a] Bound	Upper[a] Bound
Thickness of contaminated zone	m	2	1×10^{-10}	1,000
Radiation dose limit	mrem/yr	30	0.01	10,000
Dilution length for airborne dust	m	3	0	1,000
Seafood consumption rate				
Fish	kg/yr	5.4	0	1,000
Other seafood	kg/yr	0.9	0	100
Fruit, vegetable, and grain consumption rates	kg/yr	160	0	1,000
Inhalation rate	m^3/yr	8,400	0	20,000
Leafy vegetable consumption rate	kg/yr	14	0	100
Livestock water intake rate				
Meat	L/d	50	0	500
Milk	L/d	160	0	500
Meat and poultry consumption rate	kg/yr	63	0	300
Shielding factor for external gamma	-	0.7	0	1
Elapsed time of waste placement	yr	0	0	1,000
Shape factor, external gamma	-	1	0[c]	1
Initial concentrations of principal radionuclide	pCi/g	d	0	1×10^{20}
Drinking water intake rate	L/yr	510	0	1,000
Fraction of drinking water from site	-	1	0	1
Fraction of aquatic food from site	-	0.5	0	1
Mass loading for foliar deposition	g/m^3	1×10^{-4}	0	1
Depth of soil mixing layer	m	0.15	0	1
Fraction from groundwater				
Drinking water	-	1	0	1
Livestock water	-	1	0	1
Irrigation water	-	1	0	1

[a] The lower and upper bound values represent the lower and upper limit of an input parameter that can be used in RESRAD. For some secondary (derived) parameters (e.g., leach rate) the upper and lower bounds are derived from other primary (basic) parameters

(e.g., thickness of contaminated zone).

[b] A hyphen indicates that the parameter is dimensionless.

[c] A negative value for this parameter serves as a flag in RESRAD. See the section in the handbook on the particular parameter for details.

[d] The default value is radionuclide dependent.

2 SOIL DENSITY

2.1 DEFINITION

Density, as applied to any kind of homogeneous monophasic material of mass M and volume V, is expressed as the ratio of M to V. Under specified conditions, this definition leads to unique values that represent a well-defined property of the material. For heterogeneous and multiphasic materials, however, such as porous media, application of this definition can lead to different results, depending on the exact way the mass and volume of the system are defined.

Soil is a typical heterogeneous multiphasic porous system which, in its general form, contains three natural phases: (1) the solid phase or the soil matrix (formed by mineral particles and solid organic materials); (2) the liquid phase, which is often represented by water and which could more properly be called the soil solution; and (3) the gaseous phase, which contains air and other gases. In this three-phase soil system, the concept of average density can be used to define the following densities: (1) density of solids or soil particle density, ρ_s; (2) bulk or dry density, ρ_b; and (3) total or wet density, ρ_t.

The masses and volumes associated with the three soil phases must be defined before the definitions of the different densities that characterize the soil system can be formalized. Thus, consider a representative elementary volume (REV) of soil that satisfies the following criteria (Bear 1972; Marsily 1986):

1. A sufficiently large volume of soil containing a large number of pores, such that the concept of mean global properties is applicable, and

2. A sufficiently small volume of soil so that the variation of any parameter of the soil from one part of the domain to another can be approximated by continuous functions.

Within a REV, the masses of the phases composing the soil can be defined as follows:

M_s = the mass of solids,

M_l = the mass of liquids,

M_g = the mass of gases (negligible compared with the masses of the solid and liquid phases), and

M_t = $M_s + M_l$ = the total mass.

APPENDIX D

Total Porosity, Dry Density and Hydraulic Conductivity Calculations and Supporting Documentation

LEGGETTE, BRASHEARS & GRAHAM, INC.

TOTAL POROSITY CALCULATIONS

Shannon and Wilson Data	
MW or Piez	**Total Porosity**
PZ2	0.467
WS22	0.447
WS23	0.452
WS24	0.41
WS25	0.418
WS26	0.476
WS27	0.461
WS28	0.464
WS29	0.483
WS32	0.41
WS32	0.482
WS33	0.415
WS34	0.408
AVERAGE	**0.45**

Shannon and Wilson Data from Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*," prepared by LBG in March 1999.

DRY DENSITY CALCULATIONS

TABLE 10/Fitch Data		Shannon and Wilson Data		
MW or Piez	Density g/cm3	MW or Piez	Density pcf	Density g/cm3
PZ2	2.05	PZ2	90.1	1.44
PZ2	1.71	WS22	96.3	1.54
WS23	1.85	WS23	90.6	1.45
WS23	1.74	WS24	98.3	1.57
WS25	2.04	WS25	99.1	1.59
WS25	1.77	WS26	90.3	1.45
WS25	1.81	WS27	88.2	1.41
WS27	1.9	WS28	90.6	1.45
WS27	1.43	WS29	87	1.39
WS29	2.11	WS32	96.1	1.54
WS29	1.86	WS32	88.3	1.41
WS32	1.92	WS33	96.4	1.54
WS32	2.01	WS34	99.7	1.6
WS34	1.86			
WS34	1.85			
AVERAGE OF ALL DATA				**1.69**

Table 10/Fitch data from "*Fourth Sampling Event Report in Conjuction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*," prepared by LBG in November 1999.

Shannon and Wilson Data from Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization,*" prepared by LBG in March 1999.

HYDRAULIC CONDUCTIVITY CALCULATIONS

HORIZONTAL HYDRAULIC CONDUCTIVITY TABLE 2/LBG DATA		
MW or Piez	K (cm/sec)	K (m/yr)
WS-22	2.63E-04	8.29E+01
WS-24	6.94E-05	2.19E+01
WS-28	4.95E-05	1.56E+01
WS-33	2.05E-04	6.46E+01
PZ-1	6.62E-05	2.09E+01
WS-23	6.76E-04	2.13E+02
WS-25	3.26E-04	1.03E+02
WS-27	6.13E-04	1.93E+02
WS-29	8.27E-04	2.61E+02
WS-32	2.70E-03	8.51E+02
WS-34	3.84E-04	1.21E+02
PZ-2	2.76E-04	8.70E+01
AVERAGE		169.58

VERTICAL HYDRAULIC CONDUCTIVITY Shannon and Wilson Data			
MW or Piez	K (cm/sec)	Avg K (cm/sec)	K (m/yr)
	3.60E-07		
PZ-2	3.60E-07	3.67E-07	1.16E-01
	3.80E-07		
	4.50E-09		
WS-22	4.40E-09	4.37E-09	1.38E-03
	4.20E-09		
	2.90E-05		
WS-23	2.60E-05	2.77E-05	8.72E+00
	2.80E-05		
	2.40E-06		
WS-24	2.40E-06	2.50E-06	7.88E-01
	2.70E-06		
	4.90E-08		
WS-25	4.80E-08	4.97E-08	1.57E-02
	5.20E-08		
	5.30E-06		
WS-26	5.20E-06	5.23E-06	1.65E+00
	5.20E-06		
	4.60E-04		
WS-27	4.70E-04	4.60E-04	1.45E+02
	4.50E-04		
	6.50E-05		
WS-28	6.30E-05	6.47E-05	2.04E+01
	6.60E-05		
	1.80E-07		
WS-29	2.00E-07	1.90E-07	5.99E-02
	1.90E-07		
	1.90E-05		
WS-32	2.00E-05	1.93E-05	6.10E+00
	1.90E-05		
	2.00E-05		
WS-32	2.00E-05	2.03E-05	6.41E+00
	2.10E-05		
	1.70E-08		
WS-33	2.00E-08	1.83E-08	5.78E-03
	1.80E-08		
	1.70E-08		
WS-34	1.90E-08	1.83E-08	5.78E-03
	1.90E-08		
AVERAGE			14.56

Table 2/LBG data from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999.

Shannon and Wilson Data from Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*," prepared by LBG in March 1999. The permeability (K) for each sample was derived by averaging the last three readings from the test (verbal communication with Chris Groves - Vice-President, Shannon & Wilson, August 13, 2003). Vertical permeability (K) determined according to ASTM 5084-90.

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ject: Combustion Engineering | Test. by: KDM-10/19/98

Job No.: E-1039-01 | Boring: PZ-2 | Sample: 25.0-27.0 | Checked by: KWH - 12/7/98

Description: Dark grey fat CLAY, with some Fe stains, occa f & c gravels, rare sm roots

Depth: | Permeant: tap water | Test Method: ASTM 5084-90

Permeameter No.: 8 | Standpipe Vol (cc/cm) Inflow: 1.297 Outflow: 1.294

	Before Test	After Test		Before Test	After Test
Sample Diameter (in)	2.869	2.875	Tare No.	K1	82
Sample Length (in)	2.752	2.762	Tare Wt. (g)	2.63	83.62
Sample Area (cm^2)	41.71	41.88	Wet Soil + Tare (g)	98.32	633.61
Sample Volume (CC)	291.54	293.83	Dry Soil + Tare (g)	75.87	501.19
Sample Wt. (g)	549.92	549.99	Water Content (%)	30.7	31.7
Wet Density (pcf)	117.7	116.8	Porosity	0.467	
Dry Density (pcf)	90.1	88.7	Pore Volume (CC)	136.23	
Effective Consolidation (psi)	5 min	6 max	Degree of Saturation		95
			Specific Gravity		2.71

Read Time y	hr	min	Pcell psi	Pin psi	Pout psi	Readings (cm) hin	hout	Inflow PV	Outflow PV	Storage PV	Total PV	i	K cm/s
1	9	42	50	45	44	64.20	64.20	---	---	---	---	10.1	---
1	11	4	50	45	44	63.55	64.85	-0.01	0.01	0.00	0.01	9.9	4.1E-07
1	12	34	50	45	44	62.80	65.45	-0.01	0.01	0.00	0.01	9.7	4.0E-07
1	13	23	50	45	44	62.45	65.80	0.00	0.00	0.00	0.02	9.6	3.8E-07
1	15	11	50	45	44	61.65	66.50	-0.01	0.01	0.00	0.02	9.4	3.8E-07
1	16	24	50	45	44	61.15	67.00	0.00	0.00	0.00	0.03	9.2	3.8E-07
1	16	43	50	45	44	61.00	67.10	0.00	0.00	0.00	0.03	9.2	3.7E-07
2	9	55	50	45	44	60.80	67.00					9.2	
2	12	34	50	45	44	59.70	68.05	-0.01	0.01	0.00	0.04	8.9	3.9E-07
2	13	57	50	45	44	59.20	68.55	0.00	0.00	0.00	0.04	8.7	3.5E-07
2	16	35	50	45	44	58.20	69.55	-0.01	0.01	0.00	0.05	8.4	3.8E-07
2	18	27	50	45	44	57.55	70.10	-0.01	0.01	0.00	0.06	8.3	3.3E-07
3	8	13	50	45	44	53.05	74.40	-0.04	0.04	0.00	0.10	7.0	3.6E-07
3	9	37	50	45	44	52.60	74.75	0.00	0.00	0.00	0.10	6.9	3.5E-07
3	11	1	50	45	44	52.20	75.15	0.00	0.00	0.00	0.10	6.8	3.6E-07
3	14	25	50	45	44	51.25	76.10	-0.01	0.01	0.00	0.11	6.5	3.6E-07
3	17	53	50	45	44	50.15	76.95	-0.01	0.01	0.00	0.12	6.2	3.8E-07

rev 3.2.97

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

Project: Combustion Engineering Test. by: KDM-10/29/98

Job No.: E-1039-01 Boring: WS-22 Sample: 16.0-18.0 Checked by: KMK - 12/7/98

Description: Brown & grey fat CLAY, with some Fe stains, some sm Fe nodules, occa decomposed roots

Depth: Permeant: tap water Test Method: ASTM 5084-90

Permeameter No.: 16 Standpipe Vol (cc/cm) Inflow: 1.312 Outflow: 1.308

	Before Test	After Test
Sample Diameter (in)	2.850	2.886
Sample Length (in)	2.316	2.349
Sample Area (cm^2)	41.16	42.20
Sample Volume (CC)	242.11	251.81
Sample Wt. (g)	479.39	485.79
Wet Density (pcf)	123.6	120.4
Dry Density (pcf)	96.3	92.8
Effective Consolidation (psi)	5 min	6 max

	Before Test	After Test
Tare No.	K2	109
Tare Wt. (g)	2.63	84.34
Wet Soil + Tare (g)	79.99	570.13
Dry Soil + Tare (g)	62.91	459.02
Water Content (%)	28.3	29.7
Porosity	0.447	
Pore Volume (CC)	108.23	
Degree of Saturation		95
Specific Gravity		2.79

Read Time			Pcell	Pin	Pout	Readings (cm)		Inflow	Outflow	Storage	Total	i	K
	hr	min	psi	psi	psi	hin	hout	PV	PV	PV	PV		cm/s
1	12	55	50	45	44	64.40	65.40	---	---	---	---	11.8	---
2	8	13	50	45	44	64.00	65.50	0.00	0.00	0.00	0.00	11.7	9.8E-09
2	15	3	50	45	44	63.95	65.55		0.00	0.00	0.00	11.7	5.5E-09
2	15	4	50	45	43	63.95	65.55					23.6	
3	9	43	50	45	43	63.55	65.80	0.00	0.00	0.00	0.00	23.5	6.5E-09
4	8	31	50	45	43	63.10	66.00	-0.01	0.00	0.00	0.01	23.4	5.4E-09
5	8	13	50	45	43	62.70	66.20	0.00	0.00	0.00	0.01	23.3	4.8E-09
5	17	56	50	45	43	62.60	66.30	0.00	0.00	0.00	0.01	23.3	3.9E-09
6	12	6	50	45	43	62.30	66.40	0.00	0.00	0.00	0.01	23.2	4.2E-09
6	12	7	50	45	43	60.70	60.05					24.0	
9	8	45	50	45	43	59.95	60.65	-0.01	0.01	0.00	0.02	23.8	3.6E-09
10	8	30	50	45	43	59.60	60.80	0.00	0.00	0.00	0.02	23.7	3.9E-09
11	8	15	50	45	43	59.30	61.00	0.00	0.00	0.00	0.02	23.6	3.9E-09
12	17	40	50	45	43	58.90	61.35	0.00	0.00	0.00	0.03	23.5	4.2E-09
13	16	45	50	45	43	58.60	61.60	0.00	0.00	0.00	0.03	23.4	4.5E-09
14	10	6	50	45	43	58.35	61.75	0.00	0.00	0.00	0.03	23.3	4.4E-09
17	9	59	50	45	43	57.30	62.30	-0.01	0.01	0.00	0.04	23.1	4.2E-09

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ject Combustion Engineering | Test. by KDM-10/28/98

Job No. E-1039-01 | Boring WS-23 | Sample 26.5-28.5 | Checked by KMW - 12/7/98

Description Dark grey fat CLAY, with occa sm roots & root holes, some worm burrows, sl blocky

Depth | Permeant tap water | Test Method ASTM 5084-90

Permeameter No. 7 | Standpipe Vol (cc/cm) Inflow: 1.304 Outflow: 1.288

	Before Test	After Test		Before Test	After Test
Sample Diameter (in)	2.872	2.870	Tare No.	K3	78
Sample Length (in)	2.508	2.510	Tare Wt. (g)	2.63	83.16
Sample Area (cm^2)	41.80	41.74	Wet Soil + Tare (g)	94.29	589.43
Sample Volume (CC)	266.25	266.09	Dry Soil + Tare (g)	73.14	469.60
Sample Wt. (g)	502.58	506.27	Water Content (%)	30.0	31.0
Wet Density (pcf)	117.8	118.7	Porosity	0.452	
Dry Density (pcf)	90.6	90.6	Pore Volume (CC)	120.36	
Effective Consolidation (psi)	5 min	6 max	Degree of Saturation		100
			Specific Gravity		2.65

Read Time y	hr	min	Pcell psi	Pin psi	Pout psi	Readings (cm) hin	hout	Inflow PV	Outflow PV	Storage PV	Total PV	i	K cm/s
1	15		50	45	44	61.85	63.10	—	—	—	—	10.8	—
1	15	1	50	45	44	61.20	63.90	-0.01	0.01	0.00	0.01	10.6	3.5E-05
1	15	2	50	45	44	60.60	64.45	-0.01	0.01	0.00	0.01	10.4	2.8E-05
1	15	3	50	45	44	60.10	64.95	-0.01	0.01	0.00	0.02	10.3	2.5E-05
1	15	4	50	45	44	59.70	65.35	0.00	0.00	0.00	0.02	10.2	2.0E-05
1	15	6	50	45	44	59.00	66.00	-0.01	0.01	0.00	0.03	9.9	1.7E-05
1	15	8	50	45	44	58.35	66.65	-0.01	0.01	0.00	0.04	9.7	1.7E-05
1	15	10	50	45	44	57.75	67.25	-0.01	0.01	0.00	0.04	9.5	1.6E-05
3	8		50	45	44	57.45	65.85					9.7	
3	8	1	50	45	44	56.20	67.20	-0.01	0.01	0.00	0.06	9.3	7.1E-05
3	8	2	50	45	44	55.25	68.15	-0.01	0.01	0.00	0.07	9.0	5.4E-05
3	8	3	50	45	44	54.40	69.00	-0.01	0.01	0.00	0.08	8.7	4.9E-05
3	8	4	50	45	44	53.60	69.80	-0.01	0.01	0.00	0.09	8.5	4.8E-05
3	8	6	50	45	44	52.35	71.05	-0.01	0.01	0.00	0.10	8.1	3.9E-05
3	8	9	50	45	44	50.65	72.75	-0.02	0.02	0.00	0.12	7.6	3.7E-05
3	8	11	50	45	44	49.75	73.65	-0.01	0.01	0.00	0.13	7.3	3.1E-05
3	8	13	50	45	44	48.95	74.45	-0.01	0.01	0.00	0.14	7.0	2.9E-05

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

Project Combustion Engineering Test. by KDM-10/28/98

Job No. E-1039-01 Boring WS-23 Sample 26.5-28.5 Checked by KMB 12/7/98

Description Dark grey fat CLAY, with occa sm roots & root holes, some worm burrows, sl blocky

Depth ______ Permeant tap water Test Method ASTM 5084-90

Permeameter No. 7 Standpipe Vol (cc/cm) Inflow: 1.304 Outflow: 1.288

3	8	15	50	45	44	48.15	75.25	-0.01	0.01	0.00	0.15	6.8	3.0E-05
3	8	17	50	45	44	47.45	75.95	-0.01	0.01	0.00	0.15	6.6	2.7E-05
3	8	19	50	45	44	46.80	76.60	-0.01	0.01	0.00	0.16	6.4	2.6E-05
3	8	21	50	45	44	46.20	77.20	-0.01	0.01	0.00	0.17	6.2	2.5E-05
6	9	2	50	45	44	44.50	61.60					8.4	
6	9	4	50	45	44	43.55	62.55	-0.01	0.01	0.00	0.18	8.1	3.0E-05
6	9	6	50	45	44	42.70	63.40	-0.01	0.01	0.00	0.19	7.8	2.8E-05
6	9	7	50	45	44	54.80	63.80					9.6	
6	9	16	50	45	44	50.30	68.30	-0.05	0.05	0.00	0.23	8.2	2.9E-05
6	9	17	50	45	44	50.30	62.00					9.2	
6	9	22	50	45	44	47.80	64.40	-0.03	0.03	0.00	0.26	8.4	2.9E-05
[illegible]	9	25	50	45	44	46.60	65.65	-0.01	0.01	0.00	0.27	8.1	2.6E-05
6	9	28	50	45	44	45.30	66.90	-0.01	0.01	0.00	0.29	7.6	2.8E-05

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ject	Combustion Engineering			Test. by	KDM-10/15/98
Job No.	E-1039-01	Boring	WS-24	Sample 16.0-18.0	Checked by KWW -12/7/98

Description: Brown lean CLAY, with numerous Fe stains, some sm Fe nodules, occa sm roots, sl blocky

Depth: ______ Permeant: tap water Test Method: ASTM 5084-90

Permeameter No. 17 Standpipe Vol (cc/cm) Inflow: 1.298 Outflow: 1.293

	Before Test	After Test		Before Test	After Test
Sample Diameter (in)	2.871	2.859	Tare No.	K4	96
Sample Length (in)	2.212	2.224	Tare Wt. (g)	2.63	83.29
Sample Area (cm^2)	41.77	41.42	Wet Soil + Tare (g)	88.57	546.78
Sample Volume (CC)	234.66	233.97	Dry Soil + Tare (g)	70.80	452.15
Sample Wt. (g)	465.96	463.49	Water Content (%)	26.1	25.7
Wet Density (pcf)	123.9	123.6	Porosity	0.410	
Dry Density (pcf)	98.3	98.4	Pore Volume (CC)	96.23	
Effective Consolidation (psi)	5 min	6 max	Degree of Saturation	99	
			Specific Gravity	2.67	

Read Time			Pcell	Pin	Pout	Readings (cm)		Inflow	Outflow	Storage	Total	i	K
y	hr	min	psi	psi	psi	hin	hout	PV	PV	PV	PV		cm/s
1	12		50	45	44	64.80	66.20	—	—	—	—	12.3	---
1	12	15	50	45	44	63.80	67.20	-0.01	0.01	0.00	0.01	11.9	2.9E-06
1	12	41	50	45	44	62.40	68.60	-0.02	0.02	0.00	0.03	11.4	2.4E-06
1	13	3	50	45	44	61.25	69.75	-0.02	0.02	0.00	0.05	11.0	2.4E-06
1	13	19	50	45	44	60.50	70.50	-0.01	0.01	0.00	0.06	10.7	2.2E-06
1	13	51	50	45	44	59.00	72.00	-0.02	0.02	0.00	0.08	10.2	2.3E-06
1	14	12	50	45	44	58.10	72.90	-0.01	0.01	0.00	0.09	9.9	2.2E-06
1	14	40	50	45	44	56.90	74.05	-0.02	0.02	0.00	0.11	9.5	2.2E-06
1	15	15	50	45	44	55.50	75.50	-0.02	0.02	0.00	0.12	9.0	2.3E-06
1	15	34	50	45	44	54.75	76.25	-0.01	0.01	0.00	0.14	8.7	2.3E-06
1	15	46	50	45	44	54.30	76.70	-0.01	0.01	0.00	0.14	8.5	2.3E-06
1	16	5	50	45	44	53.60	77.40	-0.01	0.01	0.00	0.15	8.3	2.3E-06
1	16	28	50	45	44	52.80	78.20	-0.01	0.01	0.00	0.16	8.0	2.2E-06
1	17	6	50	45	44	51.40	79.60	-0.02	0.02	0.00	0.18	7.5	2.5E-06
3	8	34	50	45	44	50.85	79.40					7.4	
3	8	55	50	45	44	50.20	80.20	-0.01	0.01	0.00	0.19	7.2	2.4E-06
3	9	17	50	45	44	49.45	80.90	-0.01	0.01	0.00	0.20	6.9	2.4E-06

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ect Combustion Engineering Test. by KDM-10/15/98

Job No. E-1039-01 Boring WS-24 Sample 16.0-18.0 Checked by KWH - 12/7/98

Description Brown lean CLAY, with numerous Fe stains, some sm Fe nodules, occa sm roots, sl blocky

Depth ______ Permeant tap water Test Method ASTM 5084-90

Permeameter No. 17 Standpipe Vol (cc/cm) Inflow: 1.298 Outflow: 1.293

3 11 45	50	45	44	45.30	85.05	-0.06	0.06	0.00	0.26	5.4	2.4E-06
3 13 55	50	45	44	42.05	88.30	-0.04	0.04	0.00	0.30	4.3	2.7E-06

rev 3.2.97

TRIAXIAL PERMEABILITY DATA SHEET
SHANNON & WILSON, INC.

ject Combustion Engineering Test. by KMH/KDM-11/2/98
Job No. E-1039-01 Boring WS-25 Sample 30.0-31.5 Checked by KMH - 12/7/98
Description Dark grey fat CLAY, with some c sands, occa f gravels, rare sm roots
Depth Permeant tap water Test Method ASTM 5084-90

Permeameter No. 8 Standpipe Vol (cc/cm) Inflow: 1.297 Outflow: 1.294

	Before Test	After Test		Before Test	After Test
Sample Diameter (in)	2.880	2.884	Tare No.	AB1	95
Sample Length (in)	2.366	2.365	Tare Wt. (g)	2.63	84.26
Sample Area (cm^2)	42.03	42.15	Wet Soil + Tare (g)	67.67	587.10
Sample Volume (CC)	252.58	253.17	Dry Soil + Tare (g)	54.65	485.10
Sample Wt. (g)	501.38	502.84	Water Content (%)	25.0	25.4
Wet Density (pcf)	123.9	123.9	Porosity	0.418	
Dry Density (pcf)	99.1	98.8	Pore Volume (CC)	105.68	
Effective			Degree of Saturation		96
Consolidation (psi)	5 min	6 max	Specific Gravity		2.73

Read Time y	hr	min	Pcell psi	Pin psi	Pout psi	Readings (cm) hin	hout	Inflow PV	Outflow PV	Storage PV	Total PV	i	K cm/s
1	8	13	50	45	44	68.85	71.30	---	---	---	---	11.3	---
1	17	40	50	45	44	68.15	71.90	-0.01	0.01	0.00	0.01	11.1	5.3E-08
2	8	55	50	45	44	67.15	72.80	-0.01	0.01	0.00	0.02	10.8	4.9E-08
2	16	44	50	45	44	66.65	73.25	-0.01	0.01	0.00	0.02	10.6	4.9E-08
3	10	12	50	45	44	65.50	74.30	-0.01	0.01	0.00	0.04	10.2	5.2E-08
5	7	49	50	45	44	62.90	76.80	-0.03	0.03	0.00	0.07	9.4	4.9E-08
6	7	50	50	45	44	61.60	78.20	-0.02	0.02	0.00	0.08	8.9	5.3E-08
7	10	12	50	45	44	60.30	79.70	-0.02	0.02	0.00	0.10	8.5	5.2E-08
8	8	42	50	45	44	59.15	75.25					9.0	
8	15	21	50	45	44	58.80	75.60	0.00	0.00	0.00	0.11	8.9	5.0E-08
9	9	25	50	45	44	57.90	76.50	-0.01	0.01	0.00	0.12	8.6	4.9E-08
10	10	15	50	45	44	56.75	77.70	-0.01	0.01	0.00	0.13	8.2	4.8E-08
12	11	24	50	45	44	54.40	80.00	-0.03	0.03	0.00	0.16	7.4	5.2E-08

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

Project Combustion Engineering — Test. by KMH-11/19/98

Job No. E-1039-01 — Boring WS-26 — Sample 13.0-15.0 — Checked by KMH -12/7/98

Description Grey fat CLAY, with some Fe stains, some sm Fe nodules, weathered shells, slickensides

Depth ______ — Permeant tap water — Test Method ASTM 5084-90

Permeameter No. 5 — Standpipe Vol (cc/cm) Inflow: 1.280 Outflow: 1.281

	Before Test	After Test		Before Test	After Test
Sample Diameter (in)	2.875	2.879	Tare No.	K5	100
Sample Length (in)	2.538	2.558	Tare Wt. (g)	2.63	86.14
Sample Area (cm^2)	41.88	42.00	Wet Soil + Tare (g)	83.24	604.41
Sample Volume (CC)	270.00	272.88	Dry Soil + Tare (g)	64.42	478.21
Sample Wt. (g)	509.68	518.27	Water Content (%)	30.5	32.2
Wet Density (pcf)	117.8	118.5	Porosity	0.476	
Dry Density (pcf)	90.3	89.7	Pore Volume (CC)	128.44	
			Degree of Saturation		96
Effective Consolidation (psi)	5 min	6 max	Specific Gravity		2.76

Read Time day	hr	min	Pcell psi	Pin psi	Pout psi	Readings (cm) hin	hout	Inflow PV	Outflow PV	Storage PV	Total PV	i	K cm/s
1	13	25	50	45	44	63.25	66.35	---	---	---	---	10.4	---
1	13	43	50	45	44	58.05	71.45	-0.05	0.05	0.00	0.05	8.8	1.5E-05
2	9		50	45	44	58.00	58.20					10.9	
2	9	5	50	45	44	56.90	59.20	-0.01	0.01	0.00	0.06	10.6	1.0E-05
2	9	10	50	45	44	56.00	60.10	-0.01	0.01	0.00	0.07	10.3	8.8E-06
2	9	20	50	45	44	54.40	61.60	-0.02	0.01	0.00	0.08	9.8	7.9E-06
2	9	34	50	45	44	52.70	63.30	-0.02	0.02	0.00	0.10	9.3	6.5E-06
4	7	10	50	45	44	52.20	64.80					9.0	
4	7	20	50	45	44	50.85	66.15	-0.01	0.01	0.00	0.12	8.5	7.9E-06
4	7	36	50	45	44	49.15	67.85	-0.02	0.02	0.00	0.13	8.0	6.5E-06
4	7	37	50	45	44	49.00	63.00					8.7	
4	7	48	50	45	44	47.80	64.25	-0.01	0.01	0.00	0.14	8.4	6.6E-06
4	8	4	50	45	44	46.20	65.80	-0.02	0.02	0.00	0.16	7.9	6.2E-06
4	8	20	50	45	44	44.80	67.20	-0.01	0.01	0.00	0.17	7.4	5.8E-06
4	8	43	50	45	44	43.05	69.00	-0.02	0.02	0.00	0.19	6.9	5.5E-06
4	9	9	50	45	44	41.10	70.90	-0.02	0.02	0.00	0.21	6.3	5.7E-06
4	8	59	50	45	44	63.60	70.90					9.8	

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ject Combustion Engineering Test. by KMH-11/19/98

Job No. E-1039-01 Boring WS-26 Sample 13.0-15.0 Checked by KMH - 12/7/98

Description Grey fat CLAY, with some Fe stains, some sm Fe nodules, weathered shells, slickensides

Depth ______ Permeant tap water Test Method ASTM 5084-90

Permeameter No. 5 Standpipe Vol (cc/cm) Inflow: 1.280 Outflow: 1.281

4 9 24	50	45	44	61.15	73.35	-0.02	0.02	0.00	0.24	9.0	5.3E-06
4 10 23	50	45	44	56.20	78.20	-0.05	0.05	0.00	0.28	7.5	5.1E-06
4 11 3	50	45	44	53.20	81.20	-0.03	0.03	0.00	0.31	6.6	5.4E-06
4 11 4	50	45	44	53.20	70.00					8.3	
4 11 53	50	45	44	49.30	73.90	-0.04	0.04	0.00	0.35	7.1	5.3E-06
4 12 36	50	45	44	46.40	76.80	-0.03	0.03	0.00	0.38	6.2	5.2E-06
4 13 6	50	45	44	44.60	78.60	-0.02	0.02	0.00	0.40	5.6	5.2E-06

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ect Combustion Engineering   Test. by KMH/KDM-11/20/98

Job No. E-1039-01   Boring WS-27   Sample 21.0-23.0   Checked by KMH -12/7/98

Description Dark grey fat CLAY, with occa sm roots & root holes, rare Fe stains, sl blocky

Depth ____   Permeant tap water   Test Method ASTM 5084-90

Permeameter No. 17   Standpipe Vol (cc/cm) Inflow: 1.298 Outflow: 1.293

OPALINE

	Before Test	After Test		Before Test	After Test
Sample Diameter (in)	2.885	2.891	Tare No.	AB2	96
Sample Length (in)	2.731	2.741	Tare Wt. (g)	2.63	83.40
Sample Area (cm^2)	42.17	42.35	Wet Soil + Tare (g)	74.00	634.27
Sample Volume (CC)	292.55	294.85	Dry Soil + Tare (g)	56.59	496.60
Sample Wt. (g)	546.80	550.87	Water Content (%)	32.3	33.3
Wet Density (pcf)	116.6	116.6	Porosity	0.461	
Dry Density (pcf)	88.2	87.4	Pore Volume (CC)	134.76	
			Degree of Saturation		100
Effective Consolidation (psi)	5 min	6 max	Specific Gravity		2.62

Read Time			Pcell	Pin	Pout	Readings (cm)		Inflow	Outflow	Storage	Total	i	K
	hr	min	psi	psi	psi	hin	hout	PV	PV	PV	PV		cm/s
1	8		50	45	44	59.60	75.40	---	---	---	---	7.9	---
1	8	0.5	50	45	44	55.20	79.80	-0.04	0.04	0.00	0.04	6.6	6.2E-04
1	8	1.0	50	45	44	51.95	83.05					4.6	
1	8	1.5	50	45	44	49.25	85.75	-0.03	0.03	0.00	0.07	3.9	6.5E-04
1	8	2.0	50	45	44	47.20	87.80	-0.02	0.02	0.00	0.09	3.3	5.9E-04
1	8	2.5	50	45	44	45.35	89.70	-0.02	0.02	0.00	0.11	2.7	6.4E-04
1	8	3.0	50	45	44	43.75	91.30	-0.02	0.02	0.00	0.12	2.3	6.6E-04
1	8	3.5	50	45	44	65.60	80.00					7.0	
1	8	4.0	50	45	44	61.60	84.00	-0.04	0.04	0.00	0.16	5.9	6.3E-04
1	8	4.5	50	45	44	58.40	87.20					6.0	
1	8	5.0	50	45	44	55.80	89.80	-0.03	0.02	0.00	0.18	5.2	4.8E-04
1	8	5.5	50	45	44	53.50	92.10	-0.02	0.02	0.00	0.21	4.6	4.8E-04
1	8	6.0	50	45	44	51.60	94.00	-0.02	0.02	0.00	0.22	4.0	4.5E-04
1	8	6.5	50	45	44	50.00	95.60	-0.02	0.02	0.00	0.24	3.6	4.3E-04
1	8	7.0	50	45	44	48.60	97.00	-0.01	0.01	0.00	0.25	3.2	4.3E-04
1	8	7.5	50	45	44	47.40	98.20	-0.01	0.01	0.00	0.27	2.8	4.1E-04
2	8		50	45	44	85.30	90.80					9.3	

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ject Combustion Engineering Test. by KMH/KDM-11/20/98

Job No. E-1039-01 Boring WS-27 Sample 21.0-23.0 Checked by KMH -12/7/98

Description Dark grey fat CLAY, with occa sm roots & root holes, rare Fe stains, sl blocky

Depth Permeant tap water Test Method ASTM 5084-90

Permeameter No. 17 Standpipe Vol (cc/cm) Inflow: 1.298 Outflow: 1.293

UPALINE

2 8 0.5	50	45	44	81.10	94.90	-0.04	0.04	0.00	0.30	8.1	4.9E-04
2 8 1.0	50	45	44	77.95	98.05	-0.03	0.03	0.00	0.33	7.2	4.2E-04
2 8 2.0	50	45	44	72.35	103.60	-0.05	0.05	0.00	0.39	5.6	4.5E-04
2 8 2.5	50	45	44	72.35	87.00					8.0	
2 8 3.0	50	45	44	69.00	90.30	-0.03	0.03	0.00	0.42	7.1	4.5E-04
2 8 3.5	50	45	44	66.00	93.30	-0.03	0.03	0.00	0.45	6.2	4.6E-04
2 8 4.0	50	45	44	67.55	79.80					8.4	
2 8 4.5	50	45	44	63.85	83.40	-0.04	0.03	0.00	0.48	7.3	4.8E-04
2 8 5.0	50	45	44	60.75	86.50	-0.03	0.03	0.00	0.51	6.4	4.6E-04
2 8 5.5	50	45	44	58.00	89.25	-0.03	0.03	0.00	0.54	5.6	4.7E-04
2 8 6.0	50	45	44	60.10	76.60					7.8	
2 8 6.5	50	45	44	57.00	79.90	-0.03	0.03	0.00	0.57	6.8	4.5E-04

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

...ct	Combustion Engineering					Test. by	KMH/KDM-10/30/98
Job No.	E-1039-01	Boring	WS-28	Sample	16.5-18.5	Checked by	KMH - 12/7/98
Description	Dark grey lean CLAY, with some roots & root holes, some Fe stains, sl blocky						
Depth		Permeant	tap water			Test Method	ASTM 5084-90

Permeameter No. 6 Standpipe Vol (cc/cm) Inflow: 1.266 Outflow: 1.279

	Before Test	After Test		Before Test	After Test
Sample Diameter (in)	2.882	2.881	Tare No.	AB3	94
Sample Length (in)	1.994	1.990	Tare Wt. (g)	2.63	83.35
Sample Area (cm^2)	42.09	42.06	Wet Soil + Tare (g)	85.65	489.94
Sample Volume (CC)	213.16	212.58	Dry Soil + Tare (g)	66.39	392.83
Sample Wt. (g)	402.92	406.59	Water Content (%)	30.2	31.4
Wet Density (pcf)	118.0	119.3	Porosity	0.464	
Dry Density (pcf)	90.6	90.8	Pore Volume (CC)	98.97	
			Degree of Saturation		99
Effective Consolidation (psi)	5 min	6 max	Specific Gravity		2.71

Read Time	hr	min	Pcell psi	Pin psi	Pout psi	Readings (cm) hin	hout	Inflow PV	Outflow PV	Storage PV	Total PV	i	K cm/s
1	8	8	50	45	44	61.40	70.60	---	---	---	---	12.1	---
1	8	11	50	45	44	57.95	74.00	-0.04	0.04	0.00	0.04	10.7	5.1E-05
1	8	15	50	45	44	54.40	77.55	-0.05	0.05	0.00	0.09	9.3	4.5E-05
1	8	20	50	45	44	50.80	81.15	-0.05	0.05	0.00	0.14	7.9	4.2E-05
2	10		50	45	44	56.20	66.90					11.8	
2	10	6	50	45	44	49.00	74.00	-0.09	0.09	0.00	0.23	9.0	5.8E-05
2	10	8	50	45	44	47.05	76.00	-0.02	0.03	0.00	0.25	8.2	5.8E-05
2	10	9	50	45	44	46.15	76.90	-0.01	0.01	0.00	0.27	7.8	5.7E-05
2	10	11	50	45	44	44.40	78.70	-0.02	0.02	0.00	0.29	7.1	6.0E-05
2	10	12	50	45	44	43.50	79.60	-0.01	0.01	0.00	0.30	6.8	6.5E-05
2	10	13	50	45	44	42.60	80.50	-0.01	0.01	0.00	0.31	6.4	6.9E-05
2	11		50	45	44	60.25	70.40					11.9	
2	11	1	50	45	44	58.85	71.80	-0.02	0.02	0.00	0.33	11.3	6.1E-05
2	11	2	50	45	44	57.50	73.15	-0.02	0.02	0.00	0.35	10.8	6.2E-05
2	11	3	50	45	44	56.20	74.45	-0.02	0.02	0.00	0.36	10.3	6.2E-05
2	11	4	50	45	44	54.90	75.75	-0.02	0.02	0.00	0.38	9.8	6.5E-05
2	11	5	50	45	44	53.70	76.95	-0.02	0.02	0.00	0.40	9.3	6.3E-05

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ject Combustion Engineering Test. by KMH/KDM-10/30/98

Job No. E-1039-01 Boring WS-28 Sample 16.5-18.5 Checked by KMH - 12/7/98

Description Dark grey lean CLAY, with some roots & root holes, some Fe stains, sl blocky

Depth ______ Permeant tap water Test Method ASTM 5084-90

Permeameter No. 6 Standpipe Vol (cc/cm) Inflow: 1.266 Outflow: 1.279

2 11 6	50	45	44	52.60	78.05	-0.01	0.01	0.00	0.41	8.9	6.1E-05
2 11 7	50	45	44	51.55	79.10	-0.01	0.01	0.00	0.42	8.4	6.1E-05
2 11 8	50	45	44	50.50	80.15	-0.01	0.01	0.00	0.44	8.0	6.4E-05
2 11 10	50	45	44	48.50	82.15	-0.03	0.03	0.00	0.46	7.2	6.6E-05
2 11 12	50	45	44	46.65	84.00	-0.02	0.02	0.00	0.49	6.5	6.8E-05
4 8	50	45	44	61.90	71.35					12.0	
4 8 3	50	45	44	57.50	75.75	-0.06	0.06	0.00	0.54	10.3	6.6E-05
4 8 28	50	45	44	57.40	68.00					11.8	
4 8 31	50	45	44	52.90	72.30	-0.06	0.06	0.00	0.60	10.1	6.8E-05
4 8 40	50	45	44	52.90	70.10					10.5	
4 8 54	50	45	44	39.35	83.60	-0.17	0.17	0.00	0.77	5.1	6.5E-05
4 8 55	50	45	44	38.70	84.20	-0.01	0.01	0.00	0.78	4.9	6.3E-05
4 8 56	50	45	44	38.10	84.85	-0.01	0.01	0.00	0.79	4.7	6.6E-05

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

Project: Combustion Engineering | Test. by: KDM-11/19/98

Job No.: E-1039-01 | Boring: WS-29 | Sample: 20.0-22.0 | Checked by: KWH - 12/7/98

Description: Dark grey lean CLAY, with some sand, some sm roots & root holes, occa thin f sand stringers, sl blocky

Depth: | Permeant: tap water | Test Method: ASTM 5084-90

Permeameter No.: 11 | Standpipe Vol (cc/cm) Inflow: 1.290 Outflow: 1.289

	Before Test	After Test
Sample Diameter (in)	2.868	2.860
Sample Length (in)	2.797	2.773
Sample Area (cm^2)	41.68	41.45
Sample Volume (CC)	296.10	291.93
Sample Wt. (g)	553.62	545.16
Wet Density (pcf)	116.7	116.5
Dry Density (pcf)	87.0	88.5
Effective Consolidation (psi)	5 min	6 max

	Before Test	After Test
Tare No.	KT1	52
Tare Wt. (g)	2.63	83.17
Wet Soil + Tare (g)	99.49	628.33
Dry Soil + Tare (g)	74.89	497.24
Water Content (%)	34.0	31.7
Porosity	0.483	
Pore Volume (CC)	143.13	

Degree of Saturation: 95

Specific Gravity: 2.70

Read Time (day)	hr	min	Pcell psi	Pin psi	Pout psi	Readings (cm) hin	hout	Inflow PV	Outflow PV	Storage PV	Total PV	i	K cm/s
1	10	42	50	45	44	60.00	61.40	---	---	---	---	9.7	---
1	13	59	50	45	44	58.95	62.40	-0.01	0.01	0.00	0.01	9.4	2.8E-07
1	18	2	50	45	44	57.60	63.70	-0.01	0.01	0.00	0.02	9.0	3.0E-07
2	7	41	50	45	44	53.15	68.10	-0.04	0.04	0.00	0.06	7.8	3.3E-07
2	17	17	50	45	44	50.60	70.70	-0.02	0.02	0.00	0.08	7.1	3.1E-07
3	9	25	50	45	44	46.05	75.05	-0.04	0.04	0.00	0.12	5.8	3.7E-07
3	15	35	50	45	44	44.70	76.40	-0.01	0.01	0.00	0.14	5.4	3.3E-07
5	10	13	50	45	44	40.10	81.00	-0.04	0.04	0.00	0.18	4.1	1.9E-07
7	10	55	50	45	44	68.80	70.10					9.7	
7	13	42	50	45	44	68.20	70.70	-0.01	0.01	0.00	0.18	9.5	1.9E-07
7	16	11	50	45	44	67.70	71.20	0.00	0.00	0.00	0.19	9.4	1.8E-07
9	15	10	50	45	44	59.20	79.55	-0.08	0.08	0.00	0.26	7.0	1.9E-07
9	15	22	50	45	44	58.35	74.15					7.7	
10	15	15	50	45	44	54.88	77.65	-0.03	0.03	0.00	0.29	6.7	1.7E-07
10	18	17	50	45	44	54.40	78.10	0.00	0.00	0.00	0.30	6.6	2.0E-07
11	7	49	50	45	44	52.50	79.85	-0.02	0.02	0.00	0.31	6.1	1.8E-07
11	13	3	50	45	44	51.90	80.50	-0.01	0.01	0.00	0.32	5.9	1.7E-07

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

...ject Combustion Engineering Test. by KDM-11/19/98

Job No. E-1039-01 Boring WS-29 Sample 20.0-22.0 Checked by [handwritten initials] - 12/7/98

Description Dark grey lean CLAY, with some sand, some sm roots & root holes, occa thin f sand stringers, sl blocky

Depth ______ Permeant tap water Test Method ASTM 5084-90

Permeameter No. 11 Standpipe Vol (cc/cm) Inflow: 1.290 Outflow: 1.289

11	15	19	50	45	44	51.60	80.80	0.00	0.00	0.00	0.32	5.8	2.0E-07
12	9	32	50	45	44	49.45	82.90	-0.02	0.02	0.00	0.34	5.2	1.8E-07
12	14	41	50	45	44	48.95	82.90					5.1	
13	9	50	50	45	44	47.05	85.25	-0.02	0.02	0.00	0.36	4.5	2.0E-07
14	8	5	50	45	44	44.95	87.25	-0.02	0.02	0.00	0.38	3.9	1.9E-07

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ect Combustion Engineering — Test. by KMH-11/20/98

Job No. E-1039-01 — Boring WS-32 — Sample 12.0-14.0 — Checked by KMH · 12/7/98

Description Brown & grey lean CLAY, with numerous Fe stains, some sm Fe nodules, some roots & rootholes, blocky

Depth ______ — Permeant tap water — Test Method ASTM 5084-90

Permeameter No. 9 — Standpipe Vol (cc/cm) Inflow: 1.302 Outflow: 1.311

	Before Test	After Test
Sample Diameter (in)	2.875	2.885
Sample Length (in)	2.293	2.301
Sample Area (cm^2)	41.88	42.17
Sample Volume (CC)	243.93	246.49
Sample Wt. (g)	478.42	478.82
Wet Density (pcf)	122.4	121.2
Dry Density (pcf)	96.1	95.3
Effective Consolidation (psi)	5 min	6 max

	Before Test	After Test
Tare No.	KT2	74
Tare Wt. (g)	2.63	85.24
Wet Soil + Tare (g)	79.60	564.06
Dry Soil + Tare (g)	63.05	461.51
Water Content (%)	27.4	27.3
Porosity	0.410	
Pore Volume (CC)	100.04	
Degree of Saturation		100
Specific Gravity		2.61

Read Time			Pcell	Pin	Pout	Readings (cm)		Inflow	Outflow	Storage	Total	i	K
	hr	min	psi	psi	psi	hin	hout	PV	PV	PV	PV		cm/s
1	8	23	50	45	44	73.60	75.50	---	---	---	---	11.7	---
1	8	35	50	45	44	70.30	78.70	-0.04	0.04	0.00	0.04	10.6	1.3E-05
1	8	43	50	45	44	68.50	80.50	-0.02	0.02	0.00	0.07	10.0	1.1E-05
3	10		50	45	44	66.05	74.65					10.6	
3	10	5	50	45	44	64.05	76.65	-0.03	0.03	0.00	0.09	9.9	2.0E-05
3	10	9	50	45	44	62.55	78.15	-0.02	0.02	0.00	0.11	9.4	2.0E-05
3	10	12	50	45	44	61.45	79.20	-0.01	0.01	0.00	0.13	9.0	2.0E-05
3	10	13	50	45	44	61.45	74.00					9.9	
3	10	17	50	45	44	60.05	75.40	-0.02	0.02	0.00	0.14	9.4	1.9E-05
3	10	20	50	45	44	58.90	76.55	-0.01	0.02	0.00	0.16	9.0	2.2E-05
3	10	23	50	45	44	57.85	77.60	-0.01	0.01	0.00	0.17	8.7	2.1E-05
3	10	26	50	45	44	56.85	78.65	-0.01	0.01	0.00	0.19	8.3	2.1E-05
3	10	27	50	45	44	56.85	70.00					9.8	
3	10	30	50	45	44	55.85	71.00	-0.01	0.01	0.00	0.20	9.5	1.8E-05
3	10	33	50	45	44	54.85	72.00	-0.01	0.01	0.00	0.21	9.1	1.9E-05
3	10	36	50	45	44	53.80	73.00	-0.01	0.01	0.00	0.23	8.8	2.0E-05
3	10	39	50	45	44	52.85	73.95	-0.01	0.01	0.00	0.24	8.5	1.9E-05

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ject Combustion Engineering Test. by KMH-11/16/98

Job No. E-1039-01 Boring WS-32 Sample 25.0-26.0 Checked by KMH -12/7/98

Description Grey-brown lean CLAY, with some Fe stains, some sm roots & root holes

Depth Permeant tap water Test Method ASTM 5084-90

Permeameter No. 10 Standpipe Vol (cc/cm) Inflow: 1.301 Outflow: 1.301

	Before Test	After Test		Before Test	After Test
Sample Diameter (in)	2.882	2.889	Tare No.	KT3	81
Sample Length (in)	2.585	2.586	Tare Wt. (g)	2.63	82.76
Sample Area (cm^2)	42.09	42.29	Wet Soil + Tare (g)	81.26	599.66
Sample Volume (CC)	276.34	277.79	Dry Soil + Tare (g)	62.15	470.00
Sample Wt. (g)	516.49	516.90	Water Content (%)	32.1	33.5
Wet Density (pcf)	116.6	116.1	Porosity	0.482	
Dry Density (pcf)	88.3	87.0	Pore Volume (CC)	133.13	
Effective Consolidation (psi)	5 min	6 max	Degree of Saturation	95	
			Specific Gravity	2.73	

Read Time y	hr	min	Pcell psi	Pin psi	Pout psi	Readings (cm) hin	hout	Inflow PV	Outflow PV	Storage PV	Total PV	i	K cm/s
1	8	28	50	45	44	67.60	63.45	---	---	---	---	11.3	---
1	8	31	50	45	44	64.75	66.40	-0.03	0.03	0.00	0.03	10.5	4.6E-05
3	10		50	45	44	57.90	60.75					9.2	
3	10	2	50	45	44	56.75	61.85	-0.01	0.01	0.00	0.04	8.9	3.2E-05
3	10	4	50	45	44	55.80	62.80	-0.01	0.01	0.00	0.05	8.6	2.8E-05
3	10	7	50	45	44	54.55	64.10	-0.01	0.01	0.00	0.06	8.2	2.6E-05
3	10	9	50	45	44	53.80	64.85	-0.01	0.01	0.00	0.07	8.0	2.4E-05
3	10	13	50	45	44	52.50	66.15	-0.01	0.01	0.00	0.08	7.6	2.2E-05
3	10	17	50	45	44	51.25	67.45	-0.01	0.01	0.00	0.09	7.2	2.2E-05
4	9		50	45	44	69.05	79.40					9.1	
4	9	4	50	45	44	67.45	81.00	-0.02	0.02	0.00	0.11	8.6	2.3E-05
4	9	7	50	45	44	66.35	82.10	-0.01	0.01	0.00	0.12	8.3	2.2E-05
4	9	11	50	45	44	64.90	83.60	-0.01	0.01	0.00	0.14	7.9	2.3E-05
4	9	12	50	45	44	64.90	76.90					8.9	
4	9	17	50	45	44	63.15	78.70	-0.02	0.02	0.00	0.15	8.3	2.1E-05
4	9	28	50	45	44	59.55	82.40	-0.04	0.04	0.00	0.19	7.2	2.2E-05
4	9	33	50	45	44	58.15	83.75	-0.01	0.01	0.00	0.20	6.8	2.0E-05

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ect Combustion Engineering — Test. by KMH-11/16/98

ob No. E-1039-01 — Boring WS-32 — Sample 25.0-26.0 — Checked by KMH -12/7/98

Description Grey-brown lean CLAY, with some Fe stains, some sm roots & root holes

Depth ____ — Permeant tap water — Test Method ASTM 5084-90

Permeameter No. 10 — Standpipe Vol (cc/cm) Inflow: 1.301 Outflow: 1.301

4 10	50	45	44	49.20	68.35					7.8	
4 10 7	50	45	44	47.00	70.55	-0.02	0.02	0.00	0.22	7.1	2.2E-05
4 10 13	50	45	44	45.40	72.10	-0.02	0.02	0.00	0.24	6.6	2.0E-05
4 10 19	50	45	44	43.90	73.60	-0.01	0.01	0.00	0.25	6.2	2.0E-05
4 10 23	50	45	44	42.90	74.60	-0.01	0.01	0.00	0.26	5.9	2.1E-05

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ject Combustion Engineering   Test. by KDM-11/24/98

Job No. E-1039-01   Boring WS-33   Sample 20.0-22.0   Checked by KWH -12/7/98

Description Dark brown & grey fat CLAY, with some Fe nodules, occa Fe stains, occa sm roots

Depth ______   Permeant tap water   Test Method ASTM 5084-90

Permeameter No. 16   Standpipe Vol (cc/cm) Inflow: 1.312 Outflow: 1.308

	Before Test	After Test		Before Test	After Test
Sample Diameter (in)	2.866	2.876	Tare No.	LB22	82
Sample Length (in)	2.573	2.585	Tare Wt. (g)	2.63	83.50
Sample Area (cm^2)	41.62	41.91	Wet Soil + Tare (g)	70.12	621.59
Sample Volume (CC)	272.01	275.19	Dry Soil + Tare (g)	55.64	506.51
Sample Wt. (g)	534.74	538.09	Water Content (%)	27.3	27.2
Wet Density (pcf)	122.7	122.0	Porosity	0.415	
Dry Density (pcf)	96.4	95.9	Pore Volume (CC)	112.91	
			Degree of Saturation		100
Effective Consolidation (psi)	5 min	6 max	Specific Gravity		2.64

Read Time y	hr	min	Pcell psi	Pin psi	Pout psi	Readings (cm) hin	hout	Inflow PV	Outflow PV	Storage PV	Total PV	i	K cm/s
1	11	1	50	45	44	68.05	70.95	---	---	---	---	10.3	---
1	16	11	50	45	44	67.80	71.20	0.00	0.00	0.00	0.00	10.2	4.1E-08
3	15	36	50	45	44	66.15	72.75	-0.02	0.02	0.00	0.02	9.8	3.0E-08
4	9	21	50	45	44	65.60	73.15	-0.01	0.00	0.00	0.03	9.6	2.4E-08
4	18	17	50	45	44	65.40	73.40	0.00	0.00	0.00	0.03	9.5	2.3E-08
5	7	49	50	45	44	65.00	73.80	0.00	0.00	0.00	0.03	9.4	2.7E-08
5	18	12	50	45	44	64.65	74.05	0.00	0.00	0.00	0.04	9.3	2.7E-08
6	9	32	50	45	44	64.20	74.50	-0.01	0.01	0.00	0.04	9.2	2.8E-08
7	9	31	50	45	44	63.55	74.95	-0.01	0.01	0.00	0.05	9.0	2.2E-08
8	8	6	50	45	44	63.05	75.30	-0.01	0.00	0.00	0.05	8.9	1.8E-08
9	7	34	50	45	44	62.55	75.65	-0.01	0.00	0.00	0.05	8.8	1.8E-08
10	8	31	50	45	44	62.05	76.05	-0.01	0.00	0.00	0.06	8.6	1.8E-08
10	18	4	50	45	44	61.85	76.25	0.00	0.00	0.00	0.06	8.6	2.1E-08
11	7	51	50	45	44	61.60	76.50	0.00	0.00	0.00	0.06	8.5	1.9E-08
11	17	45	50	45	44	61.45	76.65	0.00	0.00	0.00	0.07	8.4	1.6E-08
12	9	35	50	45	44	61.15	76.90	0.00	0.00	0.00	0.07	8.4	1.8E-08
12	16	23	50	45	44	61.00	77.00	0.00	0.00	0.00	0.07	8.3	1.9E-08

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ect Combustion Engineering Test. by KDM-11/24/98

Job No. E-1039-01 Boring WS-33 Sample 20.0-22.0 Checked by [signature] - 12/7/98

Description Dark brown & grey fat CLAY, with some Fe nodules, occa Fe stains, occa sm roots

Depth Permeant tap water Test Method ASTM 5084-90

Permeameter No. 16 Standpipe Vol (cc/cm) Inflow: 1.312 Outflow: 1.308

13	9	20	50	45	44	60.65	77.15	0.00	0.00	0.00	0.07	8.2	1.6E-08
15	8	19	50	45	44	59.85	77.85	-0.01	0.01	0.00	0.08	8.0	1.7E-08
16	8		50	45	44	59.35	78.20	-0.01	0.00	0.00	0.08	7.9	2.0E-08
17	8	39	50	45	44	58.85	78.50	-0.01	0.00	0.00	0.09	7.8	1.8E-08

TRIAXIAL PERMEABILITY DATA SHEET

SHANNON & WILSON, INC.

ect Combustion Engineering — Test. by KDM-11/19/98

Job No. E-1039-01 — Boring WS-34 — Sample 30.7-32.0 — Checked by KMW - 12/7/98

Description Dark grey lean CLAY, with some f sand, occa thin f sand stringers; rare sm roots — 1/1/00

Depth — Permeant tap water — Test Method ASTM 5084-90

Permeameter No. 9 — Standpipe Vol (cc/cm) Inflow: 1.302 Outflow: 1.311

	Before Test	After Test		Before Test	After Test
Sample Diameter (in)	2.845	2.825	Tare No.	LB24	54
Sample Length (in)	2.741	2.708	Tare Wt. (g)	2.63	82.71
Sample Area (cm^2)	41.01	40.44	Wet Soil + Tare (g)	77.94	643.57
Sample Volume (CC)	285.54	278.15	Dry Soil + Tare (g)	62.70	540.85
Sample Wt. (g)	571.82	560.86	Water Content (%)	25.4	22.4
Wet Density (pcf)	125.0	125.8	Porosity	0.408	
Dry Density (pcf)	99.7	102.8	Pore Volume (CC)	116.61	
			Degree of Saturation		95
Effective Consolidation (psi)	5 min	6 max	Specific Gravity		2.70

Read Time day	hr	min	Pcell psi	Pin psi	Pout psi	Readings (cm) hin	hout	Inflow PV	Outflow PV	Storage PV	Total PV	i	K cm/s
1	10	49	50	45	44	64.90	68.70	---	---	---	---	9.6	---
3	15	35	50	45	44	63.50	69.95	-0.02	0.01	0.00	0.01	9.2	2.4E-08
4	9	15	50	45	44	63.00	70.30	-0.01	0.00	0.00	0.02	9.1	2.3E-08
4	18	19	50	45	44	62.80	70.55	0.00	0.00	0.00	0.02	9.0	2.4E-08
5	7	45	50	45	44	62.45	70.90	0.00	0.00	0.00	0.02	8.9	2.6E-08
5	18	14	50	45	44	62.20	71.15	0.00	0.00	0.00	0.03	8.8	2.4E-08
6	9	34	50	45	44	61.80	71.40	0.00	0.00	0.00	0.03	8.7	2.1E-08
6	14	42	50	45	44	61.65	71.55	0.00	0.00	0.00	0.03	8.7	3.0E-08
7	9	45	50	45	44	61.00	72.00	-0.01	0.01	0.00	0.04	8.5	3.0E-08
8	8	7	50	45	44	60.50	72.45	-0.01	0.01	0.00	0.04	8.4	2.2E-08
9	7	49	50	45	44	59.90	72.90	-0.01	0.01	0.00	0.05	8.2	2.4E-08
10	8	29	50	45	44	59.45	73.25	-0.01	0.00	0.00	0.05	8.1	1.8E-08
11	7	52	50	45	44	59.00	73.70	-0.01	0.01	0.00	0.06	8.0	2.1E-08
12	9	37	50	45	44	58.45	74.05	-0.01	0.00	0.00	0.06	7.9	2.0E-08
12	16	24	50	45	44	58.35	74.15	0.00	0.00	0.00	0.06	7.8	1.7E-08
15	8	20	50	45	44	57.05	75.00	-0.01	0.01	0.00	0.07	7.5	1.9E-08
16	8	5	50	45	44	56.65	75.35	0.00	0.00	0.00	0.07	7.4	1.9E-08

TABLE 2

COMBUSTION ENGINEERING
MISSOURI STATE ROUTE P
HEMATITE, MISSOURI

Geometric Mean - NSSSC Monitoring Wells/Piezometers
Summary of Results of Single Well Hydraulic Conductivity Testing

Table 2a - Feet/Minute

Well ID	Hvorslev Method Feet/minute	Bouwer-Rice Method Feet/minute	Geomean of Two Methods Feet/minute
WS-22	1.37E-04	1.96E-03	5.18E-04
WS-24	2.72E-05	6.85E-04	1.37E-04
WS-28	1.71E-05	5.53E-04	9.74E-05
WS-33	1.12E-04	1.45E-03	4.03E-04
PZ-1	1.34E-05	1.27E-03	1.30E-04
GEOMEAN	**3.95E-05**	**1.06E-03**	**2.05E-04**

Table 2b - Feet/Day

Well ID	Hvorslev Method Feet/day	Bouwer-Rice Method Feet/day	Geomean of Two Methods Feet/day
WS-22	1.97E-01	2.82E+00	7.46E-01
WS-24	3.92E-02	9.87E-01	1.97E-01
WS-28	2.47E-02	7.97E-01	1.40E-01
WS-33	1.61E-01	2.09E+00	5.80E-01
PZ-1	1.93E-02	1.83E+00	1.88E-01
GEOMEAN	**5.68E-02**	**1.53E+00**	**2.95E-01**

Table 2c - Centimeters/Second

Well ID	Hvorslev Method cm/sec	Bouwer-Rice Method cm/sec	Geomean of Two Methods cm/sec
WS-22	6.96E-05	9.94E-04	2.63E-04
WS-24	1.38E-05	3.48E-04	6.94E-05
WS-28	8.71E-06	2.81E-04	4.95E-05
WS-33	5.69E-05	7.37E-04	2.05E-04
PZ-1	6.80E-06	6.45E-04	6.62E-05
GEOMEAN	**2.00E-05**	**5.41E-04**	**1.04E-04**

TABLE 3

COMBUSTION ENGINEERING
MISSOURI STATE ROUTE P
HEMATITE, MISSOURI

Geometric Mean - DSCC Monitoring Wells/Piezometers
Summary of Results of Single Well Hydraulic Conductivity Testing

Table 3a - Feet/Minute

Well ID	Hvorslev Method Feet/minute	Bouwer-Rice Method Feet/minute	Geomean of Two Methods Feet/minute
WS-23	4.34E-04	4.09E-03	1.33E-03
WS-25	1.82E-04	2.26E-03	6.41E-04
WS-27	2.54E-04	5.74E-03	1.21E-03
WS-29	3.80E-04	6.97E-03	1.63E-03
WS-32	9.49E-05	3.11E-03	5.43E-04
WS-34	2.90E-04	4.99E-03	1.20E-03
PZ-2	9.49E-05	3.11E-03	5.43E-04
GEOMEAN	**2.13E-04**	**4.05E-03**	**9.29E-04**

Table 3b - Feet/Day

Well ID	Hvorslev Method Feet/day	Bouwer-Rice Method Feet/day	Geomean of Two Methods Feet/day
WS-23	6.24E-01	5.88E+00	1.92E+00
WS-25	2.61E-01	3.26E+00	9.23E-01
WS-27	3.66E-01	8.27E+00	1.74E+00
WS-29	5.48E-01	1.00E+01	2.35E+00
WS-32	2.00E+00	2.92E+01	7.65E+00
WS-34	2.49E-01	4.75E+00	1.09E+00
PZ-2	1.37E-01	4.48E+00	7.82E-01
GEOMEAN	**4.18E-01**	**7.19E+00**	**1.73E+00**

Table 3c - Centimeters/Second

Well ID	Hvorslev Method cm/sec	Bouwer-Rice Method cm/sec	Geomean of Two Methods cm/sec
WS-23	2.20E-04	2.08E-03	6.76E-04
WS-25	9.22E-05	1.15E-03	3.26E-04
WS-27	1.29E-04	2.92E-03	6.13E-04
WS-29	1.93E-04	3.54E-03	8.27E-04
WS-32	7.07E-04	1.03E-02	2.70E-03
WS-34	8.78E-05	1.68E-03	3.84E-04
PZ-2	4.82E-05	1.58E-03	2.76E-04
GEOMEAN	**1.47E-04**	**2.53E-03**	**6.11E-04**

APPENDIX E

Field Capacity Calculation

LEGGETTE, BRASHEARS & GRAHAM, INC.

$$p_e = p_t - \theta_r \, .\tag{4.4}$$

Therefore, the effective porosity is related to the total porosity and the field capacity according to the following expression:

Several aspects of the soil system influence the value of its effective porosity: (1) the adhesive water on minerals, (2) the absorbed water in the clay-mineral lattice, (3) the existence of unconnected pores, and (4) the existence of dead-end pores. The adhesive water in the soil is that part of the water present in the soil that is attached to the surface of the soil grains through the forces of molecular attraction (Marsily 1988). The sum of the volumes of the adhesive and absorbed water plus the water that fills the unconnected and dead-end pores constitute the volume of the adsorbed water, V_{iw}, that is unable to move through the system.

A detailed list of representative porosity values (total porosity and effective porosity) is presented in Table 3.2.

4.2 MEASUREMENT METHODOLOGY

Determination of the effective porosity, p_e, of soils can be accomplished indirectly by measuring the total porosity, p_t, and the field capacity, θ_r, and then calculating p_e from Equation 4.4. The total porosity is obtained indirectly by measuring the soil densities according to the method described in Section 3.2. To determine the field capacity of the soils, the soil sample is first saturated with water and is then allowed to drain completely under the action of gravity until it gets to its irreducible saturation. The value of θ_r can then be obtained according to the methods used for measuring volumetric water content (Section 6.2).

4.3 RESRAD DATA INPUT REQUIREMENTS

To use RESRAD, the user is required to define (or to use the default values) of the effective porosity of three distinct materials: (1) contaminated zone, (2) saturated zone, and (3) unsaturated zone. In RESRAD, the effective porosity values are entered as decimal fractions rather than as percentages. As a default value, RESRAD adopts the value of $p_e = 0.2$ for all three materials. These default values are provided for generic use of the RESRAD code. For more accurate utilization of the model, site-specific data should be used.

If site-specific data are not available and the soil type is known, Table 3.2 can be used for estimating effective porosity. However, if no information is available on soil type, then the values of effective porosity should be experimentally determined according to the method presented in Section 4.2. Effective porosity values should not be greater than total porosity values. Total porosity is discussed in Section 3.

Problem: Calculate Field Capacity of Soil

Formula: $P_e = P_t - \theta_r$

Where: P_e = Effective Porosity

P_t = Total Porosity

θ_r = Field Capacity

Given: $P_e = 0.281$ (from default value for silty-clay from Table 3.3-1 of "Development of Probabilistic RESRAD 6.0 and RESAD-Build 3.0 Computer Codes, "November 2000).

$P_t = 0.446$ (Shannon & Wilson Data)

θ_r = Unknown

Solve for θ_r $P_e = P_t - \theta_r$

$\therefore -\theta_r = P_e - P_t$

$\theta_r = P_t - P_e$

$\theta_r = 0.446 - 0.281$

$\theta_r = 0.165$

Field Capacity = 0.165

water content and residual water content to develop distributions for effective porosity by subtraction. Table 3.3-1 gives the distributions and the defining parameters for effective porosity for the 12 soil textural classes and for the generic soil type.

The distribution to be used for cases when the type of soil is not known (the RESRAD default distribution) was obtained as the weighted average of the distributions for the individual soil classes. The same weighting factor scheme as discussed for the generic soil type in Section 3.1 was used. The probability density function of the weight average was plotted, and the parameters of the normal distribution were chosen to represent the weighted average curve over the range of interest. The probability density function for the effective porosity for this generic soil type is shown in Figure 3.3-1. When a site-specific analysis is being conducted, the distribution for the soil type present at the site should be used. For consistency, distributions corresponding to the same soil type selected for this parameter should also be selected for the following parameters: soil density, total porosity, hydraulic conductivity, and the soil b parameter.

Table 3.3-1 Distribution Type and Parameters for Effective Porosity by Soil Type

Soil Type	Distribution	Mean	Standard Deviation	Lower Limit	Upper Limit
Sand	Normal	0.383	0.0610	0.195	0.572
Loamy sand	Normal	0.353	0.0913	0.0711	0.635
Sandy loam	Normal	0.346	0.0915	0.0629	0.628
Sandy clay loam	Normal	0.289	0.0703	0.0723	0.507
Loam	Normal	0.352	0.101	0.0414	0.663
Silt loam	Normal	0.383	0.0813	0.132	0.634
Silt	Normal	0.425	0.110	0.0839	0.766
Clay loam	Normal	0.315	0.0905	0.0349	0.594
Silty clay loam	Normal	0.342	0.0705	0.124	0.560
Sandy clay	Normal	0.281	0.0513	0.122	0.439
Silty clay	Normal	0.289	0.0735	0.0623	0.517
Clay	Normal	0.311	0.0963	0.0138	0.609
Generic soil type[a]	Normal	0.355	0.0906	0.075	0.635

[a] Parameters for the generic soil type were derived from the distribution enveloping all soil types. The lower and upper limits correspond to the 0.001 and 0.999 quantile values, respectively.

Sources: Carsel and Parrish (1988); Meyer et al. (1997).

APPENDIX F

Representative Values of Soil-Specific Exponential b Parameter

LEGGETTE, BRASHEARS & GRAHAM, INC.

conductivity function.

TABLE 13.1 Representative Values of Soil-Specific Exponential b Parameter

Texture	Soil-Specific Exponential Parameter, *b*
Sand	4.05
Loamy sand	4.38
Sandy loam	4.90
Silty loam	5.30
Loam	5.39
Sandy clay loam	7.12
Silty clay loam	7.75
Clay loam	8.52
Sandy clay	10.40
Silty clay	10.40
Clay	11.40

Source: Clapp and Hornberger (1978).

APPENDIX G

Well Pump Intake Calculations and Supporting Documentation

LEGGETTE, BRASHEARS & GRAHAM, INC.

WELL PUMP INTAKE CALCULATIONS

WELL PUMP INTAKE CALCULATIONS BASED ON DSCC WELLS	
MW or Piez	**Depth bgs (feet)**
WS-23	38.52
WS-25	38.21
WS-27	32.46
WS-29	27.79
WS-32	35.22
WS-34	35.45
PZ-2	33.49
OB-1	26.20
OB-2	37.00
BR3-OB	24.30
Average (feet bgs)	**32.86**
Pump Height (feet bgs)	**30.86**
Pump Height (meters bgs)	**9.41**

Pump is assumed to located 2 feet off the bottom of the well.

WESTINGHOUSE ELECTRIC CO. LLC
HEMATITE, MISSOURI FACILITY

REMEDIAL INVESTIGATION/FEASIBILITY STUDY WORK PLAN
TABLE 5 - MONITORING WELL/PIEZOMETER CONSTRUCTION DATA

WELL DESIGNATION	DATE INSTALLED	SCREEN/CASING MATERIAL	WELL CASING DIAMETER (INCHES O.D.)	GRADE ELEVATION (FEET AMSL)	TOP OF CASING ELEVATION (FEET AMSL)	WELL BOTTOM ELEVATION (FEET AMSL)	DEPTH OF WELL (FEET BGS)	DEPTH OF WELL (FEET BTOC)	SCREEN LENGTH (FEET)	SCREENED INTERVAL (FEET BGS)	HYDROSTRATIGRAPHIC ZONE MONITORED
WS-7	Unknown	PVC/Unknown	4	432.25	432.28	409.77	22.48	22.51	Unknown	Unknown	Unconsolidated
WS-8	Unknown	PVC/Unknown	4	431.71	433.70	414.04	17.67	19.66	Unknown	Unknown	Unconsolidated
WS-9	Unknown	PVC/Unknown	4	431.77	432.84	406.47	25.30	26.37	Unknown	Unknown	Unconsolidated
RMC-9	Unknown	PVC/Unknown	2	433.51	436.07	Unknown	Unknown	Unknown	Unknown	Unknown	Unconsolidated
WS-13	Unknown	PVC/PVC	2	434.02	435.80	Unknown	Unknown	20.70	Unknown	Unknown	Unconsolidated
WS-14	Unknown	PVC/PVC	2	433.56	435.65	Unknown	Unknown	25.58	Unknown	Unknown	Unconsolidated
WS-15	Unknown	PVC/PVC	2	430.58	432.76	406.79	23.79	25.97	Unknown	Unknown	Unconsolidated
WS-16	Unknown	PVC/PVC	2	430.19	432.25	410.55	19.64	21.70	Unknown	Unknown	Unconsolidated
WS-17B	26-Jun-96	PVC/PVC	2	433.39	435.36	412.85	20.54	22.51	13.00	7.0-20.0	Unconsolidated
WS-22	24-Sep-98	PVC/PVC	2	438.22	441.12	421.96	16.26	19.16	5.00	10.5-15.5	NSSSC/Unconsolidated
WS-23	24-Sep-98	PVC/PVC	2	438.15	441.16	399.63	38.52	41.53	10.00	28.52-38.52	DSCC/Unconsolidated
WS-24	23-Sep-98	PVC/PVC	2	436.76	439.64	420.00	16.76	19.64	10.00	5.5-15.5	NSSSC/Unconsolidated
WS-25	23-Sep-98	PVC/PVC	2	436.55	439.09	398.34	38.21	40.75	10.00	28.4-38.4	DSCC/Unconsolidated
WS-26	28-Sep-98	PVC/PVC	2	430.48	433.53	415.32	15.16	18.21	10.00	5.0-15.0	NSSSC/Unconsolidated
WS-27	28-Sep-98	PVC/PVC	2	430.69	433.56	398.23	32.46	35.33	10.00	21.8-31.8	DSCC/Unconsolidated
WS-28	25-Sep-98	PVC/PVC	2	425.71	428.61	409.87	15.84	18.74	10.00	6.5-16.5	NSSSC/Unconsolidated
WS-29	25-Sep-98	PVC/PVC	2	425.32	428.20	397.53	27.79	30.67	7.00	20.4-27.4	DSCC/Unconsolidated
WS-30	15-Oct-98	PVC/PVC	2	425.41	428.27	376.20	49.21	52.07	10.00	38.9-48.9	Jefferson City-Cotter Dolomite
WS-31	13-Oct-98	PVC/PVC	2	424.95	427.63	343.54	81.41	84.09	10.00	71.3-81.3	Jefferson City-Cotter Dolomite
WS-32	30-Sep-98	PVC/PVC	2	433.20	436.11	397.98	35.22	38.13	5.00	30.8-35.8	DSCC/Unconsolidated
WS-33	22-Sep-98	PVC/PVC	2	434.23	437.12	416.32	17.91	20.80	10.00	7.6-17.6	NSSSC/Unconsolidated
WS-34	21-Sep-98	PVC/PVC	2	434.21	436.96	398.76	35.45	38.20	10.00	25.6-35.6	DSCC/Unconsolidated
PZ-1	28-Sep-98	PVC/PVC	2	431.75	434.74	407.85	23.90	26.89	10.00	13.5-23.5	NSSSC/Unconsolidated
PZ-2	28-Sep-98	PVC/PVC	2	431.63	434.81	398.14	33.49	36.67	10.00	23.5-33.5	DSCC/Unconsolidated
PZ-3	13-Oct-98	PVC/PVC	2	433.23	435.85	372.28	60.95	63.57	10.00	50.3-60.3	Jefferson City-Cotter Dolomite
PZ-4	13-Oct-98	PVC/PVC	2	438.17	440.71	378.86	59.31	61.85	10.00	49.3-59.3	Jefferson City-Cotter Dolomite
OB-1	15-May-02	PVC/PVC	2	426.67	429.64	400.47	26.20	29.17	16.20	10.0-26.2	Unconsolidated
OB-2	28-May-02	PVC/PVC	2	427.71	430.52	390.71	37.00	39.81	27.00	10.0-37.0	Unconsolidated

Note
O.D. = Outside Diameter
AMSL = Above Mean Sea Level
BGS = Below Ground Surface
BTOC = Below Top of Casing
[illegible]SC = Near-Surface, Silt; Silty-Clay
DSCC = Deep, Silty-Clay; Clay

REMEDIAL INVESTIGATION/FEASIBILITY STUDY WORK PLAN
TABLE 5 - MONITORING WELL/PIEZOMETER CONSTRUCTION DATA

WELL DESIGNATION	DATE INSTALLED	SCREEN/CASING MATERIAL	WELL CASING DIAMETER (INCHES O.D.)	GRADE ELEVATION (FEET AMSL)	TOP OF CASING ELEVATION (FEET AMSL)	WELL BOTTOM ELEVATION (FEET AMSL)	DEPTH OF WELL (FEET BGS)	DEPTH OF WELL (FEET BTOC)	SCREEN LENGTH (FEET)	SCREENED INTERVAL (FEET BGS)	HYDROSTRATIGRAPHIC ZONE MONITORED
BR1-JC	06-Jun-02	PVC/PVC	1	439.29	442.08	332.29	107.00	109.79	10.00	97.0-107.0	Jefferson City-Cotter Dolomite
BR1-RB	24-Jul-02	PVC/PVC	2	440.03	442.63	275.03	165.00	167.60	40.00	125-165	Roubidoux Formation
BR2-JC	23-Jul-02	PVC/PVC	1	428.64	431.33	313.64	115.00	117.69	5.00	105-115	Jefferson City-Cotter Dolomite
BR2-RB	24-Jul-02	PVC/PVC	2	428.23	431.50	93.23	335.00	338.27	40.00	295-335	Roubidoux Formation
BR3-OB	23-Jul-02	PVC/PVC	2	418.65	421.72	394.35	24.30	27.37	11.10	13.2-24.3	DSCC/Unconsolidated
BR3-RB	24-Jul-02	PVC/PVC	2	418.12	420.73	228.12	190.00	192.61	40.00	150-190	Roubidoux Formation
BR4-JC	24-Jul-02	PVC/PVC	2	432.11	434.51	327.11	105.00	107.40	10.00	95-105	Jefferson City-Cotter Dolomite
BR4-RB	24-Jul-02	PVC/PVC	2	431.95	434.93	191.95	240.00	242.98	40.00	200-240	Roubidoux Formation

ote

.D. = Outside Diameter
MSL = Above Mean Sea Level
GS = Below Ground Surface
TOC = Below Top of Casing
SSSC = Near-Surface, Silt; Silty-Clay
SCC = Deep, Silty-Clay; Clay

APPENDIX H

Well Pumping Rate Calculation and Supporting Documentation

LEGGETTE, BRASHEARS & GRAHAM, INC.

Scenario 1: Area of Contamination = 6432 M^2

Assume: 4 Adults
4 head of cattle

225 liters/adult/day
160 liters/head/day

225 x 4 = 900 liters/day
160 x 4 = 640 liters/day

Total 1540 liters/day or 562,100 liters/yearly

Conversion:

1 liter = 0.001 M^3

562,1000 liters = 562 M^3

Pumping Rate Requirements: 562 M^3/year

Scenario 2: Area of Contamination = 77458 M^2

Assume: 4 Adults
10 head of cattle

from above:
225 x 4 = 900 liters/day
160 x 10 = 1600 liters/day

Total 2500 liters/day of 912,500 liters/yearly

Pumping Rate Requirements: 913 M^3/year

Table 3.10-1 Example Calculations for Estimating the Well Pumping Rate

Water Use Component	General Case	Water Use as a Function of Land Area		
		$100\ m^2$	$2{,}400\ m^2$	$10{,}000\ m^2$
Household	225 × 4 L/d ≡ $328.7\ m^3\ yr^{-1}$	$328.7\ m^3\ yr^{-1}$	$328.7\ m^3\ yr^{-1}$	$328.7\ m^3\ yr^{-1}$
Livestock	50+160 L/d ≡ $76.7\ m^3\ yr^{-1}$	$76.7\ m^3\ yr^{-1}$	$76.7\ m^3\ yr^{-1}$	$76.7\ m^3\ yr^{-1}$
Irrigation of vegetable plot				
Contaminated fraction	f_p = min(Area/2000, 0.5)	0	0.5	0.5
Irrigation rate	$I_r\ (m\ yr^{-1})$	0	$0.1125\ m\ yr^{-1}$	$0.1125\ m\ yr^{-1}$
Irrigation water	$f_p \times I_r \times 2000$	0	$112.5\ m^3\ yr^{-1}$	$112.5\ m^3\ yr^{-1}$
Irrigation of pasture				
Contaminated fraction	f_m = Area/20,000 $\leq$ 1	0	0.065	0.445
Irrigation rate	$I_r\ (m\ yr^{-1})$	0	$0.1125\ m\ yr^{-1}$	$0.1125\ m\ yr^{-1}$
Irrigation water	$f_m \times I_r \times 20{,}000$	0	$146.3\ m^3\ yr^{-1}$	$1001\ m^3\ yr^{-1}$
Drinking water	409.5 × 4 L/yr ≡ $1.64\ m^3\ yr^{-1}$ (Section 5.2)	$1.64\ m^3\ yr^{-1}$	$1.64\ m^3\ yr^{-1}$	$1.64\ m^3\ yr^{-1}$
Total $(m^3\ yr^{-1})$		407	666	1519

PRINCIPLES OF CONTROLLED GRAZING

David W. Pratt, U.C.C.E. Farm Advisor

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Napa & Solano Counties U.C.C.E., Livestock/Range Management Program

GRASS FARMING

Ranching is really the business of converting sunlight energy into forage and forage into harvestable livestock products in a sustainable manner. From this perspective we see that those of us in the livestock business are also in the grass business. Allan Nation, editor of the Stockman Grass Farmer would say we are "grass farmers" and our livestock are the four legged combines with which we harvest our crop.

Most of us have considered the livestock business, not the grass business, as our primary occupation. As a result, our focus has been on the animal. We have a relatively poor understanding of how our crop grows and responds to grazing. An understanding of this relationship is fundamental to successful grass farming.

GREEN LEAVES CAPTURE SUNLIGHT

Sustainable production in ranching starts with using plants to capture sunlight energy. When sunlight falls on bare soil, rocks, or anything but growing plants, its energy cannot be harvested.

Principle: Maintain 100% green plant cover in pastures for as long as possible.

THE "S" SHAPED CURVE

The efficiency with which plants convert the sun's energy into green leaves and the ability of animals to harvest and use energy from those leaves depends on the phase of growth of the plants.

After grazing, plants go through three phases of growth that form an "S" shaped curve (figure 1). **Phase I** occurs after plants have been severely grazed. After grazing, fewer leaves are left to intercept sunlight and plants require more energy for growth than they are able to produce through photosynthesis. So, to compensate, energy is mobilized from the roots. The roots become smaller and weaker as energy is used to grow new leaves.

FIGURE 1. PLANT GROWTH AFTER GRAZING (THE 'S' SHAPED CURVE)

number of head per acre:

STOCK DENSITY = HEAD ÷ ACRE

r example if 50 steers are grazing a 10 acre paddock the stock density is 5 head/acre:

STOCK DENSITY = 50 HEAD ÷ 10 ACRES = 5 head / acre

In his book Holistic Resource Management, Allan Savory says, "Low density, not overgrazing or overstocking, should bear the blame for many serious range and production problems, including trailing, successional shifts toward brush and weeds, pest outbreaks, poor animal performance, and high supplemental feed costs...". To understand why, let's take another look at the two one acre paddocks described earlier (Figure 2).

The two paddocks had identical stocking rates (100 animal days per acre), but they were grazed for different periods of time and the stock densities were drastically different.

In the first paddock, with one animal grazing for 100 days (stock density 1 animal/acre), utilization was uneven, with some plants overgrazed and others undergrazed. In the other paddock, where one hundred animals grazed for one day (stock density 100 animals/acre), utilization was more uniform and there was no overgrazing. Shortening the graze period reduced overgrazing, but it was the increase in stock density that resulted in more even utilization.

Overgrazing is a function of time.

Uniformity of utilization is a function of stock density.

Pastures with low stock density usually appear "patchy" with some patches grazed very short and other patches ·sisting of rank, "wolfy," phase III vegetation. Some ranchers mow pastures to keep vegetation uniform and ..atable. Others use fire to remove old, stemmy, ungrazed material. What they usually really need is higher stock density.

High stock density increases the uniformity of utilization and maintains forage in a more palatable, nutritious, digestible condition.

Stock density increases as the number of animals in a paddock increase or as paddock size decreases.

Principle: Use the highest stock density possible.

Twenty head per acre is the minimum stock density needed to uniformly graze irrigated pasture. Higher is better. Stock densities of over 50 cattle per acre are not uncommon on well managed irrigated pastures. Two head per acre is a reasonable target on more remote ranges. Again, higher is better.

HERD EFFECT

If you haven't already seen the movie *Dances With Wolves*, get out the popcorn and rent it tonight. When it gets to the scene where they are tracking the buffalo, stop the tape and reread this section.

After the buffalo stampeded through, the range literally looked plowed. This is a natural phenomena called herd effect. When animals are spread out and calm, their hooves tend to compact the soil. When they are concentrated and excited, ·y tend to knock down old standing vegetation and break up the soil.

Herd effect will not happen just by increasing stock density. To achieve this effect it is usually necessary to stimulate animals in some way. It can be done by herding through or feeding on the area where you want this impact.