Appendix K

Disposal Cell Groundwater Monitoring Plan

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K1.0 Introduction

K1.1 Scope

This plan describes the disposal cell groundwater monitoring program for the U.S. Department of Energy's (DOE) Weldon Spring Site, which is being conducted according to the substantive requirements of 40 CFR 264, Subpart F, and 10 CSR 25-7.264(2)(F). This plan includes a description of the sampling locations, frequency, parameters, and associated analysis and sampling procedures. A discussion about the data evaluation and the development of the evaluation approach are also included.

K1.2 Purpose

The purpose of this plan is to summarize the disposal cell groundwater monitoring program. The following specific elements are addressed: the design of the monitoring network; the results of baseline monitoring; the long-term monitoring program, which includes detection monitoring, compliance monitoring, and corrective action; and data review and reporting.

K1.3 Applicable or Relevant and Appropriate Requirements

In the *Record of Decision for the Chemical Plant Area of the Weldon Spring Site* (DOE 1993), the substantive requirements of 40 CFR 264, Subpart F of the Resource Conservation and Recovery Act (RCRA), and 10 CSR 25-7.264(2)(F) of the Missouri Hazardous Waste Regulations, were identified as applicable or relevant and appropriate requirements (ARARs) for the selected remedy (i.e., construction and operation of an engineered disposal cell). Table K−1 provides a summary of these ARARs and indicates the sections of this plan that discuss the strategy for meeting each requirement. In addition to these ARARs, relevant portions of 10 CSR 80-3.010(8) were also used as guidance in developing this monitoring plan.

K1.4 Background

Previously, this plan was documented in the *Weldon Spring Site Disposal Cell Groundwater Monitoring Plan*, Revision 2 (DOE 2004). That revision will be superceded by this appendix to the LTS&M Plan. Any future revisions to the monitoring program for the disposal cell will be documented in this appendix.

Groundwater at the chemical plant is contaminated with trichloroethylene (TCE), nitrate, uranium, and nitroaromatic compounds. The groundwater contamination originated with the Raffinate Pits and other source areas of the chemical plant site and former ordnance works area, that have been removed. Contamination is primarily limited to the weathered portion of the uppermost bedrock unit, the Burlington-Keokuk Limestone. Nitroaromatic compounds are present east and north of the disposal cell and is elevated in several of the disposal cell monitoring wells. Nitrate is present north and west of the disposal cell and is elevated in several of the disposal cell monitoring wells. Uranium is present southwest of the disposal cell; however, elevated levels are not observed in any of the disposal cell monitoring wells. TCE is also present southwest of the disposal cell, but elevated levels are not observed in any of the disposal cell monitoring wells.

Table K–1. ARARs Summary for Disposal Cell Groundwater Monitoring

Summary of Regulation	Pertinent Section of Monitoring Plan
40 CFR 264.90 Applicability Specifies the applicability requirements and exemptions for owners or operators of facilities that treat, store, or dispose of hazardous waste.	Section K1.3, Applicable or Relevant and Appropriate Requirements
40 CFR 264.91 Required Programs Specifies the criteria for determining which monitoring and response program (i.e., detection monitoring, compliance monitoring, or corrective action) should be instituted at a regulated facility.	Section K4.0, Detection Monitoring Program Section K5.0, Compliance Monitoring and Corrective Action Programs
40 CFR 264.92 Groundwater Protection Standard Requires compliance with certain conditions when hazardous constituents are detected in groundwater underlying a regulated unit.	Section K5.0, Compliance Monitoring and Corrective Action Programs
40 CFR 264.93 Hazardous Constituents Specifies the criteria for defining "hazardous constituents" to which the groundwater protection standard applies.	Section K5.0, Compliance Monitoring and Corrective Action Programs
40 CFR 264.94 Concentration Limits Specifies the criteria for establishing concentration limits for hazardous constituents detected in the groundwater underlying a regulated unit.	Section K3.4.2, Revised Baseline Tolerance Limits
40 CFR 264.95 Point Of Compliance Defines the point of compliance at which the groundwater protection standard applies and monitoring must be conducted.	Section K2.2, Groundwater Monitoring Wells
40 CFR 264.96 Compliance Period Defines the compliance period during which the groundwater protection standard applies.	Section K5.0, Compliance Monitoring and Corrective Action Programs
40 CFR 264.97 General Groundwater Monitoring Requirements Specifies general requirements for the groundwater monitoring program, such as well installation, sampling and analysis procedures, determination of groundwater surface elevation, and statistical methods to be used.	Section K2.0, Monitoring Network Design Section K3.4.2, Revised Baseline Tolerance Limits Section K4.4, Groundwater Elevation Measurements Section K6.0, Quality Control
40 CFR 264.98 Detection Monitoring Program Specifies requirements for detection monitoring programs, including monitoring parameters, sampling frequency, determination of groundwater flow, determination of statistically significant evidence of contamination, and required response to positive evidence of contamination.	Section K4.0, Detection Monitoring Program
40 CFR 264.99 Compliance Monitoring Program Specifies requirements for compliance monitoring programs, including monitoring parameters, sampling frequency, determination of groundwater flow, determination of statistically significant evidence of contamination, and required response to exceedance of the groundwater protection standard.	Section K5.0, Compliance Monitoring and Corrective Action Programs
40 CFR 264.100 Corrective Action Specifies requirements for corrective actions to be instituted to ensure compliance with the groundwater protection standard.	Section K5.0, Compliance Monitoring and Corrective Action Programs
10 CSR 25-7.264(2)(F) Releases From Solid Waste Management Units Specifies that efforts made to monitor groundwater or implement corrective action be documented, and that daily precipitation be measured. Also requires a surface water monitoring program to represent the quality of surface water hydrologically downgradient of the facility.	Section K2.3, Surface Water Monitoring Location Section K4.5, Precipitation Data Section K4.8, Detection Monitoring Reporting Section K5.0, Compliance Monitoring and Corrective Action Programs

K2.0 Monitoring Network Design

Groundwater monitoring requirements under 40 CFR 264, Subpart F, of RCRA specify that the monitoring system for a regulated unit must "consist of a sufficient number of wells, installed at appropriate locations and depths, to yield groundwater samples from the uppermost aquifer that: (1) represent the quality of background water that has not been affected by leakage from the regulated unit…; (2) represent the quality of groundwater passing the point of compliance; and (3) allow for the detection of contamination when hazardous waste or hazardous constituents have migrated from the waste management area to the uppermost aquifer." The disposal cell monitoring network at the Weldon Spring Site has been designed to meet these requirements, as described below.

K2.1 Basis of Design

The following criteria constitute the basis for design of the disposal cell groundwater monitoring network at the Weldon Spring Site:

- Regulatory requirements,
- Potentiometric surface of the shallow groundwater beneath the disposal cell,
- Design aspects of the disposal cell, and
- Physical site conditions.

The Subpart F regulations of RCRA specify that groundwater monitoring must be conducted at the point of compliance, which consists of a vertical surface that is located hydraulically downgradient of the waste management area and extends down into the uppermost aquifer. The RCRA regulations provide flexibility regarding the number, spacing, and depths of monitoring wells; however, the Missouri Sanitary Landfill regulations in 10 CSR 80-3.010, specify a minimum of one upgradient and three downgradient wells for landfills. The disposal cell network was designed to incorporate one upgradient and four downgradient wells, allowing for the possibility that wells could be added or removed as necessary. Since the original network was installed, two wells have been added and two have been eliminated. Thus, the current network still consists of one upgradient well and four downgradient wells. The location of these wells is discussed in Section K2.2.

To supplement groundwater monitoring, Missouri Hazardous Waste regulations in 10 CSR 25-7.264(2)(F) require that a surface water component be included in monitoring releases from waste management units. The surface water monitoring system must "consist of a sufficient number of points at appropriate locations to yield surface water samples that: (a) represent the quality of background surface water that has not been affected by any contamination from the facility…; and (b) represent the quality of surface water hydrologically downgradient of the facility or regulated units." The surface water monitoring location incorporated in this plan is discussed in Section K2.3.

The potentiometric surface of the shallow groundwater indicates that the flow gradient beneath the disposal cell is generally to the north and northwest, as shown in Figure K−1. The general direction of groundwater flow has remained relatively unchanged since the cell monitoring system was designed, throughout remediation of the site and construction of the disposal cell.

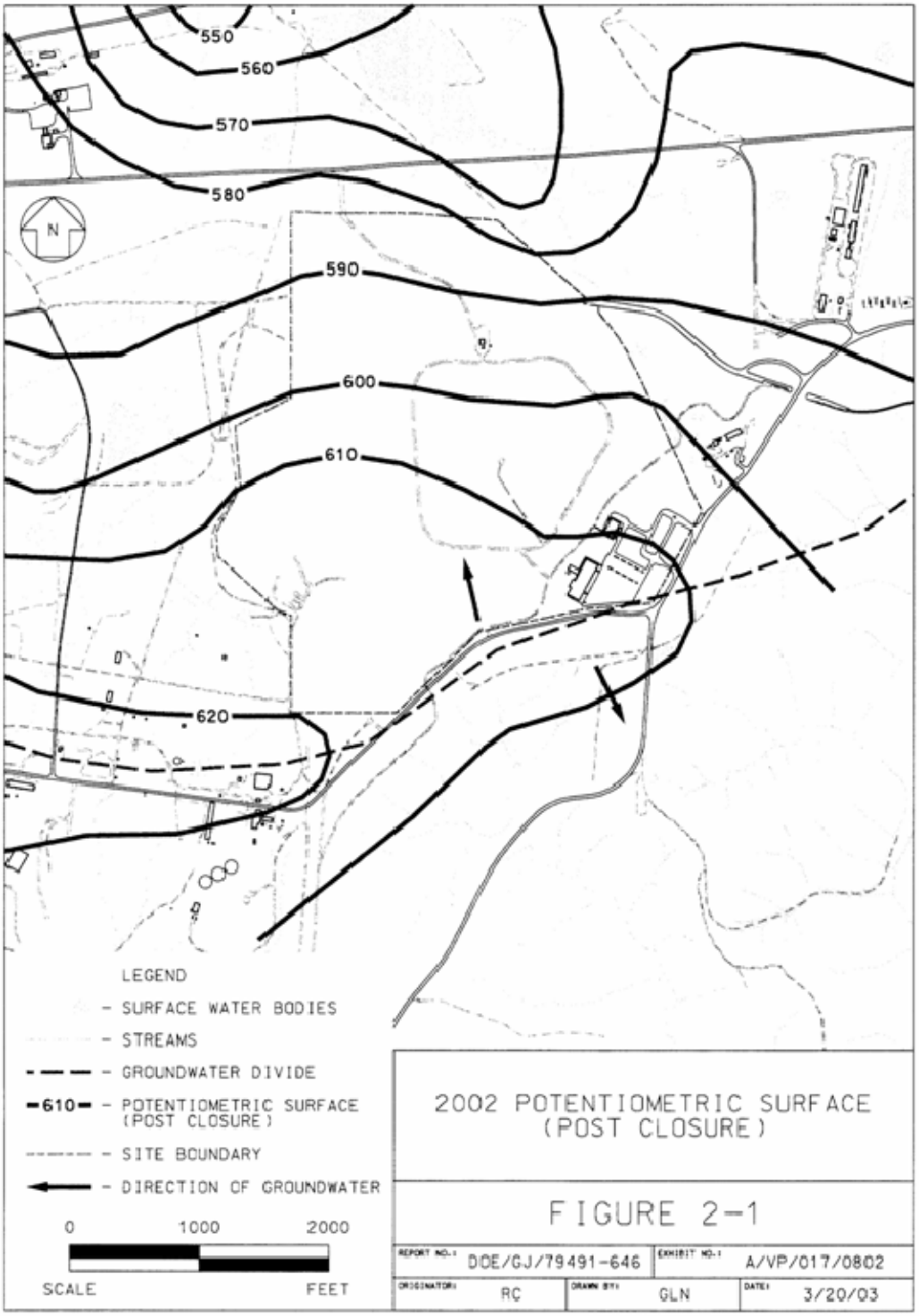

Figure K–1. 2002 Potentiometric Surface (Post Closure)

However, since construction of the disposal cell and previous remedial activities, the groundwater elevation has decreased due to dewatering of ponds/basins and diversion of surface water flow and reduced infiltration (recharge) to the shallow aquifer.

Design aspects of the disposal cell that were considered in determining the original locations of the monitoring wells included the locations of the clean fill dikes and leachate collection sump, the 1% to 1.5% northward slope along the base of the cell, and the double liner/leachate collection system. Since the monitoring network was installed while physical site conditions were undergoing frequent change due to remediation and construction activities, existing and planned locations of excavations, roads, structures, surface water bodies, staging areas, and the footprint of the disposal cell were also considered to ensure availability and access to the planned monitoring locations.

K2.2 Groundwater Monitoring Wells

The original disposal cell monitoring network was established in 1996. It included five wells: one upgradient well (MW-2048) and four downgradient wells (MW-2032, MW-2045, MW-2046, and MW-2047). The well locations, which are shown in Figure K−2, were chosen based on the criteria discussed above. Well MW-2048 was installed south of the cell to monitor water quality upgradient of the disposal cell. Wells MW-2045, MW-2046, and MW-2047 were installed northeast, north, and northwest of the cell, respectively, to monitor potential groundwater impacts downgradient of the disposal cell. Well MW-2032 was an existing well that was retained to monitor potential groundwater impacts downgradient (i.e., north) of the leachate sump. Figure K−3 provides a cross-sectional view of the monitoring system, in relation to the disposal cell and leachate sump.

While the original monitoring network consisted of five wells, it was the intent of the plan to provide flexibility for reacting to the dynamics of the system being monitored. The heterogeneous nature of the fractured bedrock aquifer and the complexities associated with monitoring a previously contaminated groundwater system created uncertainty in the actual performance of the proposed monitoring wells. Additional wells were to be incorporated into the network on an as-needed basis during both the active life and the post-closure period to replace or supplement data from poorly performing wells. Thus, since MW-2045 demonstrated consistently poor hydraulic performance and yielded widely variable analytical data, a fifth downgradient well (MW-2051) was installed in 2001 northeast of the disposal cell, as shown in Figure K–2. Under the present revision of this plan, MW-2051 replaces MW-2045 as the monitoring location for the northeast side of the disposal cell. Monitoring well MW-2051 exhibits higher hydraulic conductivities and will better represent the shallow groundwater system than MW-2045.

The original upgradient well, MW-2048 was damaged during construction activities in 2001. This well was determined to be damaged beyond repair, which led to its abandonment and installation of a replacement well shortly thereafter. The new well, MW-2055, is located approximately 20 feet upgradient (i.e., south) of MW-2048 and has replaced it as the upgradient monitoring well (see Figure K–2). Data review conducted for both monitoring wells indicated comparable upgradient water quality. No polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs) or nitroaromatic compounds were detected at either location. Concentration ranges of anions, metals, radiological and indicator parameters were similar,

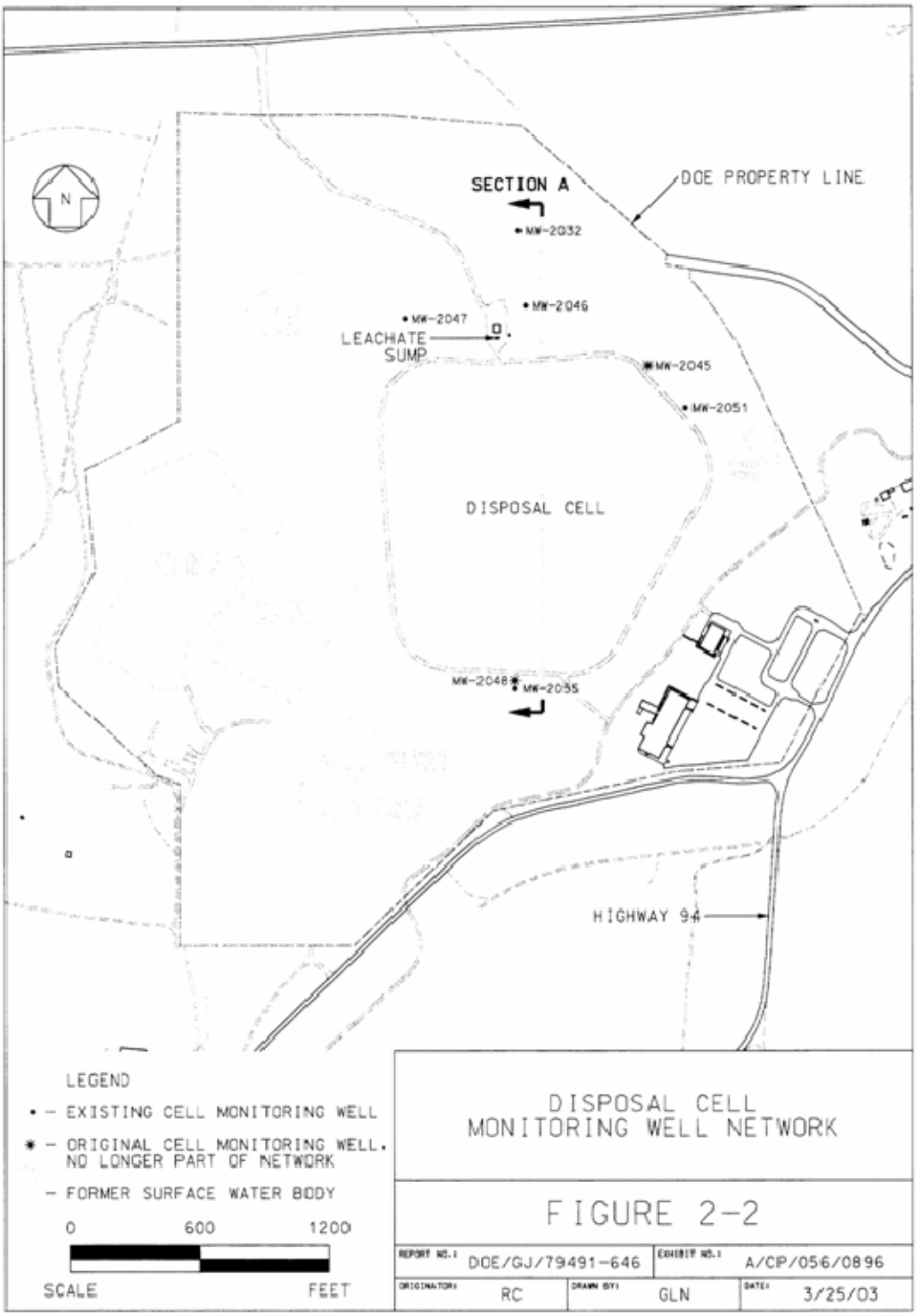

Figure K–2. Disposal Cell Monitoring Well Network

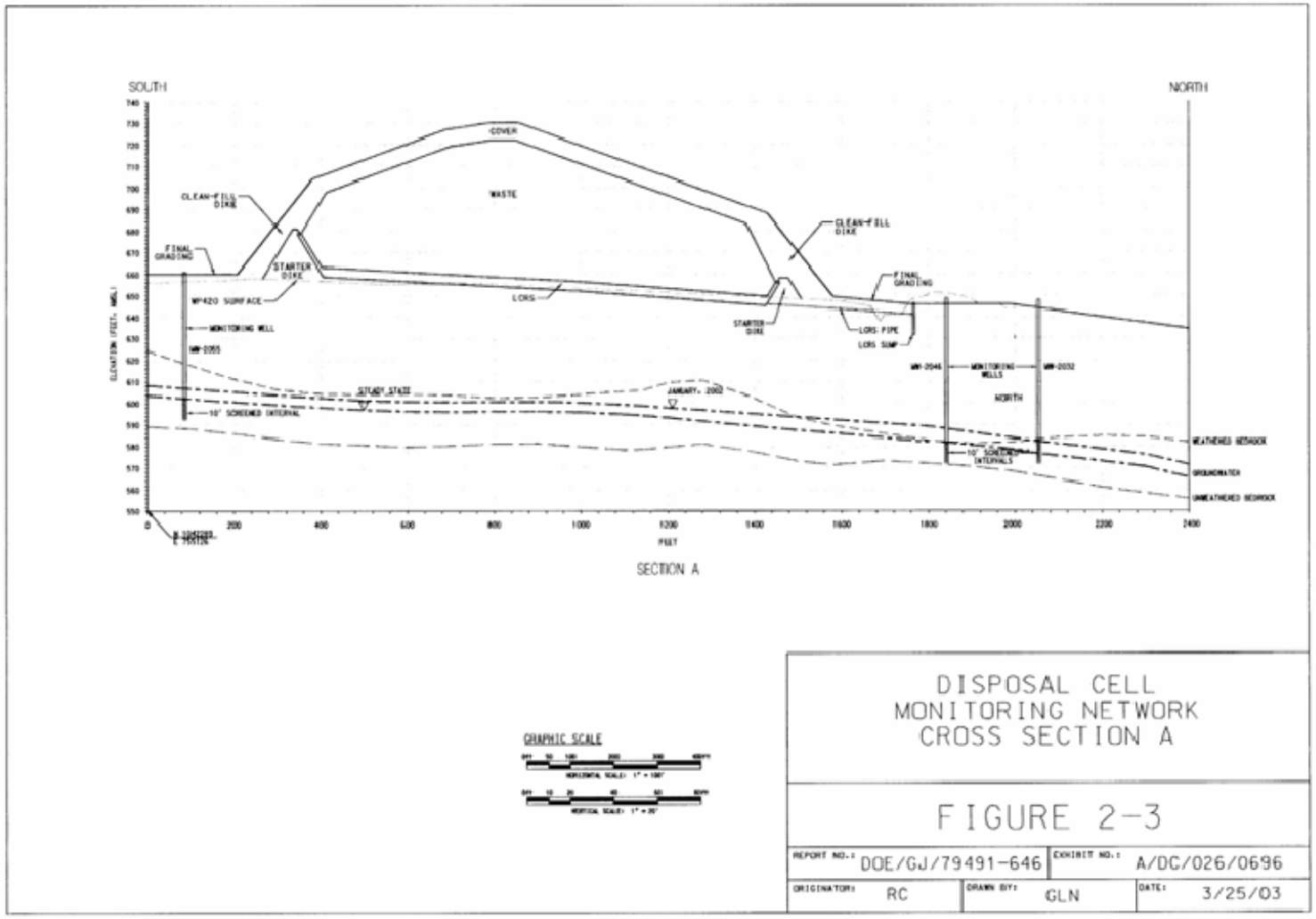

Figure K–3. Disposal Cell Monitoring Network Cross Section A

with the exception of three metals (iron, manganese, and nickel) and one indicator parameter (total organic carbon). However, the concentrations are within typical ranges for the groundwater in the weathered Burlington-Keokuk Limestone.

All wells in the disposal cell monitoring network were installed and developed in accordance with 10 CSR 23, Missouri Water Well Construction Code. Each well is constructed of 2-inch ID Grade 316 stainless steel casing, with a 10-foot length of 0.010-inch slotted screen. Total depths of the wells range from approximately 45 to 75 feet below ground surface, depending on the respective depth to water at each location. Borehole logs, well diagrams, packer test calculations, and well development forms for the original wells are contained in the *WSSRAP Disposal Cell Monitoring Well Program Installation Report* (MK-Environmental Services 1997). Attachment A of this plan contains the well diagrams for all disposal cell wells.

K2.3 Surface Water Monitoring Location

The surface water location used to detect downgradient impacts from the disposal cell is Burgermeister Spring (SP-6301) (see Figure K−4). Historical dye tests have indicated that this spring is the primary localized point of emergence for groundwater from the vicinity of the chemical plant (ANL 1997). Thus, sampling of Burgermeister Spring will yield results that are representative of both surface water and groundwater hydraulically downgradient of the disposal cell. Burgermeister Spring represents the first surface water impacted by groundwater originating from the site, including the disposal cell area. Downstream Lake 34 was not chosen as a monitoring point as Burgermeister Spring represents the worst case conditions for surface water and Lake 34 does not receive surface water contribution from the chemical plant area. It is common practice in aquifer systems dominated by fracture or conduit flow to supplement the monitoring well system by sampling springs that are hydraulically connected to the uppermost aquifer and that have shown a connection to the facility (EPA 1992). This spring was monitored routinely since 1987 under the *Environmental Monitoring Plan* (MK-F and JEG 2001a), and is a long-term monitoring location for the Groundwater Operable Unit. The spring in now monitored under this plan and the Long-Term Surveillance and Maintenance Plan. There is no upgradient surface water body included in this monitoring plan. The disposal cell is situated near both the regional surface water and groundwater divides; therefore, no surface water bodies are located upgradient of the disposal cell.

Ecological evaluations (including toxicity testing) for Burgermeister Spring have been conducted previously under site environmental monitoring and remedial investigation programs, and these results may be used for a determination of baseline ecological conditions for this plan. Results of ecological studies conducted for Burgermeister Spring as part of the *Remedial Investigation for the Groundwater Operable Unit* (ANL 1997) indicate that current conditions within the surface water and sediments in Burgermeister Spring, while exhibiting above background concentrations of both nitrate and uranium, have not measurably affected the biological community that uses the drainage. Therefore, while sampling for both radiological and chemical constituents will be conducted at Burgermeister Spring as specified in this plan, routine monitoring of biological activity will not be incorporated.

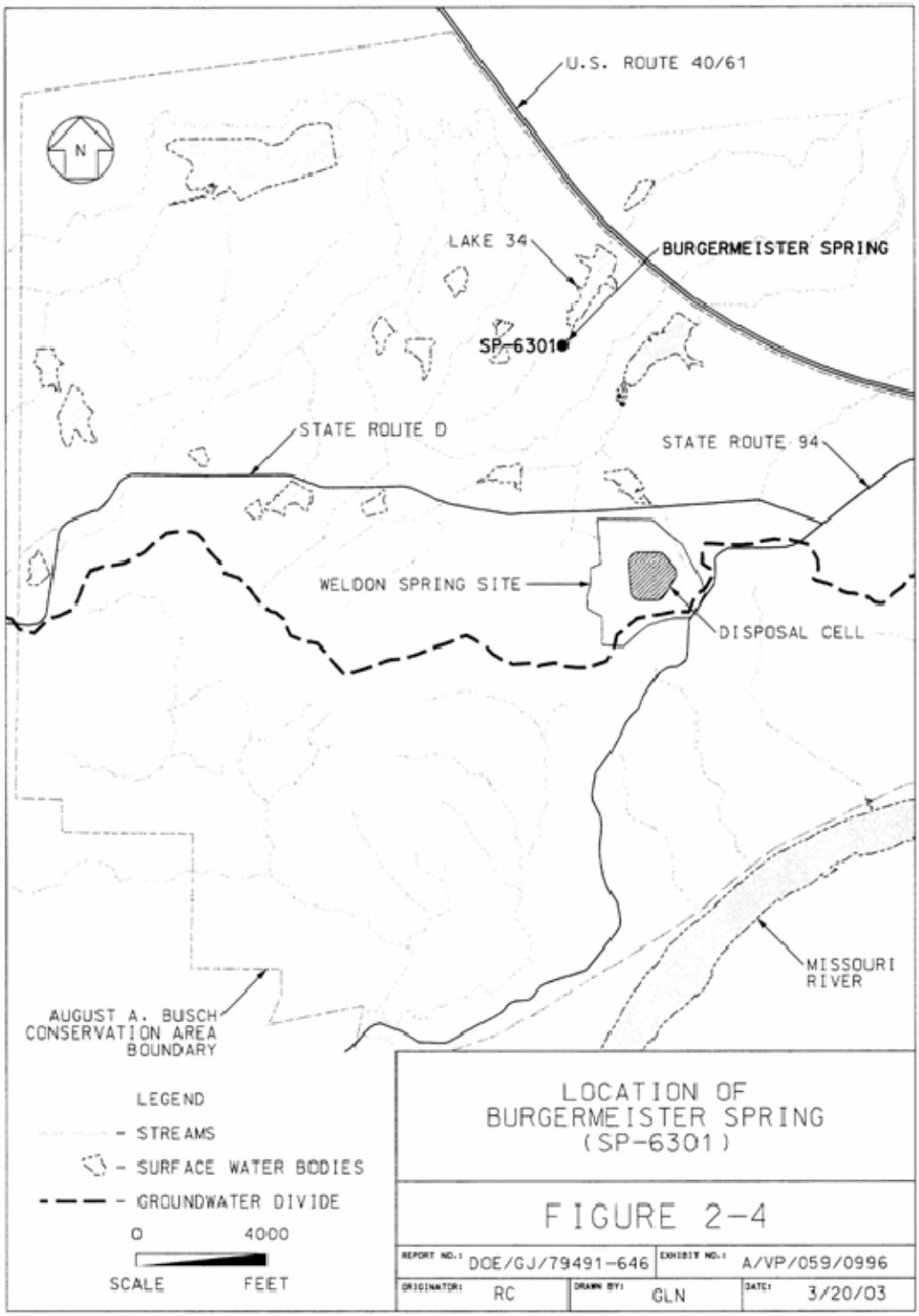

Figure K–4. Location of Burgermeister Spring (SP-6301)

K3.0 Baseline Monitoring

In accordance with 40 CFR 264.97, baseline monitoring was conducted to obtain data that represents the quality of groundwater that has not been affected by leakage from the disposal cell. The intent was to establish a baseline data set that could be used in statistical comparisons with detection monitoring data, in accordance with regulatory requirements, to detect and characterize hazardous constituents in the uppermost aquifer that may be due to leakage from the disposal cell.

Review of the initial approach to baseline monitoring and the groundwater system beneath the chemical plant has indicated that in some cases an established baseline may not be appropriate for monitoring of the disposal cell at the Weldon Spring site. The shallow aquifer beneath the chemical plant has been impacted by previous operation of the former ordnance works and the uranium feeds material plant. This limits the reliability of results obtained using the statistical methods specified in the Subpart F regulations to evaluate long term monitoring data, which is discussed further in Section K4.7 and Attachment B. It is expected that groundwater conditions for the contaminants of concern for the Groundwater Operable Unit (nitrate, uranium, trichloroethylene, and nitroaromatic compounds) will improve over time due to source removal activities. Baseline values established for these contaminants using prior data may be biased high due to existing groundwater contamination or contamination resulting from contaminated soil remediation. Later comparisons to this baseline may mask trends in the groundwater.

K3.1 Initial Baseline Monitoring

Baseline monitoring of locations MW-2032, MW-2045 through MW-2048, and SP-6301 was conducted throughout 1997 and early 1998, prior to waste placement activities. Four replicate samples were obtained from each location on a quarterly basis for approximately 1 year (i.e., five separate sampling events resulting in 20 individual samples per well). The initial baseline data indicated a large degree of temporal and spatial variability in water quality at the monitoring locations, as evidenced by the wide range of mean concentrations among monitoring locations and the high standard deviations calculated for many of the parameters. This variability is due to several contributing factors, such as the heterogeneity of the naturally occurring geochemistry, the variations in historical contaminant distribution throughout the site, and the unpredictable flow patterns in the fractured bedrock environment. Thus, the baseline conditions represented by the data were actually an indication of the groundwater quality at a particular location over a particular time period, and not a definitive characterization of background as intended by the Subpart F regulations.

Baseline monitoring of wells MW-2051 and MW-2055 began in 2001 and 2002, respectively. Samples from these wells are considered to be representative of water quality not impacted by the disposal cell since previous groundwater and leachate monitoring have indicated no reason to suspect leakage from the cell. Elements of the baseline sampling at these two wells have been similar to those listed above for the original six locations, except that the sampling events have consisted of a single sample (i.e., no replicates other than for quality control [QC] purposes).

K3.2 Previous Leachate Monitoring Evaluation

Regulations contained in 40 CFR 264.301 require leachate to be monitored during the active operation and post-closure period of a hazardous waste landfill. Although not specifically addressed by groundwater monitoring regulations, leachate monitoring is discussed in this plan because of the need to correlate the two programs to effectively monitor the potential migration of contaminants from the disposal cell.

Leachate production and analytical data have been collected routinely since waste placement activities began, in accordance with the Disposal Cell Leachate Monitoring Plan (Bennett 1998), the *Weldon Spring Site Disposal Cell Groundwater Monitoring Plan* (DOE 2004) and now this appendix to the LTS&M Plan. Samples were collected at least quarterly and analyzed for the entire list of parameters shown in Table K−2. A summary of the average and maximum concentrations of analytical constituents detected in the leachate since the sump was completed (2000) is also presented in Table K−2. Current data are reported in the Annual Site Environmental Reports.

Table K–2. Leachate Monitoring Data (10/18/00 to 5/8/02)

Parameter	Units	Concentration in Leachate (10-18-2000 to 5-8-2002)	
		Average	Maximum
Chloride[a]	(mg/L)	30.40	38.80
Fluoride[a]	(mg/L)	0.24	0.29
Nitrate-N[a]	(mg/L)	0.56	3.10
Sulfate[a]	(mg/L)	94.63	163.00
Aluminum	(µg/L)	33.12	70.50
Antimony	(µg/L)	ND	ND
Arsenic[a]	(µg/L)	3.73	9.36
Barium[a]	(µg/L)	606.88	832.00
Beryllium	(µg/L)	0.41	0.92
Cadmium	(µg/L)	ND	ND
Calcium	(mg/L)	176.25	198.00
Chromium[a]	(µg/L)	ND	ND
Cobalt[a]	(µg/L)	17.23	25.90
Copper	(µg/L)	3.48	9.90
Iron[a]	(µg/L)	12,083.00	22,100.00
Lead[a]	(µg/L)	ND	ND
Lithium	(µg/L)	7.99	13.20
Magnesium	(mg/L)	52.41	55.70
Manganese[a]	(µg/L)	5,396.00	9,970.00
Mercury	(µg/L)	ND	ND
Molybdenum	(µg/L)	5.82	7.75
Nickel[a]	(µg/L)	9.71	14.70
Potassium	(mg/L)	5.40	6.29
Selenium[a]	(µg/L)	1.24	3.95
Silver	(µg/L)	ND	ND
Sodium	(mg/L)	69.49	77.10
Thallium[a]	(µg/L)	3.45	10.60
Vanadium	(µg/L)	0.99	2.00
Zinc	(µg/L)	22.76	40.90
C.O.D. [a]	(mg/L)	28.60	35.00

Table K–2 (continued). Leachate Monitoring Data (10/18/00 to 5/8/02)

Parameter	Units	Concentration in Leachate (10-18-2000 to 5-8-2002)	
		Average	Maximum
Cyanide	(µg/L)	2.91	6.10
T.D.S. [a]	(mg/L)	867.20	970.00
T.O.C. [a]	(mg/L)	9.42	10.50
1,3,5-TNB[a]	(µg/L)	ND	ND
1,3-DNB[a]	(µg/L)	ND	ND
2,4,6-TNT[a]	(µg/L)	ND	ND
2,4-DNT[a]	(µg/L)	ND	ND
2,6-DNT[a]	(µg/L)	ND	ND
Nitrobenzene[a]	(µg/L)	ND	ND
Gross alpha	(pCi/L)	66.44	180.00
Gross beta	(pCi/L)	28.56	59.60
Ra-226[a]	(pCi/L)	0.32	0.68
Ra-228[a]	(pCi/L)	0.60	1.37
Th-228[a]	(pCi/L)	0.10	0.34
Th-230[a]	(pCi/L)	0.23	0.36
Th-232[a]	(pCi/L)	0.09	0.25
Total Uranium[a]	(pCi/L)	75.54	278.00
Pesticides	(µg/L)	ND[b]	0.26
PCBs[a]	(µg/L)	ND	ND
PAHs[a]	(µg/L)	ND	ND
VOCs	(µg/L)	ND[b]	5.20

Notes: ND = non-detect
[a]These parameters are retained for leachate analysis as of the date of this plan.
[b]All data were reported as non-detect, except for 3 or 4 isolated detections of individual compounds.

K3.3 Evaluation of Baseline Data

The original disposal cell monitoring plan specified that groundwater and surface water samples obtained under the plan be analyzed for all constituents presented in Table K−3. This comprehensive list included general water quality indicator parameters (e.g., pH, temperature, total organic carbon), chemical and radiological contaminants, and naturally occurring constituents. The list included many parameters in addition to those that would be considered "hazardous constituents" under 40 CFR 264.93, and provided the basis for a thorough assessment of groundwater quality in the vicinity of the cell.

It was anticipated that the original list of analytical parameters would be evaluated periodically and modified as necessary to eliminate constituents that could provide no conclusive information regarding the presence of hazardous constituents due to a potential breach in the cell liner system. The first such modification was instituted in December 1999, after the initial baseline data had been evaluated and the detection monitoring program had begun (Steffen 1999a). Several parameters were eliminated from the list due to the lack of measurable detections in either the groundwater or the leachate, or because they were naturally occurring parameters that were not site contaminants of concern (see footnote "a" on Table K−2).

Table K–3. Baseline Monitoring Constituents for Groundwater and Surface Water

General Indicator Parameters	Contaminants				
	Metals	Nitroaromatic Compounds	Radiological	Inorganic Ions	Other
pH[b] Temperature[b] Specific Conductance[b] COD[b] Cyanide[c] TDS[b] TOC[b] TOX[c]	Aluminum[c] Antimony[c] Arsenic[b] Barium[b] Beryllium[a] Cadmium[a] Calcium[a] Chromium[b] Cobalt[b] Copper[c] Iron[a b] Lead[b] Lithium[c] Magnesium[c] Manganese[a b] Mercury[a] Molybdenum[c] Nickel[b] Potassium[a] Selenium[b] Silver[c] Sodium[a] Thallium[a b] Vanadium[c] Zinc[c]	1,3,5-TNB[b] 1,3-DNB[b] 2,4,6-TNT[b] 2,4-DNT[b] 2,6-DNT[b] Nitrobenzene[a b]	Radium-226[b] Radium-228[b] Thorium, Isotopic[b] Uranium, Total[b]	Chloride[b] Fluoride[b] Nitrate-N[b] Sulfate[b]	PCBs[a b] PAHs[a b] VOCs[a] Pesticides[c]

COD Chemical Oxygen Demand
TDS Total Dissolved Solids
TOC Total Organic Carbon
VOCs Volatile Organic Compounds
TOX Total Organic Halogen

PCBs Polychlorinated Biphenyls: Aroclor 1248, 1254, 1260
PAHs Polyaromatic Hydrocarbons: benz(a)anthracene, benzo(b)fluorancene, benzo(k)fluorancene, benzo(a)pyrene, chrysene, indeno(1,2,3-cd)pyrene

[a]These parameters were deleted from the list in December 1999 because either they had not been detected previously in any measurable quantities or they were naturally occurring parameters that were not contaminants of concern (Steffen 1999a).
[b]These parameters are retained or reinstated for groundwater and surface water analysis in the second revision (DOE 2004).
[c]These parameters are eliminated in the second revision.

K3.3.1 Identification of Long-Term Monitoring Parameters

The second revision to this plan further modified the list of groundwater monitoring parameters based on a review of the Chemical Plant and Quarry Bulk Waste Operable Units contaminants of concern, materials known to be present in the disposal cell waste, and leachate analytical data. The following contaminants of concern were identified in wastes from the chemical plant and/or the quarry bulk waste: arsenic, chromium, lead, nickel, selenium, thallium, nitroaromatic compounds (specifically 2,4,6-DNT), radium, thorium, uranium, PCBs, and PAHs (DOE 1993 and DOE 1990). In addition, barium, manganese, and selenium were determined to be present in the water treatment processing wastes during the remediation of contaminated surface water. As more leachate analytical data became available, the following constituents were identified as being present at relatively higher concentrations in the leachate than in the underlying groundwater: arsenic, barium, cobalt, iron, manganese, uranium, and chemical oxygen demand

(COD). These parameters were important to the cell monitoring network because a breach of the cell liner system could result in detectable increases in the levels of these constituents in the groundwater.

K3.3.2 Identification of Signature Parameters

Detection monitoring data obtained from the cell well network from 1998 through 2001 were evaluated in the second revision of this plan using several of the suggested statistical methods in an attempt to identify statistically significant evidence of contamination due to the disposal cell. Results of these evaluations, which are summarized in Attachment B, demonstrate the uncertainties associated with applying the prescribed methods to data from an aquifer with preexisting contamination and where a high degree of spatial variation in contaminant distribution exists among the monitoring wells. Each type of evaluation resulted in numerous "false positive" statistical failures that, rather than providing reliable and conclusive evidence of cell leakage, were attributable to fluctuations in preexisting groundwater contamination.

The list of monitoring parameters in Table K−3 includes indicator parameters and waste constituents that for an uncontaminated aquifer would provide a reliable indication of the presence of hazardous constituents in groundwater due to leakage from the disposal cell. However, most of these parameters are already present in the groundwater at higher levels than in the leachate, either naturally or due to historical contamination, or are not present in either the groundwater or the leachate at concentrations above the detection limit. Thus, most of the parameters on this list are not able to provide conclusive evidence of cell leakage since impacts from the leachate would not cause detectable changes in the underlying groundwater.

The most reliable means of detecting potential impacts due to leakage of the disposal cell is to focus on parameters that exist at significantly higher concentrations in the leachate than in the groundwater. An increasing trend in these parameters in the groundwater would be detectable and, most likely, attributable to cell leachate since all other sources have been remediated.

To this end barium, uranium, iron, and manganese were identified as "signature parameters" for the disposal cell detection monitoring program in the second revision to this plan (DOE 2004). All four of these parameters have been detected at concentrations at least an order of magnitude higher in the leachate (Table K−2) than in the underlying groundwater or Burgermeister Spring (with the exception of uranium), which enhances the reliability of any conclusions that are drawn based on fluctuations in groundwater constituents. Increasing trends of these four parameters in the groundwater would be considered a signature of cell leachate that has migrated to the underlying aquifer and additional actions will be taken as described in Section K4.7. Also, these four parameters are naturally occurring and with the exception of uranium should not change via attenuation overtime. Uranium, a contaminant of concern for the Groundwater Operable Unit, is expected to attenuate with time where uranium impact occurs. However, the activity measured in the disposal cell monitoring wells is similar to background and likely will not change substantially over time. It was anticipated that the list of signature parameters may be modified, as necessary, based on future changes in leachate and/or groundwater concentrations.

It should be noted that the uranium concentrations in Burgermeister Spring can be similar or higher than those exhibited in the leachate. This location is impacted by not only contaminated groundwater originating from the Raffinate Pit area, but also residual contamination that is

present in the losing stream segment that extends from the Ash Pond area of the site to Burgermeister Spring. Increasing trends in uranium should not be used as the only indicator of possible leakage from the disposal cell.

K3.4 Statistical Analysis of Data

K3.4.1 Distribution of Data

The data for the signature parameters at the cell wells locations were examined to determine whether the data is normal or log-normal (Attachment B). The data shows a stronger evidence of log-normality than normality. However, to demonstrate that there is little difference in the method used to calculate the baseline tolerance limits, values were calculated for the signature parameters at three of the locations using six methods. The methods used were: U.S. Environmental Protection Agency (EPA) guidance suggested method on normal and log-normal data, tolerance limits on normal and log-normal data, and the mean plus 3 standard deviations on normal and log-normal data. All of the data from each location was used in this evaluation. The values calculated using the six methods yielded similar values for each of the signature parameters. Based on the evaluation (Attachment B), it is recommended to maintain the existing methodology of calculating baseline tolerance limits for the signature parameters and assume the data is distributed normally. Every 5 years, likely in conjunction with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 5-year reviews, the distribution of the data will be reevaluated.

K3.4.2 Revised Baseline Tolerance Limits

Tolerance limits for signature parameters were calculated using the dataset from 1997 through 2002, using 95% confidence and 95% coverage, based on the assumption that the data are normally distributed. In the case of the newer wells (MW-2051 and MW-2055), the available data used is fairly small: however the tolerance limits for these wells are representative of groundwater conditions at these locations. Every 5 years, likely in conjunction with the CERCLA five-year reviews, the baseline tolerance limits will be recalculated.

In calculating the baseline tolerance limit (BTL), results reported as non-detect (ND) or less than the detection limit (DL) were assigned a value of one-half the DL. Estimated values less than the DL, when reported, were used rather than one-half the DL.

In accordance with the EPA guidance on Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities (EPA 1989b), the following formula was used to calculate BTLs:

$$BTL = x + k (s)$$

where: x = arithmetic mean of the baseline data
s = standard deviation of the baseline data
k = one-sided normal tolerance factor, based on number of values in the data set

The original tolerance limits for each location using data collected through December 2002 is included in Attachment B. One-sided tolerance factors can be found in Table 5 - Appendix B of the EPA guidance (EPA 1989b) and are also included in Attachment B.

K4.0 Detection Monitoring Program

The goal of the detection monitoring program is to be able to detect releases of hazardous constituents from the disposal cell to the underlying aquifer. Detection monitoring is conducted in accordance with 40 CFR 264.98 throughout the life of the disposal cell to allow for the detection of hazardous constituents that may be migrating from the disposal cell.

The detection monitoring program, which began at this site in June 1998, has evolved since its inception as additional groundwater and leachate data have been obtained and evaluated in light of the relevant regulatory requirements. Resulting modifications to the plan have been incorporated through correspondence (Steffen 1999a and Steffen 1999b), annual revisions to the site *Environmental Monitoring Plan* (MK-F and JEG 2001a), and through revisions to this appendix of the LTS&M. An evaluation of the groundwater and leachate data collected through 2007 is included in Attachment C and includes rationale for modifications to the detection monitoring program.

K4.1 Sampling Locations

Samples will be collected from monitoring wells MW-2032, MW-2046, MW-2047, MW-2051, and MW-2055. Samples will also be collected from Burgermeister Spring (SP-6301).

K4.2 Groundwater Monitoring

Samples collected from the monitoring wells and Burgermeister Spring will be analyzed for the list of parameters given in Table K−4. Based on a review of groundwater and leachate data, the list of monitoring parameters has been reduced to only those that have been identified as COCs for either the chemical plant and/or quarry bulk wastes or generated during water treatment processes. Quality control sampling is discussed in Section K6.

Table K–4. Detection Monitoring Parameter List for Groundwater and Surface Water

Radiological	Metals	Nitroaromatic Compounds	Other	General Indicator Parameters
Radium-226 Radium-228 Th-228 Th-230 Th-232 Uranium, Total[a]	Arsenic Barium[a] Chromium Lead Manganese Nickel Selenium Thallium	1,3,5-TNB 1,3-DNB 2,4,6-TNT 2,4-DNT 2,6-DNT Nitrobenzene	PCBs PAHs	pH Temperature Specific Conductance

[a]Signature parameters (see Section K3.3.2)

K4.3 Sampling Frequency

Each monitoring well and Burgermeister Spring will be sampled on a semiannual frequency. Samples will be collected during June and December of each year. This sampling frequency will provide an adequate dataset for use in developing a moving baseline for each location

(Section K3.3), and assists in eliminating the spatial and temporal variability seen in earlier datasets. Burgermeister Spring will be sampled during baseflow conditions, which is the stage of spring discharge when the water is least influenced by active surface runoff. Samples will be collected no sooner than 1 week following the end of a precipitation event of sufficient intensity to result in surface runoff. The flow rate of the spring will be estimated and recorded at each sampling event.

The original disposal cell groundwater monitoring plan called for collecting four replicates at each monitoring location on a semi-annual basis. In 1999, the monitoring frequency was reduced to a single sample collected semi-annually from each location since independent replicates could not be collected within a short time period because of slow groundwater flow rates.

K4.4 Groundwater Elevation Measurements

Groundwater elevations will be measured semiannually at each of the disposal cell monitoring well locations prior to each sampling event. Groundwater flow rates and flow directions will be evaluated annually and reported in the Annual Site Environmental Report.

K4.5 Precipitation Data

To support leachate monitoring activities at a regulated unit, Missouri Hazardous Waste regulations require the collection of local precipitation data. An onsite meteorological station was used to monitor daily and hourly precipitation until December 2001, as described in the *Environmental Monitoring Plan* (MK-F and JEG 2001a). More recent and future regional precipitation data (e.g., from the Spirit of St. Louis Airport in Chesterfield, Missouri) is obtained as needed through the National Oceanographic and Atmospheric Administration at the following internet address: http://weather.noaa.gov.

K4.6 Leachate Monitoring

Regulations contained in 40 CFR 264.301 require leachate to be monitored during the active operation and post-closure period of a hazardous waste landfill. Although not specifically addressed by groundwater monitoring regulations, leachate monitoring is discussed in this plan because of the need to correlate the two programs to effectively monitor the potential migration of contaminants from the disposal cell.

The leachate monitoring parameters will be a larger set than that monitored in the groundwater. This larger set has been selected because of the potential for changes in the composition of leachate over time. The leachate will continue to be monitored semiannually for the parameters outlined in Table K−5. Samples will be collected in June and December of each year.

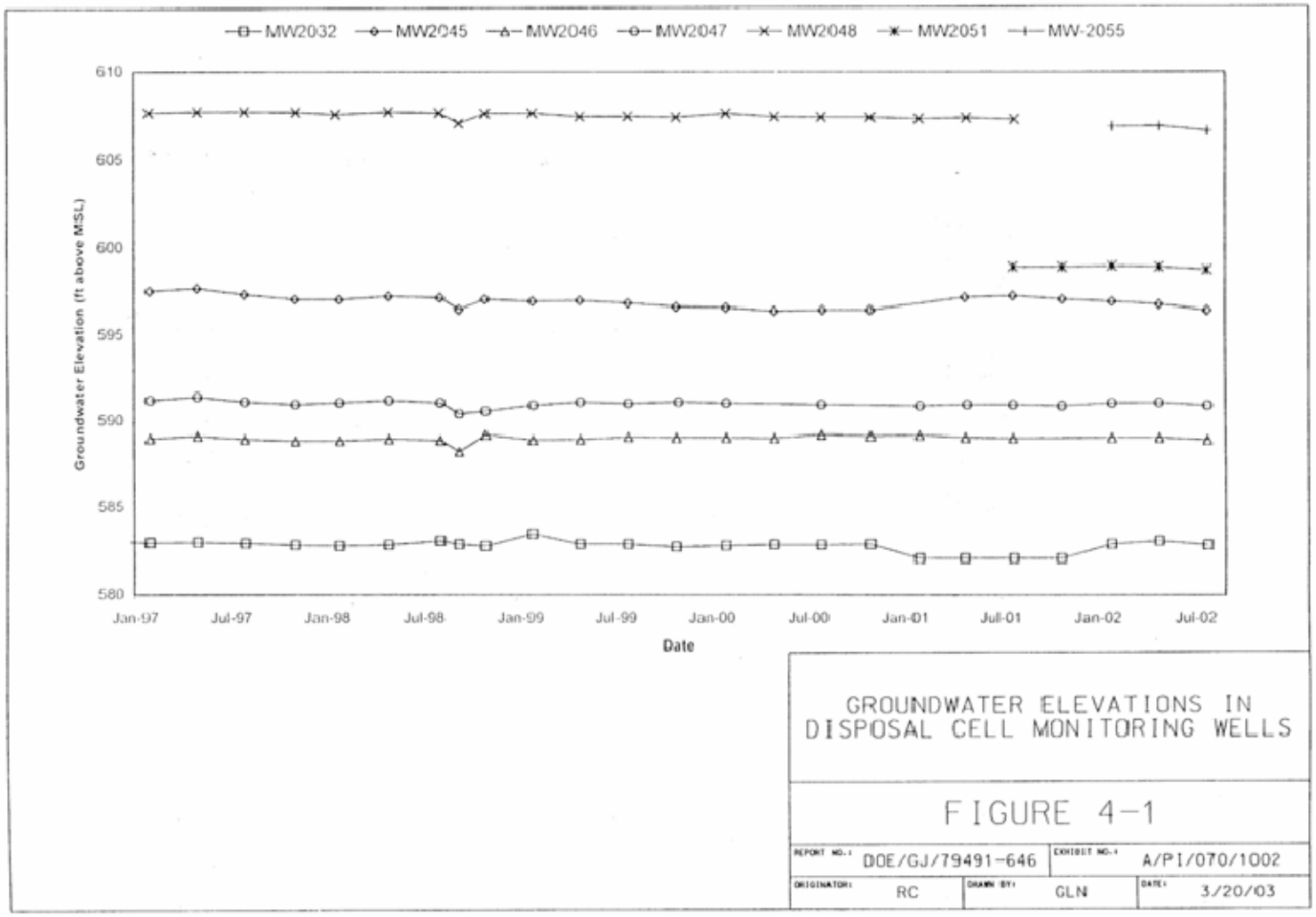

Figure K–5. Groundwater Elevations in Disposal Cell Monitoring Wells

Table K–5. Monitoring Parameter List for Leachate

Radiological	Inorganic Ions	Metals	Nitroaromatic Compounds	Other	General Indicator Parameters
Radium-226 Radium-228 Thorium, Isotopic Uranium, Total[a]	Chloride Fluoride Nitrate (as N) Sulfate	Arsenic Barium[a] Chromium Cobalt Iron[a] Lead Manganese[a] Nickel Selenium Thallium	1,3,5-TNB 1,3-DNB 2,4,6-TNT 2,4-DNT 2,6-DNT Nitrobenzene	PCBs PAHs	pH Temperature Specific Conductance COD TDS TOC Turbidity

[a]Signature parameters (see Section K3.3.2)

K4.7 Detection Monitoring Data Review

K4.7.1 Signature Parameters

Under the detection monitoring program, data for only the signature parameters from each monitoring event will be compared to baseline tolerance limits (Table K−6) to track general changes in groundwater quality and determine whether statistically significant increases in these parameters has occurred. Tolerance limits for signature parameters were calculated using the methodology presented in Section K3.4. Tolerance limits have been calculated for barium and uranium using data from 1997 through 2007.

Table K–6. Baseline Tolerance Limits for Signature Parameters in Groundwater and Surface Water

Location	Signature Parameter	
	Barium (µg/L)	Uranium (pCi/L)
MW-2032	325	5.3
MW-2046	255	1.4
MW-2047	440	2.2
MW-2051	230	2.1
MW-2055	49	4.2
SP-6301	163	100

For signature parameters (barium and uranium) that are determined to exceed the baseline tolerance limits, the following actions will be taken:

- The location will be resampled to confirm the exceedence. If the exceedence is not confirmed, detection monitoring will continue and no further action is necessary.
- If resampling results confirm the exceedence, a thorough evaluation will be performed to determine whether it is due to leakage from the disposal cell. This evaluation may include an assessment of groundwater gradients, review of leachate production and analytical data, review of sitewide monitoring data, and additional sampling. If it is shown that the upward trend is not due to leakage from the cell, a demonstration report will be prepared in

accordance with the substantive requirements of 40 CFR 264.98, and detection monitoring will continue.

K4.7.2 Other Parameters

The data from the remainder of the parameters will be reviewed to evaluate the general groundwater quality in the vicinity of the disposal cell and to determine if changes are occurring in the groundwater system. Data will be compared to the 3 most recent years of data to determine if statistically significant increases or trends in concentrations are present. A "moving average" approach, as discussed in the October 11, 1989, Federal Register (EPA 1989a), is used to better reflect naturally occurring changes in site hydrogeology, minimize temporal variations, and account for the natural attenuation of contaminants in the shallow aquifer. Data will be considered statistically significant if it is greater than the arithmetic mean plus 3 times the standard deviation for each location.

Data that are determined to be statistically significant will be evaluated as follows:

- The location will be resampled to confirm the exceedence. If the exceedence is not confirmed, no further action is necessary.
- If results of the resampling confirm the exceedence, the data will be compared to the leachate data. If the leachate data do not indicate that the exceedence could be the result of leakage from the cell (parameter is not elevated in the leachate), an assessment of the analytical data and review of sitewide monitoring data will be performed. If the exceeding parameter is a contaminant of concern for the Groundwater Operable Unit (nitrate, nitroaromatic compounds, or trichloroethylene), this information will be evaluated under the monitoring program for the Groundwater Operable Unit at the chemical plant.
- If results of the resampling confirm the exceedence, the data will be compared to the leachate data. If the leachate data indicate that the exceedence could be the result of leakage from the cell (parameter is also elevated in the leachate), the entire disposal cell monitoring network will be sampled for the full list of parameters shown in Table K–3. A revised monitoring plan, which incorporates the results of the enhanced sampling and outlines the specific details of the compliance monitoring program (Section K5.0), and an engineering feasibility plan for corrective action will be prepared in accordance with substantive requirements of 40 CFR 264.99.

K4.7.3 Leachate

Analytical data from the leachate will be compared to the analytical data from the monitoring well network to determine the adequacy of the signature parameters for this plan. If the composition of the leachate changes substantially, a parameter may be included or removed from the parameter list. If the concentration of a parameter decreases so that it is not distinguishable from concentrations (similar in concentrations) in groundwater, that parameter will be removed from the signature parameter list. Conversely, if the concentration of a parameter increases to a level that distinguishable from the concentrations in groundwater (order of magnitude greater), it would warrant its inclusion in the signature parameter list. This evaluation will be performed annually.

K4.8 Detection Monitoring Reporting

K4.8.1 Annual Reporting

Disposal cell monitoring data are reported annually in the Weldon Spring Site Environmental Reports (MK-F and JEG1999, MK-F and JEG 2000, MK-F and JEG 2001b, MK-F and JEG 2002, DOE 2005, DOE 2006a, and DOE 2007). Data to be reported includes all detectable analytical results, as well as groundwater flow rate and direction. However, since only analytical results were reported prior to 2002, groundwater flow rates and direction for the years 1998 through 2002 are included in Attachment D of this plan.

Confirmed exceedances of signature parameters are investigated further by evaluating water levels and precipitation data and reviewing historical analytical and field monitoring data to determine the likely cause and contributing factors. A summary of the exceedances and results of the investigations are reported in the annual site environmental report.

K4.8.2 Demonstration Reporting

A demonstration report will be prepared if it is shown that an upward trend in a signature parameter is not due to leakage from the cell. This report will document the evaluation used to derive the conclusion that leakage has not occurred from the disposal cell. This evaluation may include an assessment of data quality, groundwater gradients, review of leachate production and analytical data, review of sitewide monitoring data, and additional sampling.

K5.0 Compliance Monitoring and Corrective Action Programs

If it is determined that leakage from the cell has resulted in deterioration of the groundwater at the chemical plant, a review of the remedy will be necessary. This is based on the condition that the remedy is not behaving as expected and may no longer be protective of human health and the environment. Modifications or actions would be documented under CERCLA and would be consistent with 40 CFR 264.100, if appropriate. Identification of ARARs would be make at that time and my include groundwater protection standards as outlined in 40 CFR 264.92, if appropriate. At that time, a modification of this program would be documented in collaboration with EPA–Region VII and the Missouri Department of Natural Resources. The monitoring program will continue as prescribed in Section K4 and the nature and extent of the release will be investigated.

K6.0 Quality Control

All sampling, quality, and data verification will be conducted in accordance with the LTS&M Plan and the current version of the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PLN/S04351).

K7.0 References

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Attachment A

Monitoring Well Installation Logs

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WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

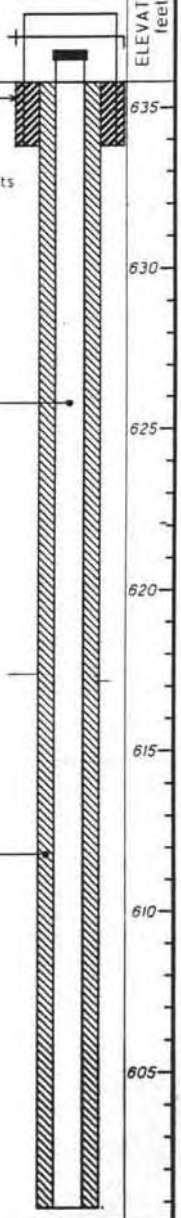
HOLE NUMBER	MW-2032
SHEET 1 OF 2	
NORTH (Y):	1044508.74
EAST (X):	755016.39
TOC ELEVATION	637.48
GROUND ELEVATION	635.81
STICKUP	1.67
HYDR CONDUCTIVITY (cm/sec)	K= N/A

WELL STATUS/COMMENTS	ACTIVE
LOCATION	27'SW MW2023, 30' SE MW2024 (AEC)
DRILLING CONTRACTOR	HANIBAL TESTING LABS
DRILL RIG MAKE & MODEL	CME 55/75, NQ WIRELINE
HOLE SIZE & METHOD	7 5/16 "O.D. 4 1/4" I.D.
ANGLE FROM HORIZONTAL & BEARING	90
BOTTOM OF HOLE (TD) (DEPTH (FT.) FROM GROUND ELEV. TO)	60.0
DRILL FLUIDS & ADDITIVES	WATER
CASING TYPE, DEPTH, SIZE	2" PVC
BEDROCK	48.5
DATE START	08-11-1989
DATE FINISH	07-15-1989
WATER LEVELS & DATES	▽12-04-92 ▼05-31-91

LITHOLOGY BY A.BENFER

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
	SS-1	10/18"	7	ML	CLAYEY SILT, dark gray to brownish yellow, low plasticity, damp, medium stiff, MnOx & FeOx.	Qlv
5	ST-2	27/30"		CL	SILTY CLAY, brownish yellow, medium plastic, 20% sand, trace rounded gravel, moist, very stiff. Becomes mottled with light gray and MnOx at 9 feet. Light yellowish brown with caliche, very stiff with silt pockets at 12.5.	Qct
	SS-3	15/18"	10			
10	ST-4	26/30"				
	SS-5	16/18"	9			
15	ST-6	24/30"				
	SS-7	18/18"	14		SILTY CLAY, brownish yellow, medium plasticity, 10% sand, fine gravel, stringers of light gray and MnOx, damp, hard. ft.	
20	ST-8	30/30"				
	SS-9	18/18"	16	CH	SILTY CLAY, as above, highly plastic	
25	ST-10	11/12"		ML CL	SILT to SILTY CLAY, light brownish gray, medium plasticity, moist, very stiff. Minor gravel, angular, up to 1.5 inches at 30 feet.	
	SS-11	18/18"	13	CH	CLAY, brownish yellow, highly plastic, moist, very stiff, contains 5% sand, 15% fine gravel and MnOx.	
30	ST-12	18/18"	34		Minor gravel, angular, up to 1.5 inches at 30 feet.	
	SS-13	13/18"	18			
35	SB-14	16/18"	33	ML		

WELL DIAGRAM



ELEVATION feet

Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

HOLE NUMBER: MW-2032

SHEET 2 OF 2

NORTH (Y): 1044508.74

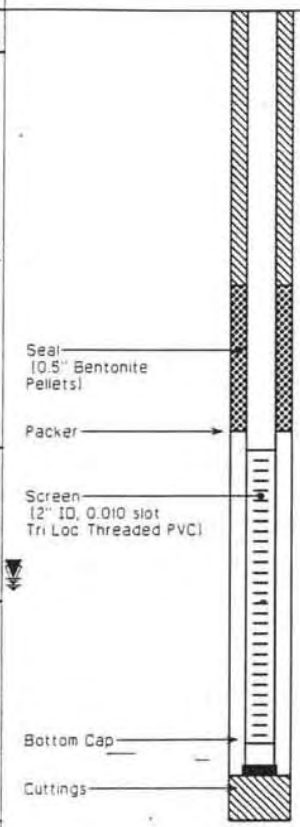
EAST (X): 755016.39

WELL STATUS/COMMENTS: ACTIVE

LOCATION: 27'SW MW2023, 30' SE MW2024 (AEC)

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
		16/18"		ML	SILT, reddish yellow, low plasticity, abundant FeOx, minor gravel, very soft.	Qct
	SS-15	16/18"	24	GC	CLAYEY GRAVEL, yellowish red, angular white chert gravel, plastic, moist, dense, hard.	
40	SS-16	12/18"	39		Highly fractured and weathered chert and 25% clay, very moist at 40 feet. Stiff at 45 feet.	pPr
45	SS-17	18/18"	15			
	NQ-1	7/54"	10	GC chrt	CHERT fragments, white, weathered, minor MnOx and FeOx.	Mbksw
50	NQ-2	66/66"	64	lms	LIMESTONE, yellow, silty, moderately weathered, contains finely disseminated oxidized pyrite. Chert, white, fresh.	
55					LIMESTONE and CHERT, as above, 50% chert distributed throughout providing a breccia appearance. Chert, white to bluish to pinkish.	Mbkw
	NQ-3	18/18"	57			
60					Total depth 60.0 feet.	
65						
70						
75						

WELL DIAGRAM



ELEVATION feet: 600, 595, 590, 585, 580, 575, 570, 565

Sample Interval | No Sample Taken | minimum | maximum | average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSMLOG-C

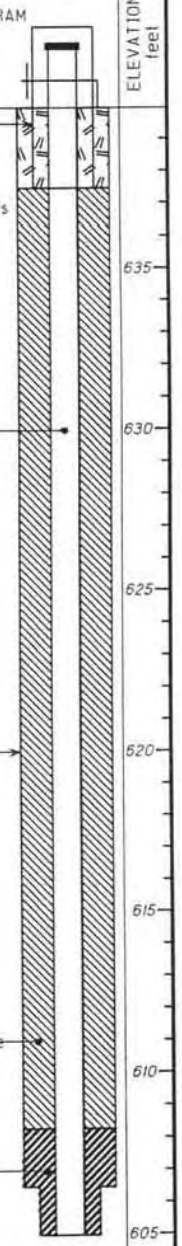
HOLE NUMBER	MW-2045 (C2)
SHEET 1 OF 2	
NORTH (Y):	1043883.98
EAST (X):	755615.24
TOC ELEVATION	641.82
GROUND ELEVATION	639.95
STICKUP	1.87
HYDR CONDUCTIVITY (cm/sec)	K= 1.44x10^{-3} (Packer Test)

WELL STATUS/COMMENTS	ACTIVE
LOCATION	Downgradient of Disposal Cell
DRILLING CONTRACTOR	GEOTECHNOLOGY INC.
DRILL RIG MAKE & MODEL	CME 750, HSA/NQWL CORE/SCHRAMM AIR ROT.
HOLE SIZE & METHOD	10 1/4" HSA to 33.5' then 6" Air
ANGLE FROM HORIZONTAL & BEARING	90
BOTTOM OF HOLE (TD) (DEPTH (FT.) FROM GROUND ELEV. 10)	50.0
DRILL FLUIDS & ADDITIVES	WATER/AIR
CASING TYPE, DEPTH, SIZE	2" 316 STAINLESS STEEL
BEDROCK	33.5
DATE START	10-15-1996
DATE FINISH	11-1-1996
WATER LEVELS & DATES	

LITHOLOGY BY P. PATCHIN/S. VINCENT

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT UNIT
	CME-1	42/42"		TS	0-.2' TOPSOIL, brownish gray with roots.	Gp
				CL ML	.2 - 1.0' SILTY CLAY/CLAYEY SILT, mottled yellowish brown (10YR 5/6) with minor brownish yellow (10YR 6/8), non-plastic to low plasticity, slightly moist, very stiff (pp=3.0), roots.	Grx
				CH	1.0 - 1.9' SILTY CLAY/CLAYEY SILT color as above, nonplastic, dry to damp, hard (pp=4.0+), minor MnOx stain, roots, FeOx blebs.	Glv
5	CME-2	60/60"		CL	1.9 - 5.8' SILTY CLAY, mottled yellowish brown (10YR 5/8), and minor grayish brown (10YR 5/2), medium to high plasticity, slightly moist, very stiff (pp=2.75), minor (<5%) angular chert gravel to 1/2".	
10	CME-3	60/60"			5.8 - 18.0' SILTY, SANDY CLAY with GRAVEL, yellowish brown (10YR 5/8) with minor light brownish gray leaching along fractures, low plasticity, dry, hard (pp=4.5+), very sandy (v.fine) with approx. 5-10% gravel (v.fine to 2"+) which is rounded (igneous) and angular (limestone and chert), very fractured with abundant MnOx along fracts., gray granular CaCO3 in thin lenses at 15.0' and 17.5'	Gct
15	CME-4	60/60"				
20	CME-5	48/48"		CL CH	18.0 - 20.0' CLAY, strong brown (7.5 YR 4/6) with minor reddish mottling, medium to high plasticity, slightly moist hard (pp=4.5+), little to no sand or gravel, grayish silty pockets (occasional), abund. FeOx nodules, abund. MnOx on fractures.	
				CL	20.0 - 22.2' CLAY, slightly silty, mottled dark red (2.5YR 4/6) and minor light brownish gray (2.5YR 6/2), low plasticity, damp to slightly moist, very stiff (pp=2.25-3.25), very crumbly and blocky structure, waxy, with silty pockets from 21.0 - 22.2'.	
	SS-6	11/11"	+50	GC	22.2' CLAYEY GRAVEL, color as above but with weathered chert gravel (60%-70%) to >2", very angular and "shattered". Chert gravel is generally white (10YR 8/1), hard to very hard, moderately weathered. Interstitial clay is as above, damp to slightly moist.	
25	SS-7	12/24"	43	CL GC	GRAVELLY CLAY/CLAYEY GRAVEL, (alternating broken chert gravel and clay with gravel), clays is strong brown (10YR 4/6), med. to high plasticity, slightly moist, very stiff, with minor fine chert gravel as above.	pPr
30					Top of Bedrock @ 33.5 ft.	Mdksw
35	RUN-1	78/120"	30	lms chrt	33.5 - 43.7' ARGILLACOUS LIMESTONE AND CHERT, interbedded and brecciated (approximately 60/40). Limestone is grayish orange (10YR 7/4) to pale yellowish brown (10YR 6/2), mottled with	

WELL DIAGRAM



ELEVATION feet: 635, 630, 625, 620, 615, 610, 605

Sample Interval No Sample Taken minimum maximum average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

HOLE NUMBER: MW-2045 (C2)

SHEET 2 OF 2

WSMLOG-C

NORTH (Y): 1043883.98

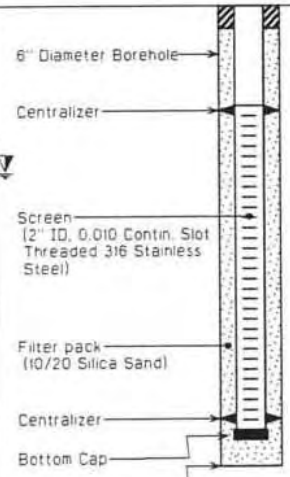
EAST (X): 755615.24

WELL STATUS/COMMENTS: ACTIVE

LOCATION: Downgradient of Disposal Cell

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
						lms chrt	very light gray (N8) chert. Limestone is fine to medium-grained, very argillaceous, thin-bedded, mod. hard, mod. weathered with vugs pinpoint to 1", abundant FeOx staining and closely fractured. Minor stylolites and fossils. Chert is brecciated and interbedded with limestone and as nodules (to 5"), very hard, fossiliferous with MnOx staining on micro-fractures and in matrix. "Strongly Weathered Burlington-Keokuk Limestone" from 34.0-39 ft. then "Weathered Burlington-Keokuk Limestone" to total depth.	MDksw
40						lms chrt		MDkw
45		RUN-2	70/72"	70			43.7 - 49.1' ARGILLACEOUS LIMESTONE AND CHERT, as above but increased clay content and very fine grained (micritic), less chert (approx. 30%), moderate to high porosity.	
							Kp = CONSTANT HEAD SINGLE PACKER PRESSURE TESTS 37.3 to 44.0 ft. K=1.4E-3 cm/sec 39.6 to 50.0 ft. k=8.8E-4 cm/sec	
50						chrt	49.1 - 50.0' CHERT, mottled very light gray (N8) and brownish gray (5YR 4/1), very hard, slightly weathered, closely fractured with heavy FeOx staining on fracture surfaces.	
							Total cored depth 50.0 feet. Switched to 6" air rotary and reamed hole to 49.2'.	
55							Note: Soil and rock color are indexed on the Muncell soil color chart.	
60								
65								
70								
75								

WELL DIAGRAM



ELEVATION (feet): 600, 595, 590, 585, 580, 575, 570, 565

Sample Interval | No Sample Taken | minimum | maximum | average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSMLOG-C

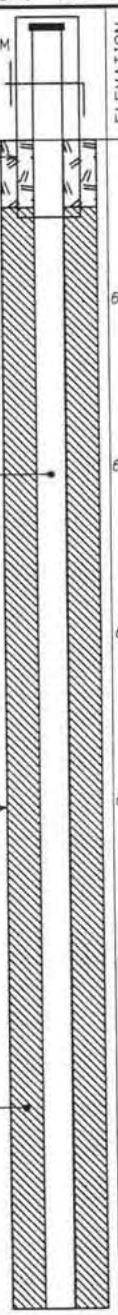
HOLE NUMBER	MW-2046 (C3)
SHEET 1 OF 2	
NORTH (Y):	1044158.17
EAST (X):	755046.76
TOC ELEVATION	653.54
GROUND ELEVATION	649.77
STICKUP	3.77
HYDR CONDUCTIVITY (cm/sec)	K= 4.85×10^{-6} (Packer Test)

WELL STATUS/COMMENTS	ACTIVE
LOCATION	Upgradient of Disposal Cell
DRILLING CONTRACTOR	GEOTECHNOLOGY
DRILL RIG MAKE & MODEL	CME 750, HSA/NQWL CORE/SCHRAMM AIR ROT.
HOLE SIZE & METHOD	10 1/4" HSA to 51.8' then 6" Air
ANGLE FROM HORIZONTAL & BEARING	90
BOTTOM OF HOLE (TD) (DEPTH (FT.) FROM GROUND ELEV. TO)	74.0
DRILL FLUIDS & ADDITIVES	WATER/AIR
CASING TYPE, DEPTH, SIZE	2" 316 STAINLESS STEEL
BEDROCK	51.8
DATE START	11-5-1996
DATE FINISH	11-15-1996
WATER LEVELS & DATES	

LITHOLOGY BY SEAN VINCENT/PAUL PATCHIN

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or ROD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
				Fill	0 - 1.5' FILL, gravel drill pad (3" minus rock)	Fill
	SS-1	18/24"	19	CL ML CH	SILTY CLAY/CLAYEY SILT, yellowish brown (10YR 5/6), low plasticity, slightly moist, very stiff (pp=3.0).	Qrx
5	SS-2	19/24"	16		1.5 - 13.8' CLAY, mottled yellowish brown (10YR 5/4) and grayish brown (10YR 5/2), medium to high plasticity, slightly moist, very stiff (pp=2.75).	
	SS-3	24/24"	12			Qlv
10	SS-4	24/24"	17		CLAY, as above, black MnOx staining is common.	
	SS-5	24/24"	20		CLAY, as above, very stiff (pp=3.5).	
15	SS-6	24/24"	25	CL CH	13.8 - 32.0' SILTY CLAY, yellowish brown (10YR 5/8) with light greenish gray (5GY 7/1) along fractures, medium to high plasticity, approx. 5% angular chert gravel to 1" with trace subrounded to rounded igneous gravel, hard (pp=4.5), grading to higher silt and fine sand content with depth.	
	SS-7	24/24"	19			
20	SS-8	24/24"	27			
	SS-9	24/24"	32			
25	SS-10	24/24"	32	CL	SILTY CLAY, as above, medium plasticity, waxy appearance, hard (pp=4.0).	Qct
	SS-11	24/24"	27			
30	SS-12	24/24"	28			
	SS-13	24/24"	28		32.0 - 34.0' SILTY CLAY, as above but with red (2.5YR 5/6) color and includes occasional subangular to angular chert fragments.	
35	SS-14	24/24"	29		34.0 - 37.5' SILTY CLAY, as above but color is yellowish brown (10YR 5/6) with light gray (10YR 7/2) silt in fractures, occasional FeOx nodules	

WELL DIAGRAM



ELEVATION feet: 645, 640, 635, 630, 625, 620, 615

Sample Interval No Sample Taken minimum maximum average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

HOLE NUMBER: MW-2046 (C3)

SHEET 2 OF 2

NORTH (Y): 1044158.17

EAST (X): 755046.76

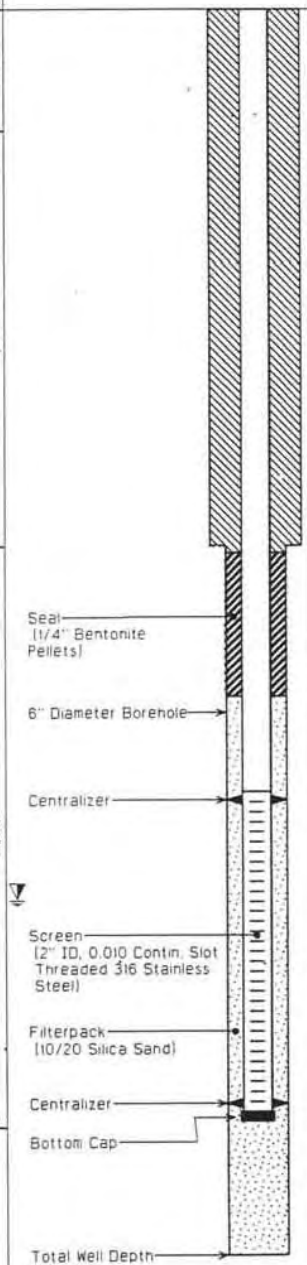
WSMLOG-C

WELL STATUS/COMMENTS: ACTIVE

LOCATION: Upgradient of Disposal Cell

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
				CL	slightly moist, very stiff (pp=3.5).	Qct
	SS-15	24/24"	16		37.5 – 38.6' SILTY CLAY, weak red (2.5YR 6/4) some fine sand, soft (pp=1.75).	
40	SS-16	11/11"	87+	GC Chrt	38.6 – 41.5' CLAYEY GRAVEL, dry, relict angular chert fragments, matrix is predominantly silt and fine sand.	pPr
	SS-17	24/24"	70		41.5 – 46.5' CLAYEY GRAVEL, angular white chert fragments to 2", hard to very hard, interstitial clay is dark red (2.5YR 4/8), moist.	
45	SS-18	24/24"	51		46.5 – 51.8' CLAYEY GRAVEL, as above but strong brown (7.5YR 5/8), increased weathering of chert gravel (coarse sand size to 1").	
	SS-19	22/24"	19			
50	SS-20	20/24"	22			
	SS-21	4/4"	>50		Top of Bedrock @ 51.8 ft.	
	RUN-1	60/72"	52	lms. chrt	51.8 – 65.6' ARGILLACEOUS LIMESTONE (65%) AND CHERT (35%), brecciated and interbedded together. Limestone is grayish orange (10YR 7/4), very fine-grained, thin to very thin-bedded, moderately hard, moderately weathered with occasional vugs, slight to moderate porosity, slightly fossiliferous, closely fractured with FeOx staining. Chert is very light gray (N8), very hard, very fossiliferous. "Weathered Burlington-Keokuk Limestone"	Mdkw
55						
	RUN-2	53/60"	60		Increased vugginess below 58.5 feet.	
60					Kp = CONSTANT HEAD SINGLE PACKER PRESSURE TESTS 55.2 to 63.5 ft. K < test method quantitation limit 60.0 to 70.0 ft. k=4.9E-6 cm/sec	
	RUN-3	78/78"	59			
65					65.6 – 70.0' ARGILLACEOUS LIMESTONE AND CHERT, as above but with less chert (25%), color is grayish orange (10YR 7/4) increased porosity and softer rock with silt on fractures. Chert is brecciated in "shattered"-looking schards. "Weathered Burlington- Keokuk Limestone"	
70					Total cored depth 70.0 feet. Switched to 6" air rotary and reamed hole to 74.0'.	
					Note: Soil and rock color are indexed on the Muncell soil color chart. Split spoon sampler is 3" O.D., 2-1/2" I.D., therefore SPT results qualitative.	
75						

WELL DIAGRAM



ELEVATION feet: 610, 605, 600, 595, 590, 585, 580, 575

Sample Interval | No Sample Taken | minimum | maximum | average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSM.OG-C

HOLE NUMBER	MW-2047 (C4)
SHEET 1 OF 2	
NORTH (Y):	1044105.67
EAST (X):	754487.53
TOC ELEVATION	640.30
GROUND ELEVATION	637.48
STICKUP	2.82
HYDR CONDUCTIVITY (cm/sec)	K= 8.03x10^{-6} (Packer Test)

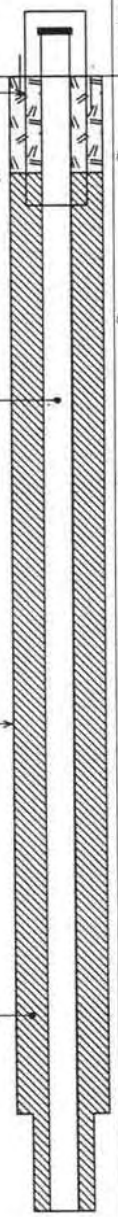
WELL STATUS/COMMENTS	ACTIVE
LOCATION	Upgradient of Disposal Cell
DRILLING CONTRACTOR	GEOTECHNOLOGY INC
DRILL RIG MAKE & MODEL	CME 750, HSA/NQWL CORE/SCHRAMM AIR ROT.
HOLE SIZE & METHOD	10 1/4" HSA to 32.0' then 6" Air
ANGLE FROM HORIZONTAL & BEARING	90
BOTTOM OF HOLE (TD)	60.2
DRILL FLUIDS & ADDITIVES	WATER/AIR
CASING TYPE, DEPTH, SIZE	2" 316 STAINLESS STEEL
BEDROCK	44.5
DATE START	12-3-1996
DATE FINISH	12-10-1996
WATER LEVELS & DATES	

DEPTH (ft.) FROM GROUND ELEV. 10.

LITHOLOGY BY PAUL PATCHIN

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or ROD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
				Fill	0 - 4.5' FILL, 3/4" crushed rock to 1 ft, 3" clean rock to 3.5', then silty clay fill with limestone gravel to 4.5'.	Fill
5	SS-1	17/24"	31	ML	SILT, light gray (2.5Y7/2), nonplastic, dry, hard (pp=4.5+) minor FeOx mottling.	Qpl
	SS-2	14/24"	24	ML	CLAYEY SILT, mottled yellowish brown (10YR5/6) and light brownish gray (2.5Y 6/2), low plasticity, slightly moist, hard (pp=4.5+), minor FeOx and MnOx.	Qrx
10	SS-3	16/24"	18	CL	SILTY CLAY, mottled light brownish gray (2.5Y 6/2) and yellowish brown (10YR 5/6), low to medium plasticity, slightly moist, very stiff to hard (pp=4.5), minor silt as lenses in clay and minor fine chert gravel, FeOx nodules and MnOx streaking (fracture fill).	Qlv
	SS-4	20/24"	22	CL	SANDY CLAY with GRAVEL, mottled yellowish brown (10YR 5/8) (primary) and minor light brownish gray (10YR 6/2), slightly moist, sandy with approx. 10% gravel (very fine to 2"), mostly angular chert with minor subrounded igneous, abundant FeOx and MnOx stain, very stiff to hard (pp= 3.75-4.5+) with near-vertical fractures exhibiting leaching (gray color) and MnOx staining.	Qct
15	SS-5	20/24"	16			
	SS-6	21/24"	22	CL CH	SILTY CLAY, distinctive yellowish-red (5YR 4/6) moderate to high plasticity, slightly moist, no gravel or sand, soapy, very hard (pp=4.5+) stiff (pp=3.0).	
20	SS-7	23/24"	65	GC	Harder drilling @ 19.0 ft.	
	SS-8	7/7"	>50		CLAYEY GRAVEL, approx. 75 - 80% angular chert gravel with plastic interstitial clay and minor sand pockets. Gravel is exclusively chert until approx. 28.0' then includes very weathered (to powder) limestone. Interstitial clay is dusky red (2.5YR 4/4), high plasticity, slightly moist, with pockets of distinctive yellow fine sand, abundant FeOx and minor MnOx stain on gravel, very dense.	pPr
	SS-9	11/11"	>50			
25					Very hard drilling @ 27 ft.	
	SS-10	22/24"	43		CLAYEY GRAVEL, as above, with weathered limestone pieces and powder.	
30					Sampler refusal @31.9 ft. Weathered limestone in sampler. Auger refusal @ 32.0 ft. Started NQ wireline coring.	
	RUN-1	37/102"	8	chrt	32.0 - 35.6' CHERT, brecciated with minor argillaceous limestone and as nodules to .5' (minor) chert is light gray (N7) to minor mottled medium gray (N5), slightly weathered, very hard, very fossiliferous, closely fractured. Minor limestone is grayish- orange (10YR 7/4), argillaceous, moderately hard, brecciated, moderately	
35						

WELL DIAGRAM



ELEVATION feet: 635, 630, 625, 620, 615, 610, 605

Sample Interval No Sample Taken minimum maximum average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

HOLE NUMBER: MW-2047 (C4)

SHEET 2 OF 2

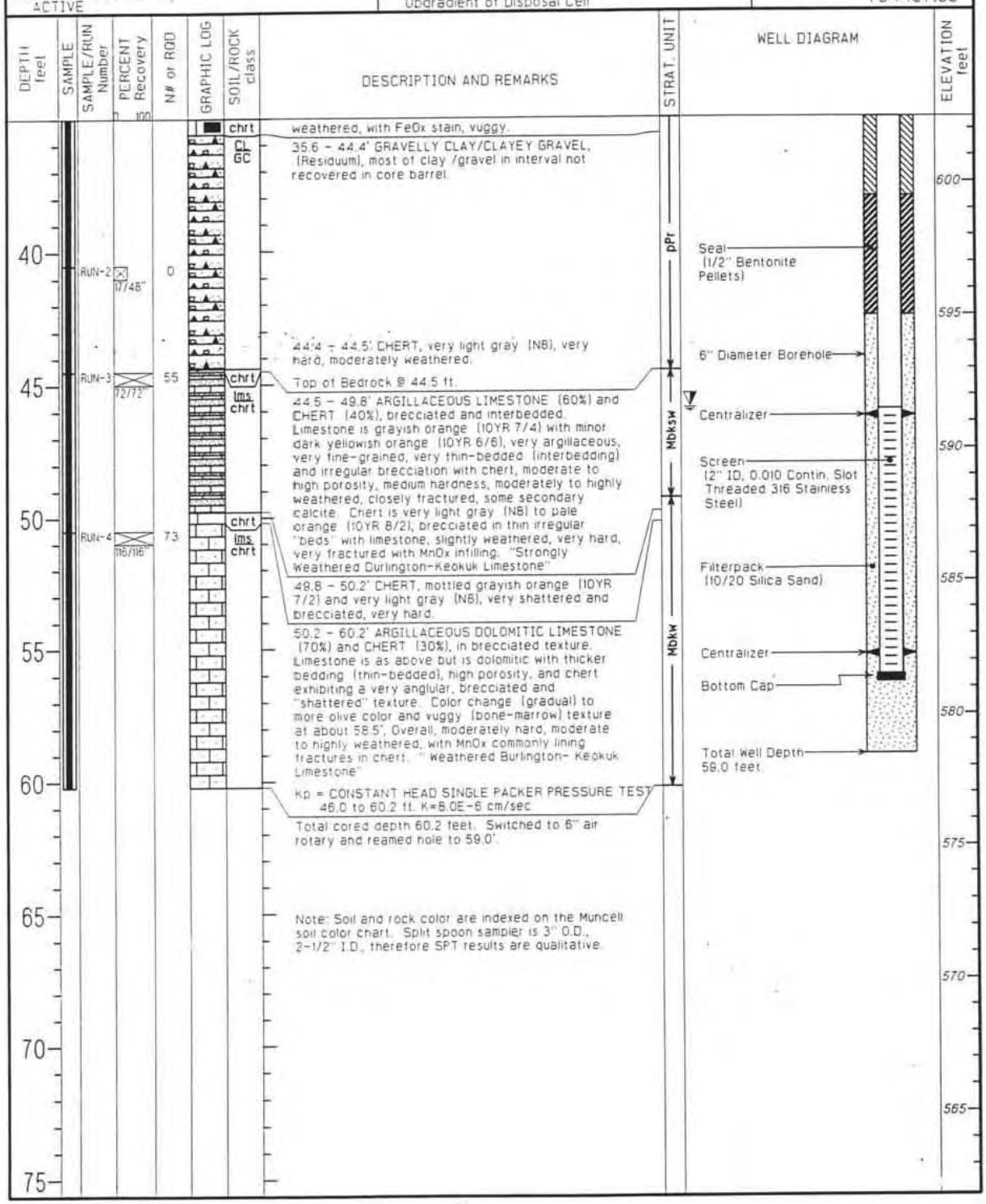
NORTH (Y): 1044105.67

EAST (X): 754487.53

WSMLOG-C

WELL STATUS/COMMENTS: ACTIVE

LOCATION: Upgradient of Disposal Cell



Sample Interval No Sample Taken minimum maximum average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

MSMLOG-C

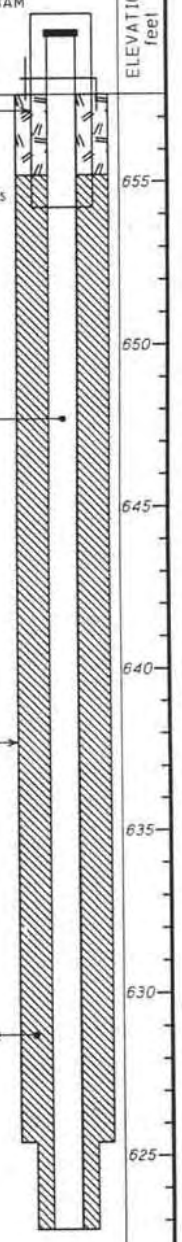
HOLE NUMBER	MW-2048 (C1)
SHEET 1 OF 2	
NORTH (Y):	1042435.46
EAST (X):	755000.96
TOC ELEVATION	659.85
GROUND ELEVATION	657.72
STICKUP	2.13
HYDR CONDUCTIVITY (cm/sec)	K= 7.91x10^{-4} (Packer Test)

WELL STATUS/COMMENTS	ACTIVE
LOCATION	Upgradient of Disposal Cell
DRILLING CONTRACTOR	GEOTECHNOLOGY INC.
DRILL RIG MAKE & MODEL	CME 750, HSA/NQWL CORE/SCHRAMM AIR ROT.
HOLE SIZE & METHOD	10 1/4" HSA to 32.3' then 6" Air
ANGLE FROM HORIZONTAL & BEARING	90
BOTTOM OF HOLE (TD) (DEPTH (FT.) FROM GROUND ELEV. 10)	60.0
DRILL FLUIDS & ADDITIVES	WATER/AIR
CASING TYPE, DEPTH, SIZE	2" 316 STAINLESS STEEL
BEDROCK	32.3
DATE START	12-12-1996
DATE FINISH	12-19-1996
WATER LEVELS & DATES	

LITHOLOGY BY PAUL PATCHIN

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
				Fill	FILL, silty clay, dark brown, damp.	Fill
5	SS-1	15/24"	8	CL	SILTY CLAY, light brownish gray (2.5Y 6/2) with minor yellowish brown (10Y 5/6) mottling, medium plasticity, slightly moist, very stiff (pp=3.25), abundant FeOx nodules (2mm) and MnOx streaks.	Qlv
	SS-2	14/24"	19	CH	CLAY, as above but with increased plasticity (high) and yellowish brown mottling, very stiff (pp=3.0), decrease in silt content and no gravel.	
10	SS-3	21/24"	16		CLAY, as above, very stiff (pp=3.0).	
	SS-4	23/24"	13		CLAY, as above, very stiff (pp=2.75), minor coarse sand-size chert at bottom.	
15	SS-5	22/24"	12	CL CH	SILTY CLAY, as above, increase in yellowish brown color, MnOx streaking, and coarse sand and fine gravel content at bottom of sample, very stiff (pp=3.0).	
	SS-6	23/24"	19	CL	SANDY CLAY with GRAVEL, yellowish brown (10YR 5/8) with minor light brownish gray (2.5Y 6/2) mottling, medium plasticity, slightly moist, hard (pp=4.5+), contains approx. 10% angular weathered chert gravel (coarse sand size to 1"), abundant MnOx streaks and FeOx stain.	Qct
20	SS-7	24/24"	16		SANDY CLAY with GRAVEL, as above, increased moisture (moist), very stiff (pp=2.75), with minor softer zones.	
	SS-8	24/24"	15	CL CH	CLAY, mottled strong brown (7.5YR 5/6) and dark red (2.5YR 4/6), medium to high plasticity, moist, no sand, trace v. fine gravel, abundant MnOx, streaks.	
25	SS-9	24/24"	18	CL CH	CLAY with GRAVEL, strong brown (7.5YR 5/6) with minor light gray, medium to high plasticity, slightly moist, very stiff (pp=3.5+), contains no sand and approx. 10-15% very fine to 1.5" gravel (chert and igneous), abundant MnOx streaks (increasing with depth), last 5' very gravelly with very abundant MnOx and FeOx nodules.	
	SS-10	19/24"	30	CL	GRAVELLY CLAY, strong brown (7.5 YR 5/6), high plasticity, approx. 40% angular chert gravel and minor limestone gravel, clay is moist with FeOx nodules and MnOx streaks and conspicuous calcareous sand pocket (decomposed rock?) at 26.5-27.0'.	
30	SS-11	9/14"	+91			pPr
	SS-12	11/18"	24	CL GC	GRAVELLY CLAY, as above but siltier and sandier, contains decomposed limestone, chert, hard, damp.	
	RUN-1	36/78"	9	lms. chrt	GRAVELLY CLAY/CLAYEY GRAVEL, as above but increased gravel (approx. 50%), hard, damp.	
					Top of Bedrock @ 32.3 ft.	Mdksm
35					32.3 - 41.8' ARGILLACOUS LIMESTONE AND CHERT, interbedded and brecciated. Approximately 70% limestone which is grayish orange (10YR 7/4), fine-grained, thin-bedded, slightly to highly	

WELL DIAGRAM



ELEVATION feet: 655, 650, 645, 640, 635, 630, 625

Sample Interval | No Sample Taken | minimum | maximum | average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

HOLE NUMBER: MW-2048 (C1)

SHEET 2 OF 2

WSMLOG-C

NORTH (Y): 1042435.46

EAST (X): 755000.96

WELL STATUS/COMMENTS: ACTIVE

LOCATION: Upgradient of Disposal Cell

DEPTH (feet)	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	WELL DIAGRAM	ELEVATION feet
40		RUN-2	18/34"	0		lms chrt	weathered, moderately hard to hard, with weathered pyrite crystals in matrix and locally heavy FeOx staining and vugginess. Closely to very closely fractured with minor clay, stylolites, and fossils. Chert is brecciated and interbedded with limestone and in beds up to 8". Color varies from white (N9) to grayish orange (10YR 7/4) to light bluish gray (5B 7/1), generally very hard, cryptocrystalline, fossiliferous with sealed fractures and MnOx infilling. Entire interval has numerous small void zones (bit drops) with a void from 40.5–41.2' showing very weathered residual chert gravel and clay. Overall, slight to moderate porosity. "Strongly weathered Burlington–Keokuk Limestone"		6" Diameter Borehole	620
		RUN-3	60/64"	49		GC chrt	41.8 – 43.0' CHERT GRAVEL, (void fill) with minor clay. Chert is very weathered and vuggy providing a breccia appearance. Chert, white to bluish to pinkish.		Seal (1/4" Bentonite Pellets)	615
45						CL chrt				
						lms chrt	43.0 – 44.5 SILTY CLAY with GRAVEL, brown (10YR 5/3), void fill.			
		RUN-4	12/24"	20			44.5 – 59.3 ARGILLACEOUS LIMESTONE and CHERT, as above. Limestone exhibits stronger iron oxide staining (color to dark yellowish orange 10YR 6/6), moderate to high porosity, abundant solution features (vugs) pinpoint to 1/2", numerous small voids (bit drops) to approx. 51.5. Less vugs below 53.5. Minor intervals of medium crystalline limestone. Some secondary calcite in matrix. Chert is brecciated, bedded (to 5'), and nodular. "Strongly Weathered Burlington–Keokuk Limestone"	Mdksw	Centralizer	610
50		RUN-5	54/60"	54					Screen (2" ID, 0.010 Contin. Slot Threaded 316 Stainless Steel)	605
55		RUN-6	60/60"	66			Kp = CONSTANT HEAD SINGLE PACKER PRESSURE TESTS 35.5 to 47.3 ft. K=7.8E-4 cm/sec 48.4 to 59.3 ft. K=6.8E-4 cm/sec		Filter pack (10/20 Silica Sand)	
									Centralizer	600
									Bottom Cap	
60							Total cored depth 59.3 feet. Switched to 6" air rotary and reamed hole to 60.0.		Total Well Depth 60.0 feet	595
65							Note: Split spoon sampler is 3" O.D., 2-1/2" I.D., therefore SPT results are qualitative. Soil and rock colors are indexed on the Muncell soil color chart.			590
70										585
75										

Sample Interval ☐ No Sample Taken minimum maximum average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSMLOG-C

HOLE NUMBER	MW-2048 (a)
SHEET 1 OF 2	
NORTH (Y):	
EAST (X):	
TOC ELEVATION	
GROUND ELEVATION	
STICKUP	
HYDR CONDUCTIVITY (cm/sec)	K= 7.91x10^{-4} (Packer Test)

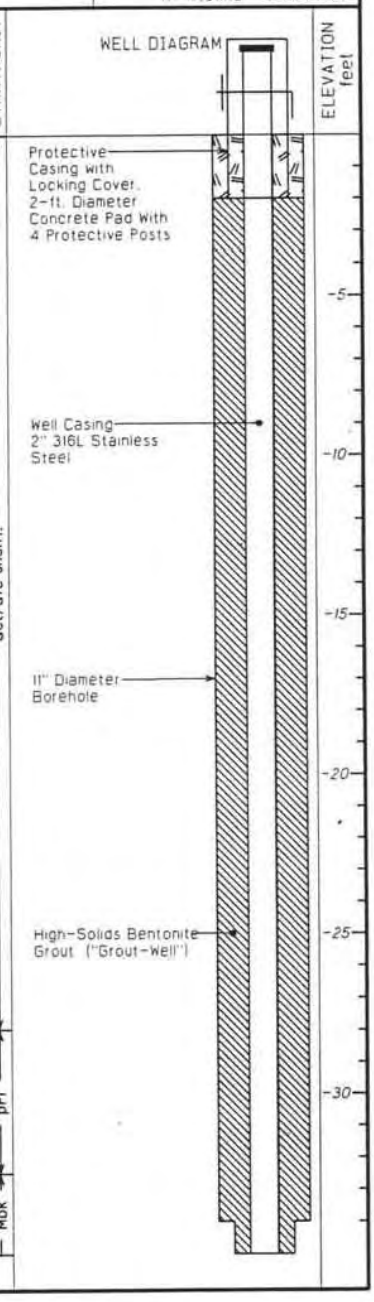
WELL STATUS/COMMENTS	ACTIVE
LOCATION	SO. OF DISPOSAL CELL; PERIMETER WELL
DRILLING CONTRACTOR	LAYNE WESTERN Inc.
DRILL RIG MAKE & MODEL	CME-750 HSA/NQWL; I-R TH-60 AIR ROTARY
HOLE SIZE & METHOD	9" HSA-34; NQ-62; 6" AIR-63
ANGLE FROM HORIZONTAL & BEARING	Vertical
BOTTOM OF HOLE (TD)	63.0, 62.0 Mon. Well
DRILL FLUIDS & ADDITIVES	Water core; Air ream
CASING TYPE, DEPTH, SIZE	2" 316 SS Mon. Well
BEDROCK	32.5
DATE START	11-9-01
DATE FINISH	12-5-01, Mon. Well
WATER LEVELS & DATES	

DEPTH (FT.) FROM GROUND ELEV. TO

LITHOLOGY BY ALAN BENFER

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery (0–100)	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
							Soil not sampled or logged from the surface to 28.0-ft.	Qct/Qtc undift.
5								
10								
15								
20								
25								
30		SPT-1		9		CH	CLAY, high plasticity, ~40% angular chert and weathered limestone gravel, mostly yellow brown, moist, firm CH. Residuum.	pPr
		SPT-2		14			CLAY, gravelly to clayey gravel, high plasticity clay, reddish brown, moist, hard, CH-GC. Residuum.	
		SPT-3		76+				
35		NQ-1	31/66"	15		CHRT LMS	LIMESTONE, weathered, white to yellowish brown, dry, hard. Auger refusal at 34.0-ft. Continue with NQ core. NQ-1, 34.0'– 39.5'. Poor recovery, loss zones unknown. Lost circulation at 34.5' permanently.	Mbk

WELL DIAGRAM



ELEVATION feet

Sample Interval No Sample Taken minimum maximum average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

HOLE NUMBER **MW-2048 (a)**

SHEET 2 OF 2

NORTH (Y):

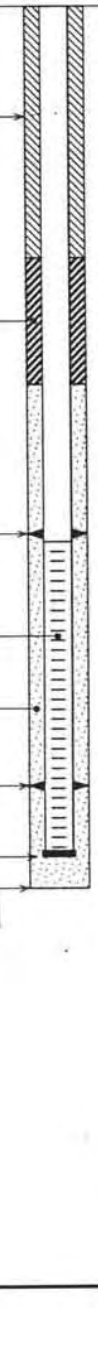
EAST (X):

WELL STATUS/COMMENTS: ACTIVE

LOCATION: SO. OF DISPOSAL CELL; PERIMETER WELL

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
						CHRT LMS	LIMESTONE, slightly weathered, crystalline-grained, locally argillaceous, with specks and thin streaks of MnOx, fossiliferous, light gray to light yellowish brown, vugs up to 1" near bottom of core, some interbedded light gray chert. Rock is relatively fresh, hard, with minimal oxidation. Two clay seams near core bottom; one is 3-1/2" thick with angular chert fragments, lower one is 6" of massive clay with some fine gravel, high plasticity, yellow brown, minor MnOx. Burlington-Keokuk Limestone.	MDk
40		NQ-2	28/40"	62			@ 39.5'- 42.8'. LIMESTONE as above, becoming oxidized at ~39.7', some styolites, ~30% scattered chert, appears brecciated, fossiliferous, mostly light gray. Up to 4+ fractures per foot, rough, open, oxidized.	
		NQ-3	52/70"	13			@ 41.5'. Scattered oxidized sulfides, increased limestone weathering at 42.7'. Bit dropped at ~41.8' to ~42.5'. Weathered Burlington- Keokuk Limestone.	MDkW
45							@ 43.5'- 44.1'. CHERT, hard, white, light and blue gray.	
							@44.6'- 45.0'. Silty clay with limestone fragments.	
		NQ-4	58/67"	54			@ 45.4'- 48.6'. LIMESTONE, moderately weathered, moderate solutioning with vugs up to 1", generally coarse-grained, some argillaceous, FeOx staining with thin streaks of MnOx, mostly light yellow brown, with ~ 30% scattered interbedded chert, generally light gray.	
50							@ 48.2'- 52.0'. CHERT, hard, with thin streaks of MnOx, fracture surfaces oxidized, white to pale yellow, with up to ~25% thinly interbedded limestone, strongly weathered at 49.2-ft., soft, argillaceous, dark yellowish orange. At 50.1 to 52.0-ft., limestone is very vuggy along bedding; clayey. One to 4+ fractures per foot, rough; broken. Strongly Weathered Burlington-Keokuk Limestone.	MDkSW
		NQ-5	61/94"	77			@ 52.0'- 53.8'. CHERT, hard, bluish gray with ~40% limestone, strongly weathered, argillaceous, generally interbedded, a few vugs, yellowish orange.	
55							@ ~53.7'. Cut fast. Very vuggy at 53.8-ft.	
60							CHERT AND LIMESTONE as above, ~40% limestone, strongly weathered, locally can be scratched with fingernail, a few vugs. Chert is bluish gray, locally fossiliferous. One to 3+ fractures per foot, rough, open, some broken.	
							@ 60.5'. 1/2" patch of oxidized pyrite.	
							Total cored depth 62.0', 11-15-01. Hole reamed to 6" diameter to 63.0' and a 2" monitoring well was constructed.	
65							Packer testing was not performed.	
70								
75								

WELL DIAGRAM



ELEVATION feet: 40, 45, 50, 55, 60, 65, 70

Sample Interval | No Sample Taken | minimum | maximum | average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

HOLE NUMBER	MW-2051
SHEET 1 OF 2	
NORTH (Y):	1042175.97
EAST (X):	753129.19
TOC ELEVATION	639.77
GROUND ELEVATION	636.43
STICKUP	3.34
HYDR CONDUCTIVITY (cm/sec)	K= 8.7x10^{-3} (Packer Test)

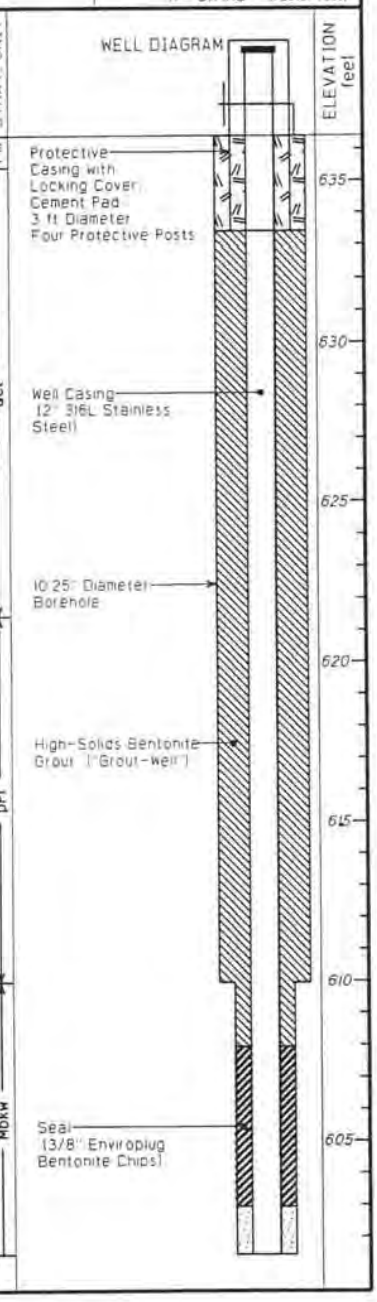
WELL STATUS/COMMENTS	ACTIVE
LOCATION	NORTHEAST EDGE OF DISPOSAL CELL
DRILLING CONTRACTOR	LAYNE WESTERN Inc.
DRILL RIG MAKE & MODEL	CME-750ATV HSA/NQWL CORE/SCHRAMM AIR ROT
HOLE SIZE & METHOD	7 1/4" Auger to 26.5' then 6" Air
ANGLE FROM HORIZONTAL & BEARING	vertical
BOTTOM OF HOLE (TD)	49.0
DRILL FLUIDS & ADDITIVES	WATER/AIR
CASING TYPE, DEPTH, SIZE	2" 316L Stainless Steel
BEDROCK	26.5
DATE START	5-2-2000
DATE FINISH	5-30-2000
WATER LEVELS & DATES	

DEPTH (FT.) FROM GROUND ELEV TO

LITHOLOGY BY ALAN BENFER/PAUL PATCHIN

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
					fill	FILL, (silty clay)	Fill
					CH	CLAY, high plasticity, mottled yellow brown and light gray, approx. 10% fine white sand, moderate black MnOx, firm, moist, CH	
	SPT-2		5		CH	CLAY, high plasticity with some sand and gravel (angular), MnOx, mottled yellow brown and light gray and black, moist, hard, CH	
	SPT-3		12			Lenses of clean fine sand between 5 and 6 ft	
5							
	SPT-4		18			CLAY, as above, approx. 10% fine sand and some fine gravel, hard, MnOx on vertical fracture surfaces, CH	
	SPT-5		12				Qct
10	SPT-6		14				
	SPT-7		23		CL	SILTY CLAY, low plasticity, with weathered FeOx nodules, light gray, moist, hard, CL	
	SPT-8		14		CH	CLAY, high plasticity, FeOx nodules, trace fine gravel, mottled light brown and light gray, moist, hard, CH	
15					CH	CLAY, as above but more reddish brown, high plasticity, with some angular chert gravel, CH	
	SPT-9		10				
	SPT-10		8				
20	SPT-11		7				pPr
	SPT-12		15				
	SPT-13		19				
25						Sampler refusal at 25.9 ft. Augered to top of rock at 26.5 ft. (auger refusal)	
	RUN-1	38/60"	8		chrt lms	26.5' – 35.3' CHERT AND ARGILLACEOUS LIMESTONE (approx 65%/35%). Chert is very light gray (N8) to minor medium light gray (N5), brecciated to very thinly bedded with limestone, very hard, slightly to moderately weathered, fossiliferous, with MnOx and FeOx staining (MnOx on microfractures in chert). Limestone is grayish orange (10YR7/4), mod. weathered, mod. hard, with vugs pinpoint to 3 mm, fine grained, very thinly bedded (interbedded with chert), slightly fossiliferous with FeOx staining (particularly in possible void zones at 28.0' – 28.5' and 34.0'–34.7').	
30	RUN-2	47/60"	46			Lost circulation at 29.0'	Mdkw
35						Possible voids from 34.0 – 34.7'	

WELL DIAGRAM



Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

HOLE NUMBER: MW-2051

SHEET 2 OF 2

MSMLOG-C

NORTH (Y): 1042175.97

EAST (X): 753129.19

WELL STATUS/COMMENTS: ACTIVE

LOCATION: NORTHEAST EDGE OF DISPOSAL CELL

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	WELL DIAGRAM	ELEVATION feet
		RUN-3	43/60"	48		chrt lms/ lms chrt	35.3' - 43.7' ARGILLACEOUS LIMESTONE (70%) and CHERT (30%) as above but increased limestone. Inreased vugs (to 1") parallel with bedding, moderately weathered. Probable voids @34.0' - 34.7' and 36.5' - 38.0' with heavy FeOx staining and residual chert gravel. Semi-fresh pyrite specks @33.5'. MnOx specks @39.5' with increased FeOx and weathering. Yellowish coloring (clay) at 40.3' - 41.5' with hematite blebs.	MDkW	---Static Water Level @ 36.9 ft.	600
40									Screen 2" (10 Slot) 316L SS Continuous Wrap	
		RUN-4	46/90"	37			41.5 - 43.2' Core loss possibly caused by caved material grinding core.		Filterpack (10/20 Silica Sand)	595
45						lms chrt	43.7' - 49.0' ARGILLACEOUS LIMESTONE, as above but color to more gray and porosity increase with CHERT (<30%) brecciated but also as large 4" irregular nodules, very fossiliferous, occasional calcite-rich (as medium grained crystals), bands to 1.5", occasional vugs, slightly weathered, abundant MnOx specks.		Centralizer Bottom Cap	590
50							Total cored depth 49.0'. Reamed hole to 6" to 47.2' and installed 2" monitoring well. Note: Color is from the GSA rock color chart.		Total Well Depth 47.2 feet. 3" Core hole to 49.0 feet.	585
							CONSTANT HEAD SINGLE PACKER TEST RESULTS: 30.5 - 41.5 ft. K=8.7E-3 cm/sec 36.1 - 49.0 ft. K=7.2E-3 cm/sec			
55										580
60										575
65										570
70										565
75										

Sample Interval No Sample Taken minimum maximum average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

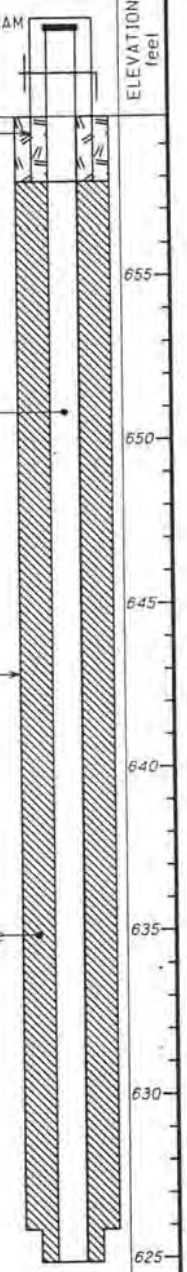
HOLE NUMBER	MW-2055
SHEET 1 OF 2	
NORTH (Y):	1042419.92
EAST (X):	755000.58
TOC ELEVATION	662.62
GROUND ELEVATION	659.86
STICKUP	2.76
HYDR CONDUCTIVITY (cm/sec)	K= 1.5x10^{-3} (Packer Test)

WELL STATUS/COMMENTS	ACTIVE
LOCATION	SO. OF DISPOSAL CELL, PERIMETER WELL
DRILLING CONTRACTOR	LAYNE WESTERN Inc.
DRILL RIG MAKE & MODEL	CME-750 HSA/NQWL; I-R TH-60 AIR ROTARY
HOLE SIZE & METHOD	9" HSA-34, NQ-62; 6" AIR-63
ANGLE FROM HORIZONTAL & BEARING	Vertical
BOTTOM OF HOLE (TD) (DEPTH (FT.) FROM GROUND ELEV. TO)	63.0
DRILL FLUIDS & ADDITIVES	Water core; Air ream
CASING TYPE, DEPTH, SIZE	2" 316 SS Mon. Well
BEDROCK	32.5
DATE START	11-9-01
DATE FINISH	12-5-01, Mon. Well
WATER LEVELS & DATES	

LITHOLOGY BY ALAN BENFER

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
						Soil not sampled or logged from the surface to 28.0-ft.	Qct/Qfc undiff.
30	SPT-1		9		CH	CLAY, high plasticity, ~40% angular chert and weathered limestone gravel, mostly yellow brown, moist, firm CH. Residuum	pPr
	SPT-2		14			CLAY, gravelly to clayey gravel, high plasticity clay, reddish brown, moist, hard, CH-GC. Residuum.	
	SPT-3		76+		CHRT LMS	LIMESTONE, weathered, white to yellowish brown, dry, hard.	Mbk
35	NQ-1	31/66"	15			Auger refusal at 34.0-ft. Continue with NQ core. NQ-1, 34.0'- 39.5'. Poor recovery, loss zones unknown. Lost circulation at 34.5' permanently.	

WELL DIAGRAM



ELEVATION feet

Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

HOLE NUMBER: MW-2055

SHEET 2 OF 2

NORTH (Y): 1042419.92

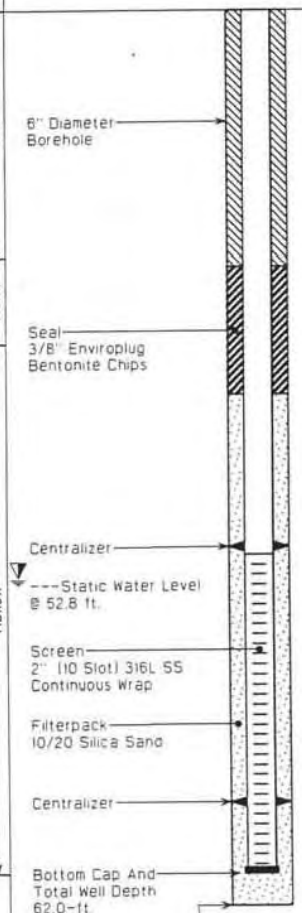
EAST (X): 755000.58

WELL STATUS/COMMENTS: ACTIVE

LOCATION: SO. OF DISPOSAL CELL: PERIMETER WELL

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
					CHRT LMS	LIMESTONE, slightly weathered, crystalline-grained, locally argillaceous, with specks and thin streaks of MnOx, fossiliferous, light gray to light yellowish brown, vugs up to 1" near bottom of core, some interbedded light gray chert. Rock is relatively fresh, hard, with minimal oxidation. Two clay seams near core bottom; one is 3-1/2" thick with angular chert fragments, lower one is 6" of massive clay with some fine gravel, high plasticity, yellow brown, minor MnOx. Burlington-Keokuk Limestone.	Mdk
40	NQ-2	28/40"	62			@ 39.5'- 42.8'. LIMESTONE as above, becoming oxidized at ~39.7', some styolites, ~30% scattered chert, appears brecciated, fossiliferous, mostly light gray. Up to 4+ fractures per foot, rough, open, oxidized.	
	NQ-3	52/70"	13			@ 41.5'. Scattered oxidized sulfides, increased limestone weathering at 42.7'. Bit dropped at ~41.8' to ~42.5'. Weathered Burlington- Keokuk Limestone.	Mdkw
45						@ 43.5'- 44.1' CHERT, hard, white, light and blue gray.	
						@44.6'- 45.0'. Silty clay with limestone fragments.	
	NQ-4	58/67"	54			@ 45.4'- 46.6'. LIMESTONE, moderately weathered, moderate solutioning with vugs up to 1", generally coarse-grained, some argillaceous, FeOx staining with thin streaks of MnOx, mostly light yellow brown, with ~ 30% scattered interbedded chert, generally light gray.	
50						@ 48.2'- 52.0'. CHERT, hard, with thin streaks of MnOx, fracture surfaces oxidized, white to pale yellow, with up to ~25% thinly interbedded limestone, strongly weathered at 49.2-ft., soft, argillaceous, dark yellowish orange. At 50.1 to 52.0-ft., limestone is very vuggy along bedding; clayey. One to 4+ fractures per foot, rough; broken. Strongly weathered Burlington-Keokuk Limestone.	Mdksw
	NQ-5	91/94"	77			@ 52.0'- 53.8'. CHERT, hard, bluish gray with ~40% limestone, strongly weathered, argillaceous, generally interbedded, a few vugs, yellowish orange.	
55						@ ~53.7'. Cut fast. Very vuggy at 53.6-ft.	
60						CHERT AND LIMESTONE as above, ~40% limestone, strongly weathered, locally can be scratched with fingernail, a few vugs. Chert is bluish gray, locally fossiliferous. One to 3+ fractures per foot, rough, open, some broken.	
						@ 60.5'. 1/2" patch of oxidized pyrite.	
						Total cored depth 62.0', 11-15-01. Hole reamed to 6" diameter to 63.0' and a 2" monitoring well was constructed.	
65						Packer testing was not performed.	
70							
75							

WELL DIAGRAM



ELEVATION feet: 620, 615, 610, 605, 600, 595, 590, 585

Sample Interval | No Sample Taken | minimum | maximum | average

Attachment B

Statistical Evaluation of Detection Monitoring Data (1998 to 2001)

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B.1 Evaluation Summary – 1998 through 2001

Under the original version of this plan, the elements of the detection monitoring program included:

- Collecting four replicate samples at each location on a semiannual basis,
- Measuring groundwater elevation at each well location, as well as flow rate for the spring, on a quarterly schedule and immediately prior to each semiannual sampling event,
- Analyzing for the entire list of constituents presented in Table K–3 of the main text of this report, and noting any unusual colors, odors, or turbidity,
- Evaluating analytical data in comparison with background levels to identify statistically significant increases that may indicate an impact from the disposal cell, and
- For parameters that appear to exceed background levels: reviewing analytical results for potential errors, evaluating cell leachate volume data to confirm liner integrity, and resampling individual locations for the suspect parameters.

The detection monitoring data obtained from 1998 to 2001 were evaluated in accordance with the EPA guidance on *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (EPA 1989). This document provides guidance on conducting various types of statistical analyses under the RCRA groundwater monitoring regulations (40 CFR 264, Subpart F). The foundational assumption of each statistical method is that the waste management unit is situated on an uncontaminated aquifer and that the only source of increases in contaminant concentrations in the groundwater is leakage from the waste management unit. The guidance cautions against the use of the prescribed methods in evaluating data from wells that have shown evidence of preexisting contamination or where a high degree of spatial variation exists between the background wells and compliance wells, both of which are true for the Weldon Spring Site.

In the absence of regulatory guidance on more appropriate statistical methods for use at a site with preexisting groundwater contamination, detection monitoring data have been evaluated by several different methods, as discussed below.

B.1.1 1998 Results

Detection monitoring data from 1998 were evaluated by means of both parametric and nonparametric analysis of variances (ANOVA) analyses. Results of these analyses, which are presented in the *Weldon Spring Site Environmental Report for Calendar Year 1998* (MK-F and JEG 1999), are based on a comparison of data from the compliance wells, MW-2032 and MW-2045 through MW-2047, with data from the upgradient (i.e., “background”) well, MW-2048. These analyses resulted in a large number of statistical failures which, if they had been based on data from a previously uncontaminated aquifer, would have provided evidence of groundwater impact due to the disposal cell.

Many of the test failures were determined to be attributable to preexisting concentrations of certain parameters being higher in the compliance wells than in the upgradient well prior to waste placement (March 1998). However, after disregarding the parameters in which this was the case, the following parameters still failed at least one of the statistical tests:

- MW-2032 Chromium, silver, thallium

- MW-2045 Calcium, radium-228
- MW-2046 Silver, vanadium, TOX
- MW-2047 Vanadium, zinc, 1,3,5-TNB

The monitoring data for parameters that failed the interwell comparisons were further evaluated by means of ANOVA procedures based on intrawell comparisons with baseline data from the same locations. This testing resulted in the following statistical failures:

- MW-2045 Calcium
- MW-2046 Vanadium
- MW-2047 Vanadium, 1,3,5-TNB

All of the above statistical failures were attributed to natural fluctuations in the existing groundwater quality. It was not reasonable to consider these test failures to be indicators of cell leakage because waste placement, and subsequent leachate production, began only a few months before the first 1998 detection monitoring event, and contaminant fate and transport analyses had predicted a 53-year interval before contaminants leaking from the cell would be detected in the monitoring wells (Tomasko et al. 1996). In addition, the use of the upgradient well, MW-2048, as a "background" well was determined to be inappropriate since several constituents were already higher in this well than in any of the compliance wells before waste placement began.

B.1.2 1999 Results

The detection monitoring program was modified in 1999, after review of the previous 2 years of groundwater and leachate data. Several parameters were eliminated from the monitoring list. Also, the monitoring frequency was reduced to a single sample obtained semiannually from each location instead of the four replicates previously collected.

In an effort to derive a more reliable means of evaluating data, an intrawell tolerance interval approach was used to evaluate the 1999 data instead of the ANOVA procedures used the previous year. A intrawell tolerance limit approach was considered the preferred method of evaluating data because this approach resulted in fewer false positive results that any of the other types of statistical analyses performed to date. Also, due to the heterogeneous nature of the aquifer it can be expected that each well would act independently because it monitors a discrete portion of the aquifer. By this method, each monitoring location (including the upgradient well) was considered to be a point of compliance, and "background" conditions were described by the contaminant concentrations measured at each location during baseline monitoring. Tolerance limits were calculated for each parameter at each monitoring location according to the methodology in S*tatistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (EPA 1989).

Using the baseline data collected prior to waste placement, upper tolerance limits were established based on the assumptions of a normal data distribution and a 95% level of confidence. Data from the two semiannual monitoring events were compared to the baseline values, and any exceedances were investigated through the data verification process, sample reanalysis, and/or resampling. All confirmed exceedances were reported as statistically significant increases. The *Weldon Spring Site Environmental Report for Calendar Year 1999*

(MK-F and JEG 2000b) summarizes the results of statistical analysis of the 1999 data, in which the following parameters exceeded baseline for at least one of the sampling events:

- MW-2032 Chemical oxygen demand (COD), chromium, nickel
- MW-2045 Arsenic, chromium, molybdenum, nickel
- MW-2046 Aluminum, barium, chromium, magnesium, nickel, COD
- MW-2047 COD
- MW-2048 Magnesium, sulfate

As in the previous 2 years, the above statistical failures were attributed to natural fluctuations in the existing groundwater quality. However, in accordance with the original version of this plan, a thorough study of the monitoring network was conducted in 2000 to confirm that the recurring baseline exceedances were not true indicators of cell leakage. This study was documented in the *Weldon Spring Site Cell Groundwater Monitoring Demonstration Report* (MK-F and JEG 2000a). It included an evaluation of historical site-wide groundwater quality, review of leachate flow rate and analytical data, analysis of groundwater elevation fluctuations, comparison of filtered and unfiltered samples for metals analysis, and review of cell well construction and performance information.

The demonstration report concluded that the baseline exceedances were not due to contaminant migration from the cell, but rather were the result of variations in previously existing groundwater contamination compounded by poor hydraulic performance of some of the wells. The following actions were recommended to alleviate the recurrence of similarly false positive results in future sampling events:

- Attempt to improve the flow rate and clarity of groundwater in MW-2045 by redeveloping it prior to the next sampling event,
- Install an additional compliance well in the vicinity of MW-2045 to provide supplemental monitoring on the northeast side of the disposal cell, and
- Recalculate the upper tolerance limit for the baseline values of each parameter at each well. The new limits should be based on the assumption that the four replicates obtained during each quarterly baseline event were not truly independent samples but represented a single event.

Results of the filtered metals analyses confirmed that most of the metals exceedances coincided with high turbidity and likely resulted from metals adhering to suspended clay particles in the groundwater. Although the filtering of groundwater samples for metals analyses is an acceptable sampling procedure, it was not listed as a recommendation in the demonstration report because baseline values were already established using unfiltered samples.

B.1.3 2000 Results

The recommendations from the demonstration report were implemented, and the 2000 data were evaluated using the tolerance interval approach with the recalculated tolerance limits. The *Weldon Spring Site Environmental Report for Calendar Year 2000* (MK-F and JEG 2000)

contains the results of this evaluation, in which the following parameters exceeded the new baseline tolerance limits during at least one of the semiannual sampling events:

- MW-2045 Chromium, molybdenum
- MW-2046 Molybdenum
- MW-2047 Chromium
- MW-2048 Chromium, magnesium, molybdenum, sulfate

B.1.4 2001 Results

Results of the 2001 detection sampling, which were evaluated in the same manner as in the previous year, are presented in the *Weldon Spring Site Environmental Report for Calendar Year 2001* (MK-F and JEG 2001). The following parameters were identified as exceeding baseline tolerance limits during at least one of the semiannual sampling events:

- MW-2045 Chromium, molybdenum, nickel
- MW-2046 Nickel, 2,4,6-TNT
- MW-2048 Sulfate

Two new wells were installed and one was abandoned under the disposal cell monitoring program in 2001. MW-2051 and MW-2055 were installed and MW-2048 was abandoned. Baseline monitoring data was collected from these wells in 2001 and 2002, and they were added to the detection monitoring program in 2002.

B.2 Evaluation Summary–2004

In response to a comment from the Missouri Department of Natural Resources regarding the distribution of the groundwater data from the disposal cell wells, a statistical evaluation of the data was performed. This analysis consisted of a determination of the data distribution and the appropriateness of the baseline tolerance limits for evaluation of the detection monitoring data.

B.2.1 Data Distribution

The data for the signature parameters at locations MW-2032, MW-2046, MW-2047, MW-2051, MW-2055, and SP-6301 were reexamined to determine whether the data is Normal or log-Normal. Testing for Normality or log-Normality were done by three different methods, as suggested as alternative tests in the EPA *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities* – Addendum to Interim Final Guidance (EPA 1992). These tests were:

- Probability Plot Correlation Coefficient
- Shaprio-Wilk Test of Normality (n<50) or Shaprio-Francia Test of Normality (n>50)
- Coefficient of Skewness

The tests were performed for both the non-transformed data and log-transformed data for each of the four signature parameters at each location. Each of the signature parameters at each of the locations passed at least one of the three tests for Normality and log-Normality. For example, at location MW-2051 the results were:

Analyte	Test Method					
	PPCC	CS	SW/SF	PPCC	CS	SW/SF
	Non-transformed Data			Log-transformed Data		
Barium	N		N	N	N	N
Iron		N			N	
Manganese	N	N	N	N	N	N
Uranium	N		N	N	N	N

PPCC – Probability Plot Correlation Coefficient
CS – Coefficient of Skewness
SW – Shapiro-Wilk Test of Normality (n<50)
SF – Shapiro-Francia Test of Normality (n>50)
N – Criteria for Normality met

The other locations show similar results. Although the data shows a slightly stronger evidence of log-Normality than Normality, the data can be treated as Normal because of the difficulty in calculating the mean and variance/standard deviation for a log-Normal distribution.

B.2.2 Review of Baseline Tolerance Limits

All the available data was used in calculating baseline tolerance limits. Data points that may have been compromised in some manner should be excluded. Compromised data may include data collected after any disturbance of the sub-surface such as by drilling, excavation, soil sampling, etc. that may dramatically increase the mobility/solubility of some contaminants.

To demonstrate that there is little difference in the method used to calculate the baseline tolerance limit, values for the signature parameters at three of these locations were calculated using six methods (Table B−1). All of the data for each location were used in the calculations.

The method outlined in the EPA Guidance (EPA 1989 and EPA 1992) is designed to treat below detection limit values differently from other methods of calculating a benchmark or baseline tolerance limit where below detection limit values are typically set at one-half the detection limit. However, the EPA Guidance method assumes that all the below detection limit values have the same detection limit, which is seldom the case and complicates the analysis.

The values in the table for MW-2051 show more variation than the other locations, particularly for iron, manganese, and uranium. This is likely due to the small data sets, where only five or six values for each of the signature parameters have been collected, and one or two extreme or outlier values can skew the calculated value.

Table B−1. Calculated Baseline Tolerance Limits for MW-2032, MW-2046, and MW-2051

Location	Method	Ba (µg/L)	Fe (µg/L)	Mn (µg/L)	U (pCi/L)
MW-2032	EPA Guidance – Normal Data[a]	338.8	889.9	45.2	5.60
	Tolerance Limit – Normal Data[b]	376.7	1125.2	56.6	6.42
	xbar+3s – Normal Data	389.9	117.8	56.3	6.73
	EPA Guidance – log-Normal Data[a,c]	334.2	926.7	45.7	6.96
	Tolerance Limit – log-Normal Data[b,c]	370.7	1178.1	57.4	9.35
	xbar+3s – log-Normal Data[c]	383.4	1170.3	57.0	9.89
MW-2046	EPA Guidance – Normal Data[a]	256.5	1238.6	147.7	1.67
	Tolerance Limit – Normal Data[b]	276.7	1577.5	186.9	1.76
	xbar+3s – Normal Data	287.0	1566.9	185.7	1.84
	EPA Guidance – log-Normal Data[a,c]	249.9	1156.0	151.2	1.48
	Tolerance Limit – log-Normal Data[b,c]	268.3	1464.2	191.9	1.92
	xbar+3s – log-Normal Data[c]	277.6	1454.6	190.7	2.02
MW-2051	EPA Guidance – Normal Data[a]	253.2	2200.8	205.5	3.68
	Tolerance Limit – Normal Data[b]	285.3	2895.9	265.4	4.51
	xbar+3s – Normal Data	236.4	1657.9	158.7	3.12
	EPA Guidance – log-Normal Data[a,c]	248.5	1384.8	286.7	3.27
	Tolerance Limit – log-Normal Data[b,c]	278.9	1799.4	374.9	4.64
	xbar+3s – log-Normal Data[c]	232.6	1061.0	217.8	3.20

[a]Calculated by method outlined in EPA Addendum to Interim Final Guidance for Statistical Analysis of Ground-Water Monitoring at RCRA Facilities.
[b]Bowker, Albert H. and Gerald J. Liberman, Engineering Statistics, Section 8.12 and 8.13.
[c]Mean and standard deviation for log-Normal calculated by method from Gilbert, Richard O., Statistical Methods for Environmental Pollution Monitoring, Section 13.1.1.

Comparison of the six different calculation methods yielded the following conclusions:

1. There is not much difference in the EPA Guidance Normal Data values and the EPA Guidance log-Normal Data values except for iron and manganese at MW-2051. Although the below detection limit values are treated the same in both these calculations, the difference is likely due to small sample size and outlier values as noted above.

2. The EPA Guidance Normal Data values and the Tolerance Limit Normal Data show some variation in many cases. The difference is probably attributable to the difference in the treatment of below detection limit values. The same argument can be stated for the EPA Guidance log-Normal Data values and the Tolerance Limit log-Normal Data values.

3. The Tolerance Limit Normal Data values and the “xbar+3s” Normal Data values are very similar, except at MW-2051. This is expected because the only difference is the tolerance factor multiplier. The Tolerance Limit is calculated as “xbar+ks”, where the tolerance factor multiplier ‘k’ is from a table depending on the sample size and the probability that the calculated interval contains a give percent of the distribution. For the “xbar+3s” method the multiplier factor is always 3. The range for this factor is from approximately 2.2 to 10.5. As the sample size decrease the tolerance factor multiplier increases. This accounts for the difference in the values at MW-2051. The same argument can be stated for the Tolerance Limit log-Normal Data values and the “xbar+3s” log-Normal values.

Based on the analysis discussed above, it was not recommend to change the method currently used (tolerances limits) for calculation of benchmarks for the signature parameters. All of the available data that has not been compromised should be used. In addition, the 'arithmetic mean plus 3 standard deviations' is appropriate for the non-signature parameters since they are not a concern in the leachate.

B.5 References

EPA (U.S. Environmental Protection Agency), 1989. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities - Interim Final Guidance*, EPA/530-SW-89-026, Office of Solid Waste, Waste Management Division,Washington, D.C., April.

EPA (U.S. Environmental Protection Agency), 1992. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities - Interim Final Guidance*, EPA/530-SW-93-001, Office of Solid Waste, Waste Management Division,Washington, D.C., November.

MK-F and JEG (MK-Ferguson Company and Jacobs Engineering Group), 1999. *Weldon Spring Site Environmental Report for Calendar Year 1998*, Rev. 0, DOE/OR/21548-773, prepared for the U.S. Department of Energy, Oak Ridge Operations Office, Weldon Spring, Missouri, July.

MK-F and JEG (MK-Ferguson Company and Jacobs Engineering Group), 2000a. *Weldon Spring Site Cell Groundwater Monitoring Demonstration Report*, Rev. 0, DOE/OR/21548-864, prepared for the U.S. Department of Energy, Oak Ridge Operations Office, St. Charles, Missouri, November.

MK-F and JEG (MK-Ferguson Company and Jacobs Engineering Group), 2000b. *Weldon Spring Site Environmental Report for Calendar Year 1999*, Rev. 0, DOE/OR/21548-845, prepared for the U.S. Department of Energy, Oak Ridge Operations Office, Weldon Spring, Missouri, July.

MK-F and JEG (MK-Ferguson Company and Jacobs Engineering Group), 2001. *Weldon Spring Site Environmental Report for Calendar Year 2000*, Rev. 0, DOE/OR/21548-886, prepared for the U.S. Department of Energy, Oak Ridge Operations Office, Weldon Spring, Missouri, July.

Tomasko, D., J.J. Quinn, L.A. Durham, 1996. *Groundwater Flow at the Chemical Plant Area of the Weldon Spring Site: Simulations of the Effect of the Disposal Cell on the Flow Field*, prepared by Argonne National Laboratory, Environmental Assessment Division, Argonne, Illinois, October.

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Attachment C

Review of Groundwater and Leachate Data—2007

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It was determined that periodic review of the groundwater and leachate data should be performed in order to evaluate possible changes in groundwater quality and composition of the leachate that could impact the monitoring program. Also, it was determined that every 5 years, the baseline tolerance limits for the signature parameters would be recalculated.

The following are general discussions regarding the groundwater and leachate data. Summary statistics for the groundwater and leachate are presented in Table C−1. Specific discussions regarding the groundwater and seep data are presented in the annual reports.

C.1 Groundwater

From 2003 through 2007, the cell wells and Burgermeister Spring have been sampled semiannually. The general groundwater quality has been stable and has shown little variation over time. During the time period of 2003 through 2007, the concentrations of the signature parameters in the cell wells and Burgermeister Spring have been less than the baseline tolerance limits, with the exception of iron and manganese in MW-2032. Increases in iron and manganese, as well as other parameters in this well were attributed to biodegradation of natural organic material (ants) in the well as discussed in the *Cell Groundwater Monitoring Demonstration Report for the December 2004 Sampling Event* (DOE 2005). This well exhibited a conversion from fully oxidizing to chemically reducing due to the decay of ants in the well. After implementation of corrective action, the geochemistry of the well as returned to normal in 2006.

C.2 Leachate

In general, the composition of the leachate has remained stable over time, with the exception of iron, manganese, and uranium. These three constituent have shown a general decline over time. Increasing concentrations over time have not been identified in any of the monitored constituents in the leachate.

C.3 Evaluation of Signature Parameters

It was anticipated during development of the detection monitoring program that the list of signature parameters may be modified, as necessary, based on future changes in leachate and/or groundwater concentrations. Barium, iron, manganese, and uranium were identified in the *Weldon Spring Site Disposal Cell Groundwater Monitoring Plan, Revision 2* (DOE 2004) as "signature parameters" for the disposal cell detection monitoring program. Based on data collected from 2000 through 2002, all four of these parameters had been detected at concentrations at least an order of magnitude higher in the leachate than in the underlying groundwater or Burgermeister Spring (with the exception of uranium), which enhances the reliability of any conclusions that are drawn based on fluctuations in groundwater constituents. It was determined that increasing trends of these four parameters in the groundwater would be considered a signature of cell leachate that has migrated to the underlying aquifer.

A comparison of the annual averages for each signature parameters in the leachate and cells wells or Burgermeister Spring indicates that the concentrations of iron (Figure C−1) and manganese (Figure C−2) in the leachate have decreased to levels that no longer exceed those detected in the groundwater by an order of magnitude. Although the levels of uranium in the leachate have decreased over time (Figure C−3), the levels are still an order of magnitude greater

than those detected in groundwater. Barium concentrations in the leachate (Figure C−4) have remained stable in the leachate and continue to be greater in the leachate than in the groundwater.

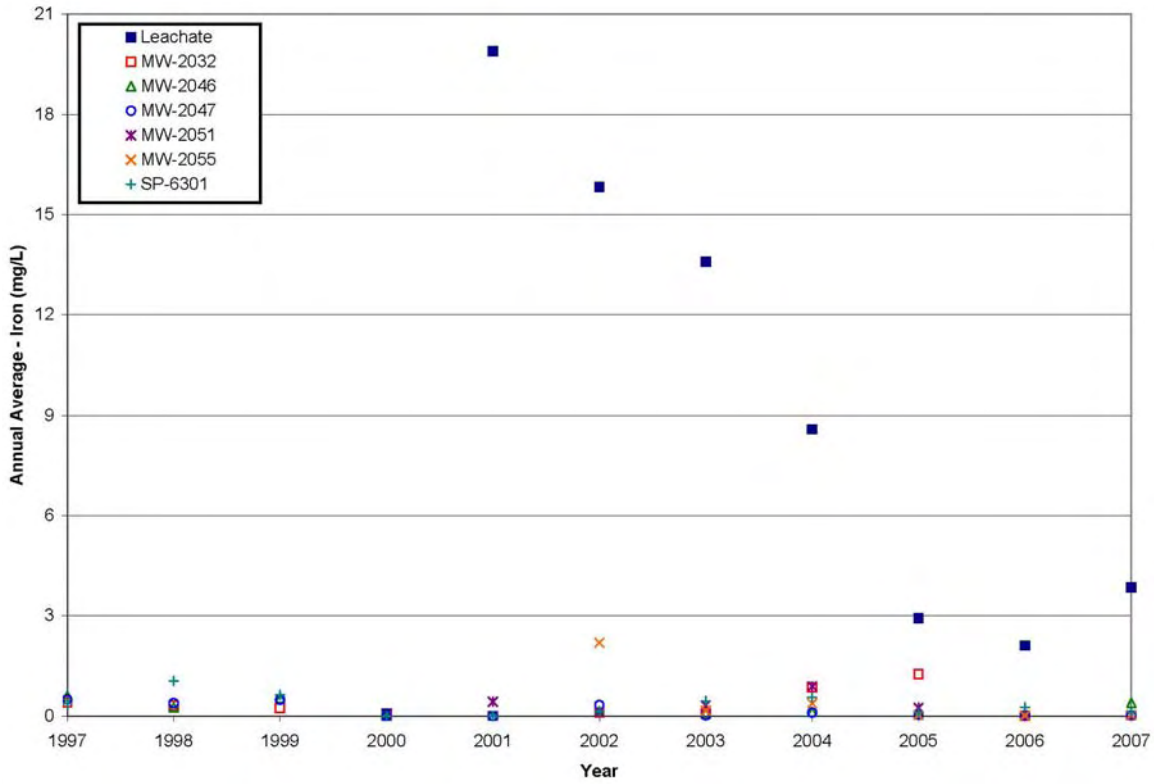

Figure C−1. Annual Averages for Iron in Leachate and Cell Monitoring Network

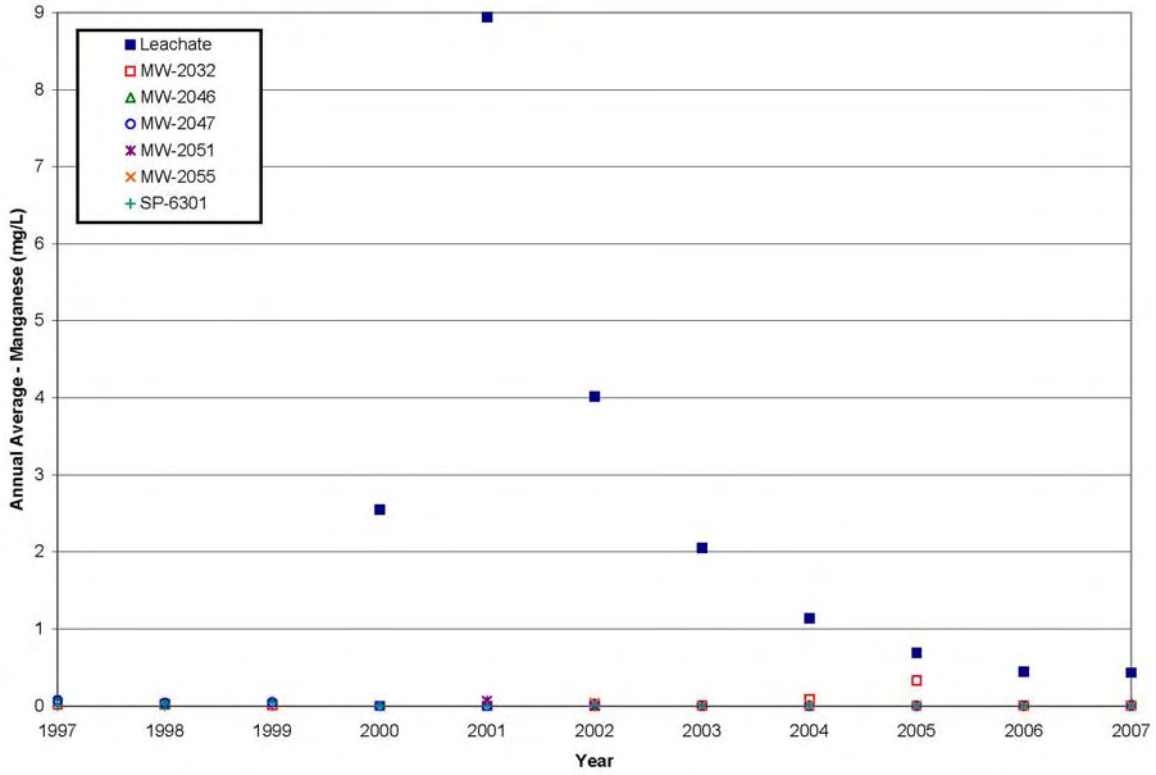

Figure C−2. Annual Averages for Manganese in Leachate and Cell Monitoring Network

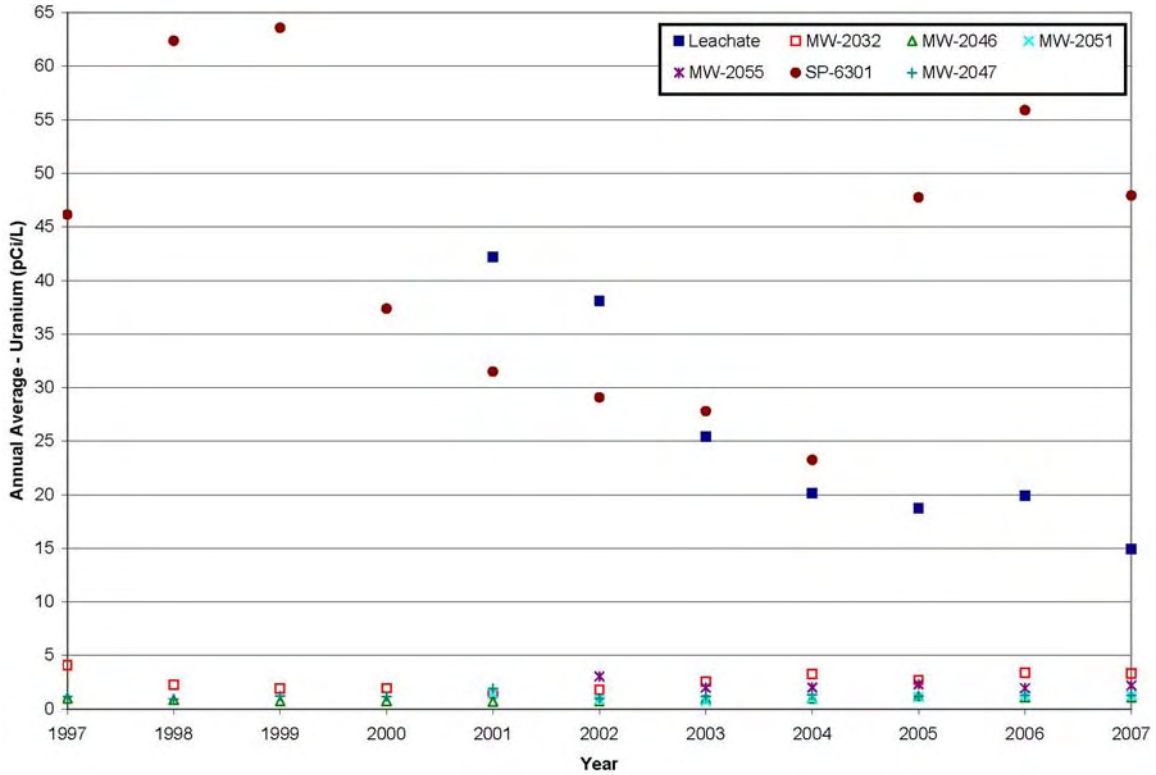

Figure C−3. Annual Averages for Uranium in Leachate and Cell Monitoring Network

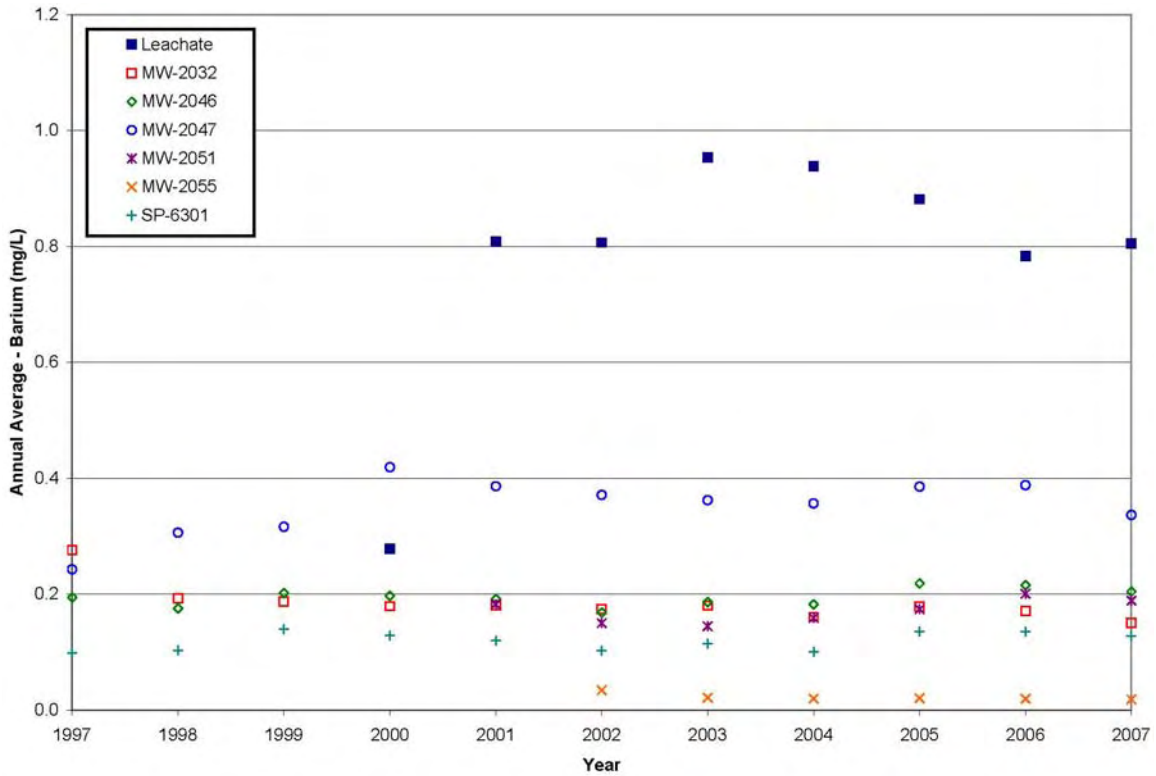

Figure C−4. Annual Averages for Barium in Leachate and Cell Monitoring Network

Based on the evaluation of the concentrations of the signature parameters in the leachate and the groundwater, it is concluded that barium and uranium will continue to be monitored as signature parameters under the baseline monitoring program. New baseline tolerance limits will be calculated for the 5 disposal cell monitoring wells and Burgermeister Spring. Iron and manganese will no longer be used as signature parameters. The concentrations of these two parameters have decreased over time to levels that no longer distinguish possible cell leakage from the natural groundwater chemistry.

C.4 Evaluation of Long-Term Monitoring Parameters

The monitoring program must include those constituents that have been detected in the groundwater and that are reasonably expected to be in or derived from waste in the disposal cell. Based on the review of the groundwater and leachate data, the following contaminants will continue to be monitored in the five disposal cell wells and Burgermeister Spring: arsenic, barium, chromium, lead, manganese, nickel, selenium, thallium, nitroaromatic compounds, radium-226/228, thorium-228/230/232, PAHs, and PCBs. These constituents have been identified as COCs for either the chemical plant and/or bulk wastes or were generated during water treatment processes.

The leachate will continue to be monitored for the present list or parameters. If changes are identified in the composition of the leachate, monitoring parameters for the groundwater will be evaluated.

Average of RESULT		LOCATION_CODE						
ANALYTE	YEAR	LW-DC10	MW-2032	MW-2046	MW-2047	MW-2051	MW-2055	SP-6301
Arsenic	1997		0.00275	0.00253	0.00262			0.00309
	1998		0.00236	0.00230	0.00228			0.00252
	1999		0.00200	0.00202	0.00200			0.00206
	2000	0.00150	0.00145	0.00185	0.00185			0.00165
	2001	0.00873	0.00210	0.00250	0.00215	0.00167		0.00205
	2002	0.00493	0.00220	0.00220	0.00220	0.00220	0.00214	0.00205
	2003	0.00335	0.00024	0.00011	0.00011	0.00014	0.00011	0.00033
	2004	0.00370	0.00104	0.00057	0.00057	0.00057	0.00057	0.00057
	2005	0.00360	0.00180	0.00150	0.00155	0.00150	0.00180	0.00255
	2006	0.00305	0.00190	0.00190	0.00190	0.00190	0.00190	0.00180
	2007	0.00335	0.00190	0.00190	0.00190	0.00190	0.00190	0.00190
Chemical Oxygen Demand	1997		4.37750	4.71875	4.62813			6.88063
	1998		4.97563	5.98563	4.63500			21.89700
	1999		9.28000	9.14000	7.94000			4.39400
	2000		16.66667	16.66667	17.00000			14.50000
	2001	30.60000	4.28500	3.37000	4.37000	6.66667		5.64500
	2002	27.92308	5.00000	5.00000	5.00000	5.00000	5.80000	5.00000
	2003	27.90000	9.00000	8.50000	5.00000	9.00000	11.00000	13.75000
	2004	29.83333	28.00000	4.80000	3.30000	3.30000	3.30000	7.44000
	2005	34.50000	7.00000	6.00000	3.00000	7.50000	4.00000	4.00000
	2006	32.00000	11.00000	7.20000	9.70000	6.20000	2.40000	6.60000
	2007	84.00000	59.00000	41.50000	59.50000	49.00000	44.30000	66.33333
Chloride	1997		10.88063	17.45000	8.13563			13.12500
	1998		5.70063	18.15625	6.45125			8.58769
	1999		5.84800	17.50000	6.13800			15.09778
	2000	18.60000	2.75000	14.35000	6.70000			17.58750
	2001	28.40000	4.38000	14.95000	7.06500	25.93333		17.41667
	2002	34.75000	8.50000	19.55000	7.10000	37.05000	4.18600	19.75000
	2003	34.06667	7.78000	25.96667	7.57500	36.55000	5.11000	13.28000
	2004	34.45000	6.00000	28.75000	8.05000	28.65000	4.55000	9.50000
	2005	35.50000	4.95000	31.10000	8.10000	22.25000	5.15000	20.00000
	2006	35.80000	3.05000	42.40000	7.95000	16.00000	5.40000	16.50000
	2007	37.15000	2.45000	40.00000	7.50000	11.95000	4.45000	25.80000

ANALYTE	YEAR	LW-DC10	MW-2032	MW-2046	MW-2047	MW-2051	MW-2055	SP-6301
Chromium	1997		0.00206	0.00316	0.00269			0.00431
	1998		0.00448	0.00326	0.00334			0.00272
	1999		0.00514	0.00600	0.00416			0.00244
	2000	0.00080	0.00518	0.00308	0.00870			0.00251
	2001	0.00062	0.00565	0.00345	0.00375	0.00140		0.00082
	2002	0.00170	0.00410	0.00215	0.00455	0.00190	0.00902	0.00161
	2003	0.00097	0.00280	0.00098	0.00370	0.01480	0.00455	0.00100
	2004	0.00175	0.00370	0.00245	0.00520	0.12705	0.01905	0.00228
	2005	0.00260	0.00380	0.00265	0.00605	0.04015	0.00850	0.00260
	2006	0.00310	0.00495	0.00310	0.00650	0.00700	0.00750	0.00310
	2007	0.00250	0.00250	0.00300	0.00355	0.00250	0.00400	0.00250
Cobalt	1997		0.00095	0.00138	0.00159			0.00331
	1998		0.00283	0.00264	0.00264			0.00244
	1999		0.00220	0.00238	0.00220			0.00097
	2000	0.00300	0.00249	0.00249	0.00249			0.00264
	2001	0.02540	0.00185	0.00225	0.00121	0.00149		0.00091
	2002	0.01459	0.00119	0.00119	0.00119	0.00119	0.00352	0.00160
	2003	0.00807	0.00100	0.00100	0.00115	0.00110	0.00100	0.00100
	2004	0.00570	0.00157	0.00025	0.00025	0.00077	0.00070	0.00024
	2005	0.00370	0.00167	0.00166	0.00166	0.00166	0.00052	0.00166
	2006	0.00500	0.00266	0.00267	0.00273	0.00266	0.00267	0.00500
	2007	0.00505	0.00500	0.00500	0.00500	0.00500	0.00500	0.00500
Dissolved Oxygen	2001	1.09000	5.20000	5.68667	5.45333	4.93000		6.45000
	2002		4.95250	4.91000	4.62500	6.19200	4.86200	6.85500
	2003	2.78000	8.24000	8.58000	7.93500	9.67500	7.70500	7.97857
	2004	4.31800	5.60000	7.62500	6.91500	8.99000	10.26500	8.85200
	2005	5.27333	2.49250	8.33667	6.84000	10.22667	7.18500	8.98000
	2006	4.67429	4.89250	7.60000	5.84500	8.24000	6.02500	6.86000
	2007	3.20714	4.50000	6.96500	5.26000	8.27000	6.83000	8.05667
Fluoride	1997		0.27125	0.05844	0.16794			0.18650
	1998		0.26825	0.35113	0.40163			0.28738
	1999		0.19800	0.33000	0.25100			0.25067
	2000	0.20000	0.21000	0.13500	0.12500			0.39475
	2001	0.21650	0.19450	0.08550	0.08700	0.29000		0.25640
	2002	0.26600	0.27000	0.34000	0.19500	0.36000	0.12400	0.26667
	2003	0.17907	0.12715	0.19710	0.01875	0.15670	0.16110	0.13805
	2004	0.29000	0.18000	0.11000	0.10800	0.15500	0.10950	0.08300
	2005	0.24000	0.20500	0.10150	0.10500	0.17500	0.13500	0.19000
	2006	0.25000	0.17000	0.10350	0.09650	0.17000	0.10900	0.15667
	2007	0.22500	0.16000	0.11500	0.06850	0.13500	0.08950	0.14000

ANALYTE	YEAR	LW-DC10	MW-2032	MW-2046	MW-2047	MW-2051	MW-2055	SP-6301
Lead	1997		0.00156	0.00161	0.00158			0.00193
	1998		0.00159	0.00166	0.00163			0.00173
	1999		0.00140	0.00150	0.00140			0.00166
	2000	0.00160	0.00200	0.00440	0.00200			0.00188
	2001	0.00121	0.00122	0.00257	0.00122	0.00128		0.00122
	2002	0.00152	0.00205	0.00170	0.00205	0.00205	0.00259	0.00197
	2003	0.00067	0.00050	0.00141	0.00028	0.00038	0.00037	0.00045
	2004	0.00069	0.00110	0.00110	0.00110	0.00110	0.00110	0.00110
	2005	0.00084	0.00084	0.00084	0.00084	0.00084	0.00057	0.00084
	2006	0.00160	0.00105	0.00105	0.00105	0.00105	0.00105	0.00160
	2007	0.00240	0.00240	0.00240	0.00240	0.00240	0.00240	0.00240
Nickel	1997		0.00358	0.00786	0.01946			0.00493
	1998		0.01099	0.00975	0.00991			0.00680
	1999		0.00728	0.02386	0.01156			0.00184
	2000	0.00290	0.00883	0.02518	0.01020			0.00120
	2001	0.01390	0.00386	0.03975	0.00595	0.02407		0.00201
	2002	0.01072	0.00505	0.02713	0.00700	0.00830	0.02088	0.00365
	2003	0.00754	0.00345	0.01005	0.00315	0.03230	0.02785	0.00097
	2004	0.00943	0.01950	0.01080	0.00685	0.06820	0.03170	0.00288
	2005	0.00785	0.01328	0.01615	0.00620	0.00775	0.01695	0.00310
	2006	0.00750	0.00610	0.01955	0.00790	0.00630	0.01520	0.00750
	2007	0.00775	0.00460	0.00885	0.00460	0.00460	0.01085	0.00460
Nitrate as Nitrogen	1997		64.86875	1.53063	78.95625			7.43722
	1998		15.34375	1.86000	98.23125			4.94417
	1999		9.90000	1.78400	61.48000			10.67000
	2000	3.10000	6.26000	3.02500	86.70000			7.11375
	2001	0.07500	4.33500	2.66000	69.95000	0.58933		10.48500
	2002	0.80900	3.10000	1.45000	42.40000	2.01500	0.65600	3.49267
	2003	0.20800	3.61500	2.09000	69.55000	1.44000	0.96300	3.16013
	2004	0.16820	2.23800	36.58500	68.20000	1.15850	0.79900	2.04500
	2005	0.20535	1.34200	2.21000	90.75000	1.62500	0.90000	5.07000
	2006	1.38000	1.68000	1.96000	77.10000	1.61000	1.03000	2.71000
	2007	1.05200	2.58500	2.44500	80.70000	1.80000	1.37450	4.02800

ANALYTE	YEAR	LW-DC10	MW-2032	MW-2046	MW-2047	MW-2051	MW-2055	SP-6301
Oxidation Reduction Potential	1997		118.45833	134.62500	124.82353			
	1998		115.76471	135.07143	129.69231			
	1999		199.40000	202.00000	169.40000			170.00000
	2000		154.00000	158.00000	187.00000			138.00000
	2001	-83.00000		134.00000	121.00000			159.00000
	2002						179.00000	153.75000
	2003	-66.10000		251.40000	217.30000	248.80000	256.00000	292.63333
	2004	-55.67500	39.55000	206.80000	178.70000	92.65000	183.00000	174.50000
	2005	41.28333	4.85000	226.80000	87.30000	190.30000	252.85000	120.70000
	2006	82.12857	108.47500	252.45000	227.25000	231.85000	240.50000	272.30000
	2007	55.14286	127.13333	177.45000	208.75000	181.95000	194.95000	246.37500
pH	1997		7.18417	7.08125	7.31235			6.94813
	1998		7.55381	7.15556	7.29000			6.95611
	1999		7.35167	7.15500	7.43800			7.20500
	2000		7.48000	7.26500	7.21500			6.77000
	2001	6.74000	7.61500	7.05750	7.19500	7.51667		6.78053
	2002		7.39750	6.85333	7.13500	7.41800	7.10800	6.75091
	2003	6.96778	7.65000	7.25333	7.11500	7.70000	7.72500	6.96571
	2004	6.90333	6.99500	6.89500	7.13500	7.52000	7.34500	7.30400
	2005	6.88500	6.84750	6.81667	7.03500	7.24000	6.95500	6.67000
	2006	6.95714	7.15500	6.78500	7.01500	7.17500	6.93000	6.69500
	2007	6.94429	7.23667	6.93500	6.93500	7.05500	6.96000	7.14500
Radium-226	1997		0.37569	0.37456	0.44675			0.32513
	1998		0.34850	0.27144	0.48000			0.24940
	1999		0.33260	0.26300	0.30900			0.35160
	2000	0.27800	0.23000	0.15500	0.26000			0.15733
	2001	0.83400	0.42800	0.58533	0.49800	0.59367		0.49867
	2002	0.36292	0.18650	0.20150	0.38600	0.35000	0.53040	0.23150
	2003	0.53590	0.11600	0.12500	0.20050	0.31950	0.12450	0.12200
	2004	0.51333	0.21000	0.21500	0.34000	0.32000	0.20500	0.20750
	2005	0.36500	0.33500	0.24500	0.35500	0.23600	0.27000	0.24500
	2006	0.38500	0.15500	0.20500	0.45000	0.19000	0.28000	0.18667
	2007	0.56500	0.24500	0.23000	0.45500	0.25000	0.20500	0.23667

ANALYTE	YEAR	LW-DC10	MW-2032	MW-2046	MW-2047	MW-2051	MW-2055	SP-6301
Radium-228	1997		1.61088	1.15081	0.79266			1.57813
	1998		0.59663	0.68888	0.60944			1.10780
	1999		0.65040	0.62460	0.86180			0.71140
	2000	0.46900	0.75500	0.83500	0.83000			0.95000
	2001	0.72600	0.63100	1.45000	1.30600	1.03333		1.70000
	2002	0.73338	0.37650	0.39650	0.38650	0.58650	0.81560	1.43500
	2003	0.86530	0.87500	0.93000	0.90500	0.92000	0.91500	0.90500
	2004	0.84167	0.94000	0.86500	0.85000	0.86000	0.85500	0.98750
	2005	0.69500	1.03500	0.59000	0.85000	1.27000	1.36000	0.66000
	2006	0.81500	0.80000	0.71000	0.87000	0.69000	0.79500	0.76333
	2007	0.67000	0.51000	0.57500	0.50000	0.52000	0.49000	0.43667
Selenium	1997		0.00474	0.00328	0.00386			0.00363
	1998		0.00309	0.00275	0.00339			0.00316
	1999		0.00320	0.00304	0.00312			0.00370
	2000	0.00220	0.00235	0.00280	0.00445			0.00238
	2001	0.00288	0.00235	0.00393	0.00445	0.00120		0.00235
	2002	0.00152	0.00185	0.00275	0.00265	0.00185	0.01322	0.00207
	2003	0.00080	0.00060	0.00320	0.00275	0.00026	0.01210	0.00032
	2004	0.00237	0.00110	0.00390	0.00325	0.00120	0.01365	0.00110
	2005	0.00235	0.00129	0.00465	0.00230	0.00133	0.01410	0.00133
	2006	0.00320	0.00220	0.00415	0.00300	0.00240	0.01375	0.00320
	2007	0.00370	0.00370	0.00460	0.00370	0.00370	0.01285	0.00370
Specific Conductance	1997		1158.83333	927.68750	1076.47059			499.21875
	1998		690.57143	912.77778	1229.23529			519.00000
	1999		626.33333	938.25000	1228.60000			638.00000
	2000		548.00000	887.50000	1132.00000			1323.66667
	2001		598.50000	904.75000	1233.50000	621.66667		555.17647
	2002		630.03575	942.66667	1225.00000	654.40000	1094.00000	417.63636
	2003	1331.40000	477.50000	861.66667	1108.00000	595.50000	1178.50000	378.14286
	2004	1267.60000	775.00000	967.50000	1137.50000	314.95000	1123.00000	324.00000
	2005	1200.66667	550.50000	992.66667	1242.50000	423.06333	1118.00000	537.50000
	2006	1090.85714	646.00000	959.50000	1213.00000	622.00000	1086.50000	456.50000
	2007	1023.85714	567.33333	949.50000	1184.50000	648.00000	1020.50000	476.00000

ANALYTE	YEAR	LW-DC10	MW-2032	MW-2046	MW-2047	MW-2051	MW-2055	SP-6301
Sulfate	1997		40.87500	54.21875	31.05625			51.17778
	1998		24.39375	51.44375	25.93125			38.74615
	1999		22.90000	48.98000	23.42000			45.74444
	2000	163.00000	18.40000	44.10000	23.90000			31.65000
	2001	84.60000	31.85000	44.90000	26.90000	60.50000		28.54000
	2002	70.47500	43.40000	52.30000	23.70000	52.70000	269.50000	21.50000
	2003	43.73333	55.10000	57.83333	25.90000	48.10000	283.50000	21.72500
	2004	34.10000	100.35000	57.45000	24.50000	36.05000	270.50000	20.60000
	2005	33.05000	100.10000	57.60000	24.40000	28.15000	274.00000	24.60000
	2006	45.70000	79.40000	59.15000	22.70000	20.55000	256.50000	22.00000
	2007	32.25000	33.75000	62.25000	24.60000	18.40000	256.00000	27.20000
Thallium	1997		0.00431	0.00396	0.00397			0.00526
	1998		0.00319	0.00308	0.00297			0.00313
	1999		0.00350	0.00340	0.00326			0.00354
	2000	0.00300						
	2001	0.00770				0.00313		
	2002	0.00304	0.00390	0.00520	0.00420	0.00390	0.00538	0.00660
	2003	0.00215	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011
	2004	0.00069	0.00044	0.00044	0.00044	0.00044	0.00044	0.00056
	2005	0.00205	0.00151	0.00161	0.00151	0.00151	0.00059	0.00264
	2006	0.00265	0.00166	0.00231	0.00141	0.00141	0.00141	0.00250
	2007	0.00655	0.00520	0.00520	0.00520	0.00520	0.00520	0.00520
Thorium-228	1997		0.18153	0.14853	0.14626			0.44478
	1998		0.14113	0.13950	0.17775			0.19800
	1999		0.08980	0.09880	0.22680			0.08960
	2000	0.19800	0.03900	0.06050	0.06000			0.42350
	2001	0.12120	0.12650	0.10100	0.12050	0.07033		0.15000
	2002	0.21246	0.07350	0.08550	0.09050	0.10050	0.13280	0.10050
	2003	0.16070	0.10000	0.09600	0.11800	0.11750	0.10500	0.11325
	2004	0.24940	0.20250	0.21050	0.24500	0.23500	0.21000	0.23950
	2005	0.29500	0.24500	0.39000	0.30500	0.38500	0.26000	0.18000
	2006	0.17500	0.20500	0.19500	0.20000	0.17500	0.17500	0.41000
	2007	0.22500	0.21500	0.17500	0.18500	0.16500	0.16500	0.23333

ANALYTE	YEAR	LW-DC10	MW-2032	MW-2046	MW-2047	MW-2051	MW-2055	SP-6301
Thorium-230	1997		0.11584	0.12654	0.17845			0.40773
	1998		0.25890	0.24933	0.20378			0.30955
	1999		0.19720	0.12660	0.19620			0.11078
	2000	0.35500	0.07750	0.13800	0.10250			1.19725
	2001	0.17470	0.13450	0.37350	0.14750	0.13000		0.15050
	2002	0.39377	0.25950	0.27900	0.23100	0.23350	0.24740	0.26350
	2003	0.20310	0.14550	0.13950	0.17900	0.15900	0.16500	0.15225
	2004	0.29400	0.25000	0.23000	0.26000	0.32000	0.21000	0.28250
	2005	0.31000	0.20500	0.26000	0.33500	0.17000	0.21500	0.33000
	2006	0.35500	0.32500	0.25000	0.19000	0.30500	0.22500	0.42667
	2007	0.26000	0.19500	0.26000	0.26000	0.15000	0.33000	0.24000
Thorium-232	1997		0.11408	0.08221	0.08663			0.18968
	1998		0.08174	0.07757	0.10387			0.10785
	1999		0.06700	0.04220	0.05320			0.02644
	2000	0.11100	0.02350	0.03950	0.03900			0.21900
	2001	0.06870	0.10150	0.09050	0.07450	0.07733		0.10450
	2002	0.16592	0.06750	0.10650	0.07650	0.07500	0.10440	0.05150
	2003	0.08060	0.03550	0.03600	0.03750	0.02750	0.03500	0.04675
	2004	0.14000	0.13000	0.14650	0.14500	0.12500	0.12500	0.10500
	2005	0.14000	0.13000	0.19000	0.12000	0.12500	0.10500	0.09350
	2006	0.10350	0.10000	0.09150	0.14000	0.11250	0.07900	0.10567
	2007	0.13500	0.12500	0.10400	0.11500	0.14500	0.10550	0.11433
Total Dissolved Solids	1997		763.31250	547.50000	831.00000			298.87500
	1998		444.81250	533.06250	868.56250			211.00000
	1999		359.80000	534.20000	834.40000			430.60000
	2000		337.50000	523.50000	729.00000			376.50000
	2001	941.50000	356.00000	545.50000	762.00000	399.66667		273.50000
	2002	827.40000	416.50000	575.50000	766.50000	388.50000	779.60000	341.00000
	2003	784.66667	451.50000	581.50000	752.00000	345.00000	780.00000	252.50000
	2004	716.00000	499.50000	579.50000	690.00000	347.00000	763.00000	220.75000
	2005	691.00000	303.50000	419.00000	618.00000	393.00000	764.00000	288.50000
	2006	651.00000	461.00000	589.00000	758.00000	382.00000	722.50000	279.00000
	2007	695.00000	310.00000	617.00000	758.50000	406.00000	747.00000	327.33333

ANALYTE	YEAR	LW-DC10	MW-2032	MW-2046	MW-2047	MW-2051	MW-2055	SP-6301
Total Organic Carbon	1997		6.59250	11.78938	10.41563			7.89438
	1998		1.05206	2.01750	1.26938			3.30500
	1999		0.91820	1.72800	0.88700			2.19800
	2000		0.87500	1.10000	0.86500			1.50000
	2001	9.41000	1.02000	1.91000	1.69000	1.56667		2.55000
	2002	9.58000	0.78500	1.30000	0.82500	0.96000	2.25800	1.40000
	2003	10.06667	1.67667	2.85667	1.60000	1.80000	1.60000	2.72500
	2004	10.05000	6.85000	1.70000	0.83500	1.10500	0.77000	2.17500
	2005	11.33500	1.41000	2.10000	1.20000	0.97000	3.02250	2.10000
	2006	0.47000	23.70000	23.70000	23.70000	24.30000	23.70000	23.70000
	2007	12.75000	0.76000	1.85000	0.83500	0.76000	0.76000	1.53333

Attachment D

Groundwater Flow Rate Determination

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Groundwater flow rates and flow directions will be evaluated annually as specified in Section K4.4 of the main text of this report. Results for 1998 through 2002 are presented in this attachment.

D.1 Groundwater Flow Direction

The groundwater flow direction was determined by constructing a potentiometric surface map of the shallow aquifer using the available wells at the chemical plant (Figure D−1). Potentiometric surface maps (Figures D−2 through D−6) were constructed using the average of the groundwater elevations measured during each year. A summary of the average groundwater elevations for each well is included in this attachment.

The potentiometric surface has remained relatively unchanged from 1998 through 2002. The groundwater flow direction is to the north. A groundwater divide is present along the southern boundary of the chemical plant site.

D.2 Groundwater Flow Rates

The calculation of the average groundwater flow rate (average linear velocity) is a function of the hydraulic conductivity (K), the hydraulic gradient (I) and the effective porosity (ne) of the shallow aquifer:

$$v = - Ki / ne$$

The average groundwater flow rate for each year is summarized in Table D−1.

Table D−1. Average Groundwater Flow Rate From 1998 Through 2002

Year	Hydraulic Conductivity (cm/s)[a]	Effective Porosity[b]	GW Elevation		Hydraulic Gradient (ft/ft)[d]	Average Flow Rate (ft/day)
			MW-2048[c]	MW-2032		
1998	0.007	0.10	607.5	582.9	0.012	2.4
1999			607.5	583.0	0.012	2.4
2000			607.5	582.9	0.012	2.4
2001			607.3	582.9	0.012	2.4
2002			606.8	582.9	0.011	2.2

[a]Average hydraulic conductivity using data from the cell monitoring wells.
[b]Value selected to estimate maximum groundwater flow rate.
[c]Groundwater elevation from MW-2055 was used for 2002.
[d]Horizontal distance between MW-2032 and MW-2048 is 2,100 ft.

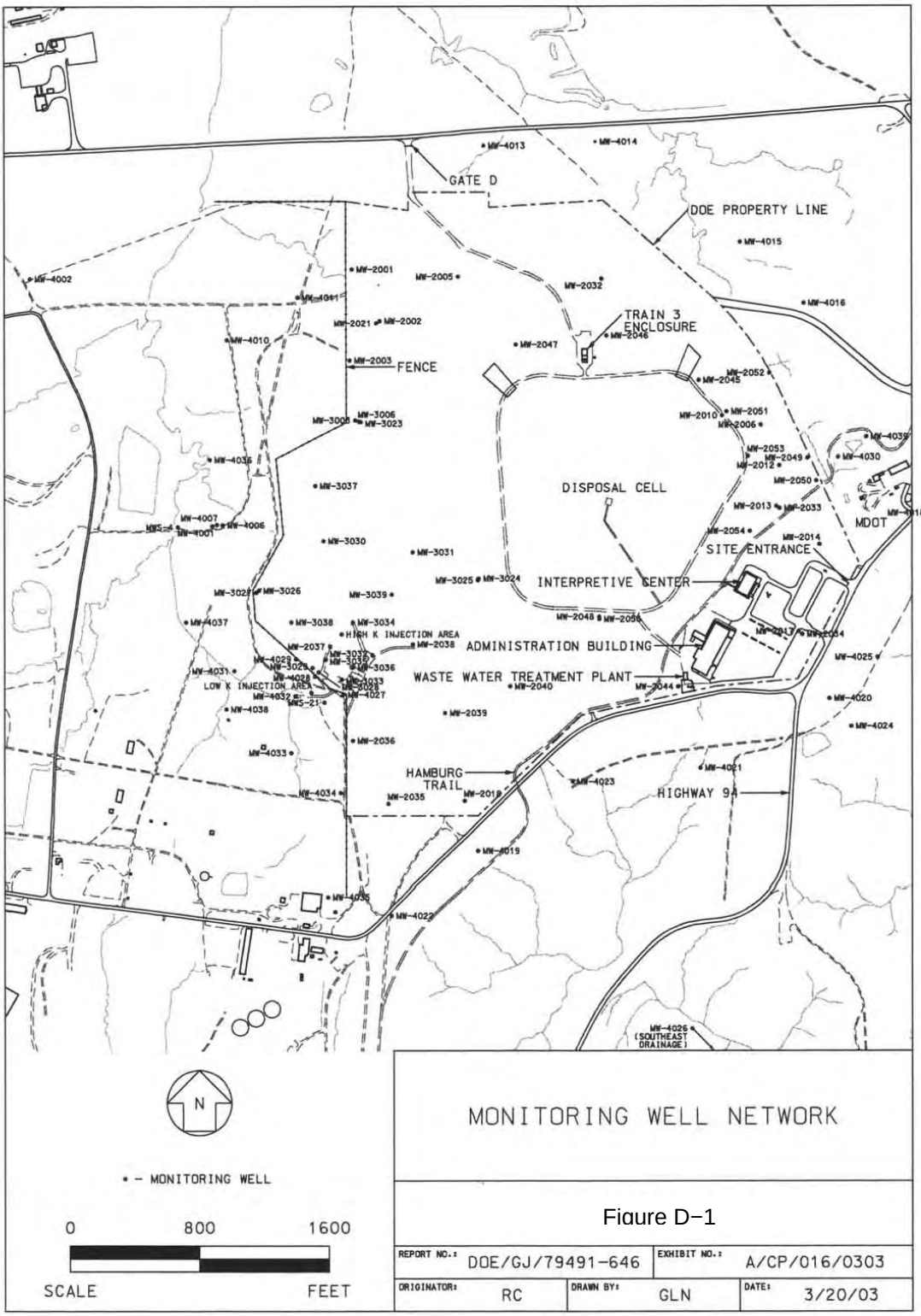
GATE D
DOE PROPERTY LINE
TRAIN 3 ENCLOSURE
FENCE
DISPOSAL CELL
MDOT
SITE ENTRANCE
INTERPRETIVE CENTER
ADMINISTRATION BUILDING
WASTE WATER TREATMENT PLANT
HIGH K INJECTION AREA
LOW K INJECTION AREA
HAMBURG TRAIL
HIGHWAY 94
(SOUTHEAST DRAINAGE)
N
• - MONITORING WELL
0 800 1600
SCALE FEET
MONITORING WELL NETWORK
Figure D-1
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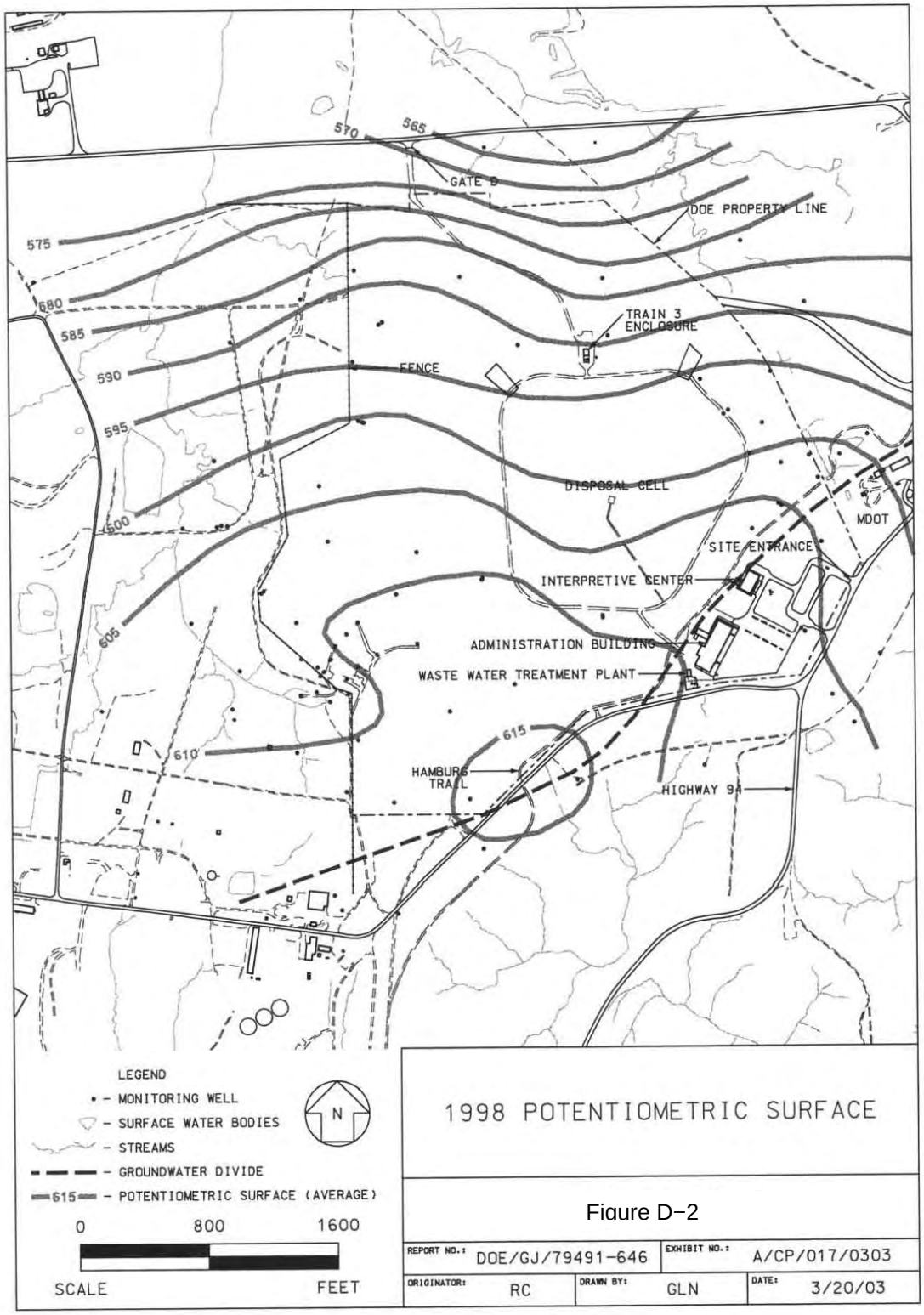
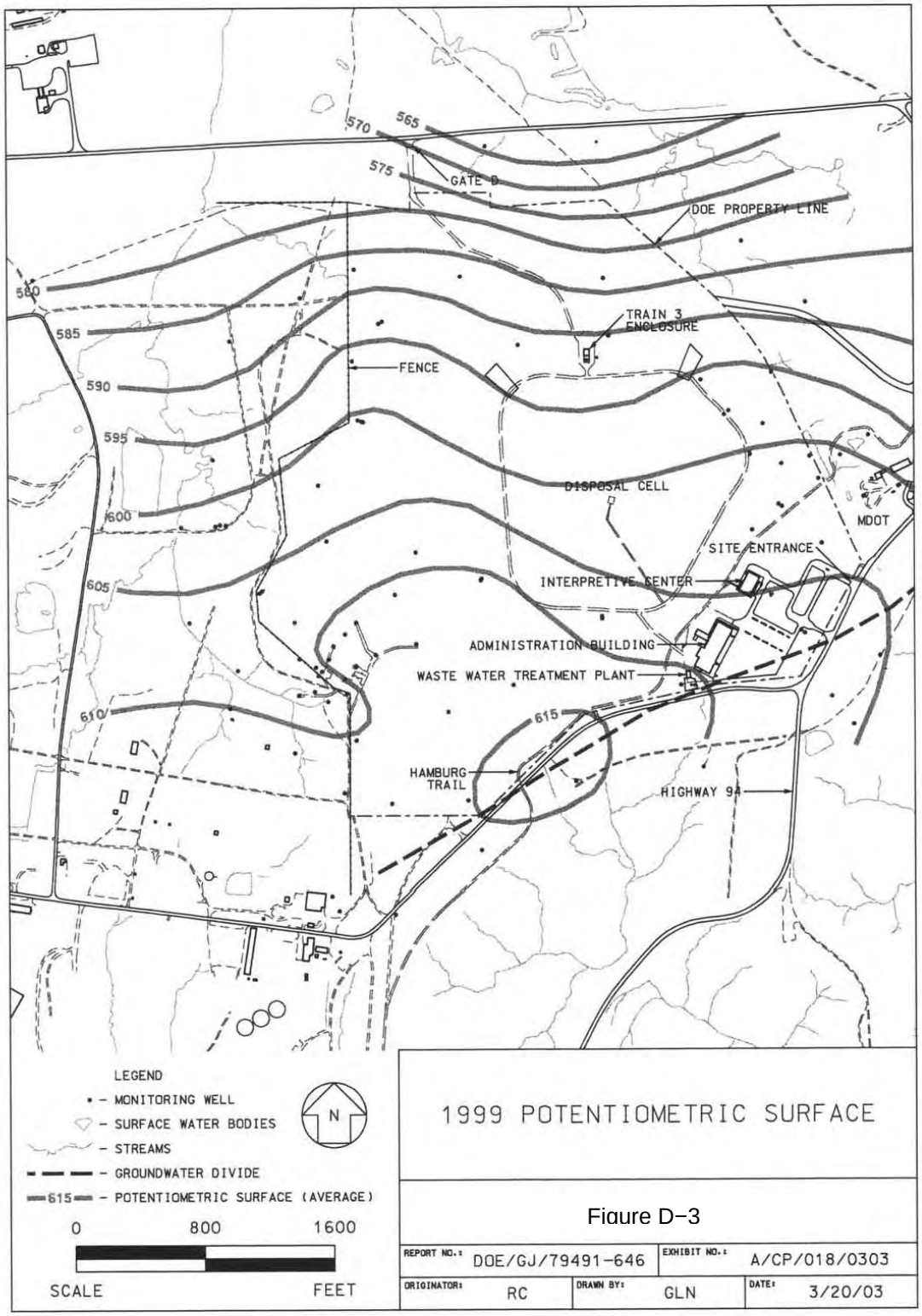
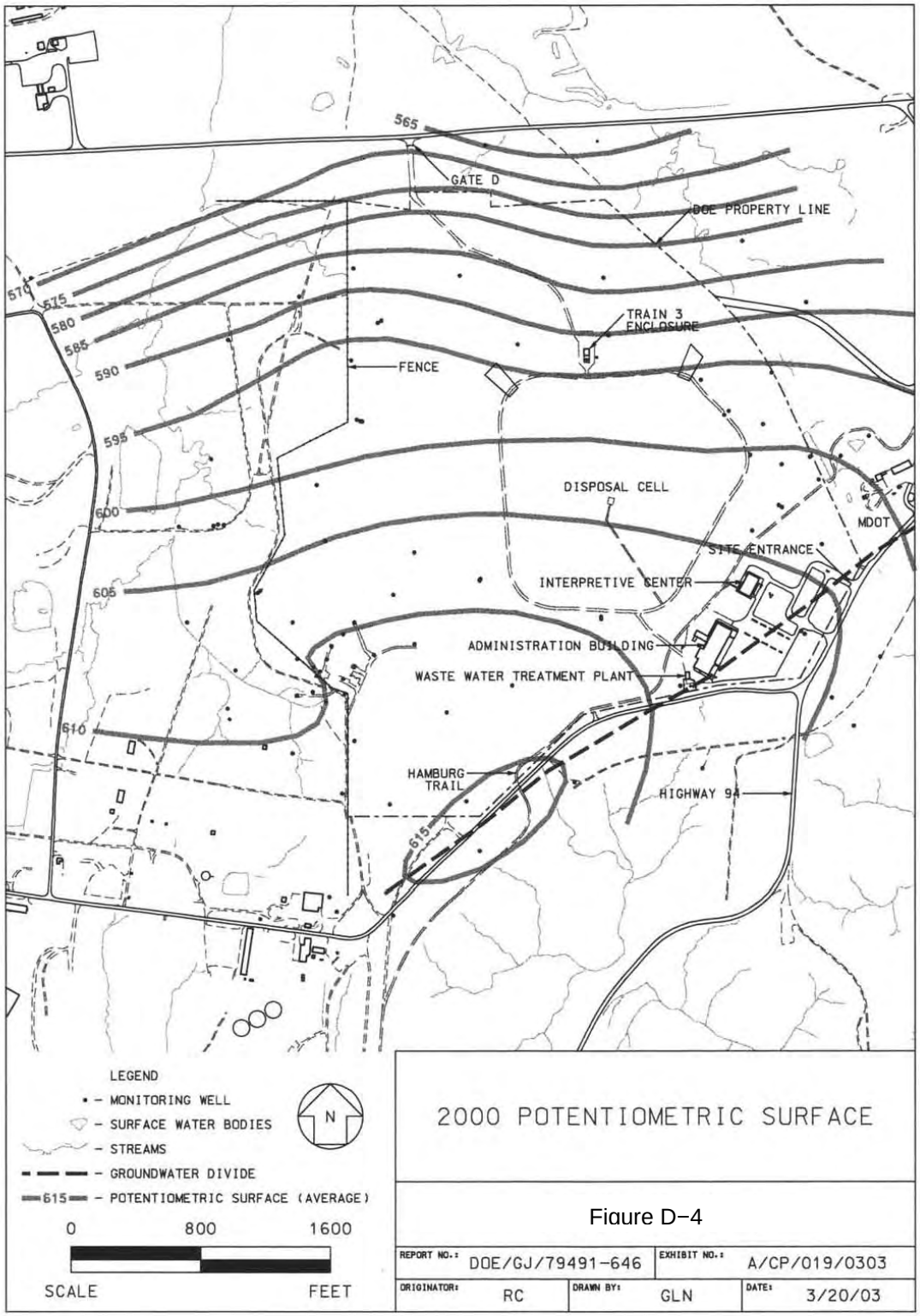
EXHIBIT NO.: A/CP/016/0303
ORIGINATOR: RC
DRAWN BY: GLN
DATE: 3/20/03


570
565
GATE D
DOE PROPERTY LINE
575
680
585
590
595
600
605
610
615
TRAIN 3
ENCLOSURE
FENCE
DISPOSAL CELL
MDOT
SITE ENTRANCE
INTERPRETIVE CENTER
ADMINISTRATION BUILDING
WASTE WATER TREATMENT PLANT
HAMBURG
TRAIL
HIGHWAY 94
LEGEND
• - MONITORING WELL
- SURFACE WATER BODIES
- STREAMS
- GROUNDWATER DIVIDE
615 - POTENTIOMETRIC SURFACE (AVERAGE)
N
0
800
1600
SCALE
FEET
1998 POTENTIOMETRIC SURFACE
Figure D-2
REPORT NO.: DOE/GJ/79491-646
EXHIBIT NO.: A/CP/017/0303
ORIGINATOR: RC
DRAWN BY: GLN
DATE: 3/20/03


570
565
575
GATE D
DOE PROPERTY LINE
580
585
590
595
600
605
610
615
TRAIN 3 ENCLOSURE
FENCE
DISPOSAL CELL
MDOT
SITE ENTRANCE
INTERPRETIVE CENTER
ADMINISTRATION BUILDING
WASTE WATER TREATMENT PLANT
HAMBURG TRAIL
HIGHWAY 94
LEGEND
• - MONITORING WELL
- SURFACE WATER BODIES
- STREAMS
- GROUNDWATER DIVIDE
615 - POTENTIOMETRIC SURFACE (AVERAGE)
N
0
800
1600
SCALE
FEET
1999 POTENTIOMETRIC SURFACE
Figure D-3
REPORT NO.: DOE/GJ/79491-646
EXHIBIT NO.: A/CP/018/0303
ORIGINATOR: RC
DRAWN BY: GLN
DATE: 3/20/03


565
GATE D
DOE PROPERTY LINE
570
575
580
585
590
TRAIN 3 ENCLOSURE
FENCE
595
DISPOSAL CELL
600
MDOT
SITE ENTRANCE
INTERPRETIVE CENTER
605
ADMINISTRATION BUILDING
WASTE WATER TREATMENT PLANT
610
HAMBURG TRAIL
HIGHWAY 94
615
LEGEND
• - MONITORING WELL
- SURFACE WATER BODIES
- STREAMS
- GROUNDWATER DIVIDE
615 - POTENTIOMETRIC SURFACE (AVERAGE)
N
0
800
1600
SCALE
FEET
2000 POTENTIOMETRIC SURFACE
Figure D-4
REPORT NO.: DOE/GJ/79491-646
EXHIBIT NO.: A/CP/019/0303
ORIGINATOR: RC
DRAWN BY: GLN
DATE: 3/20/03

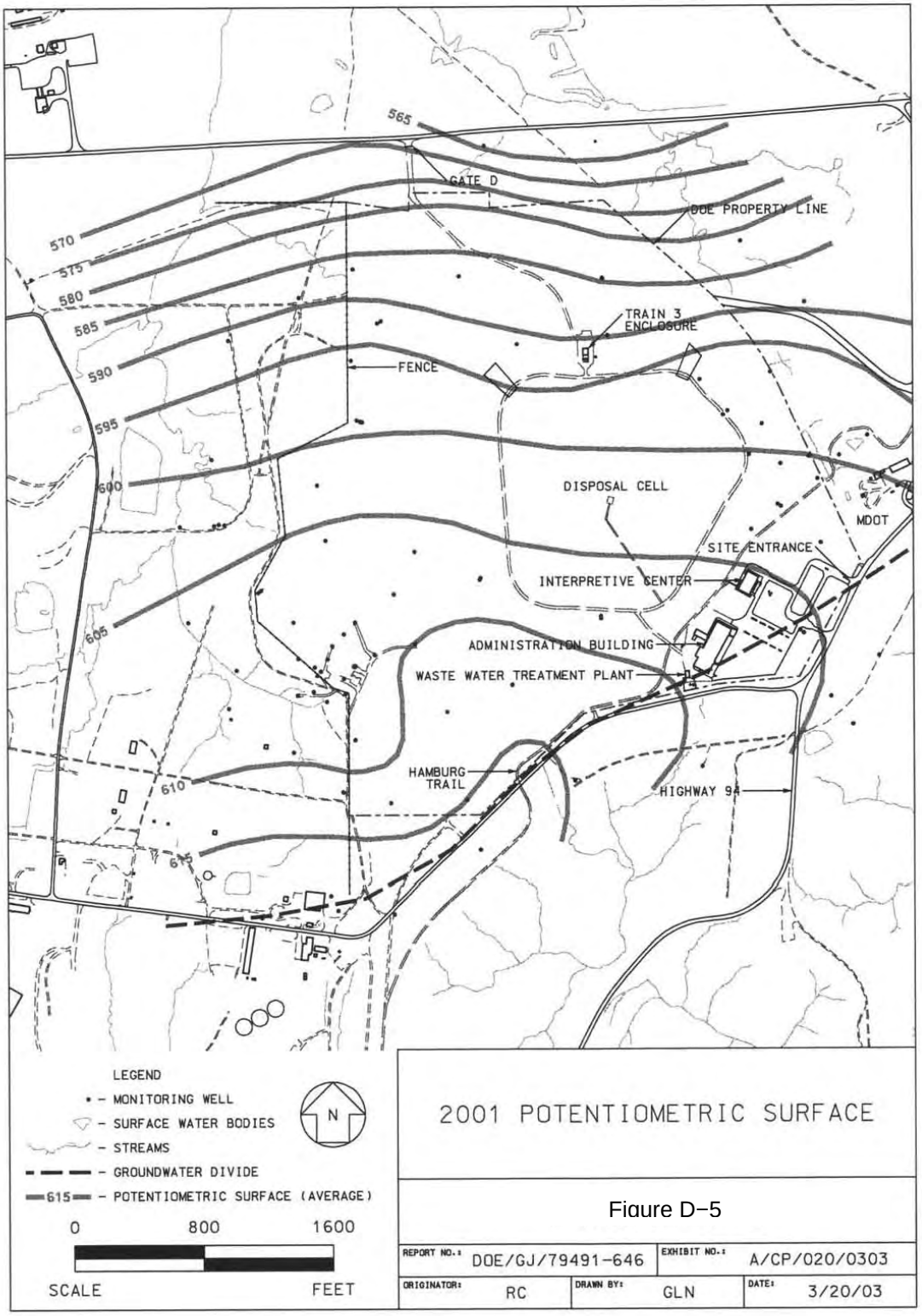
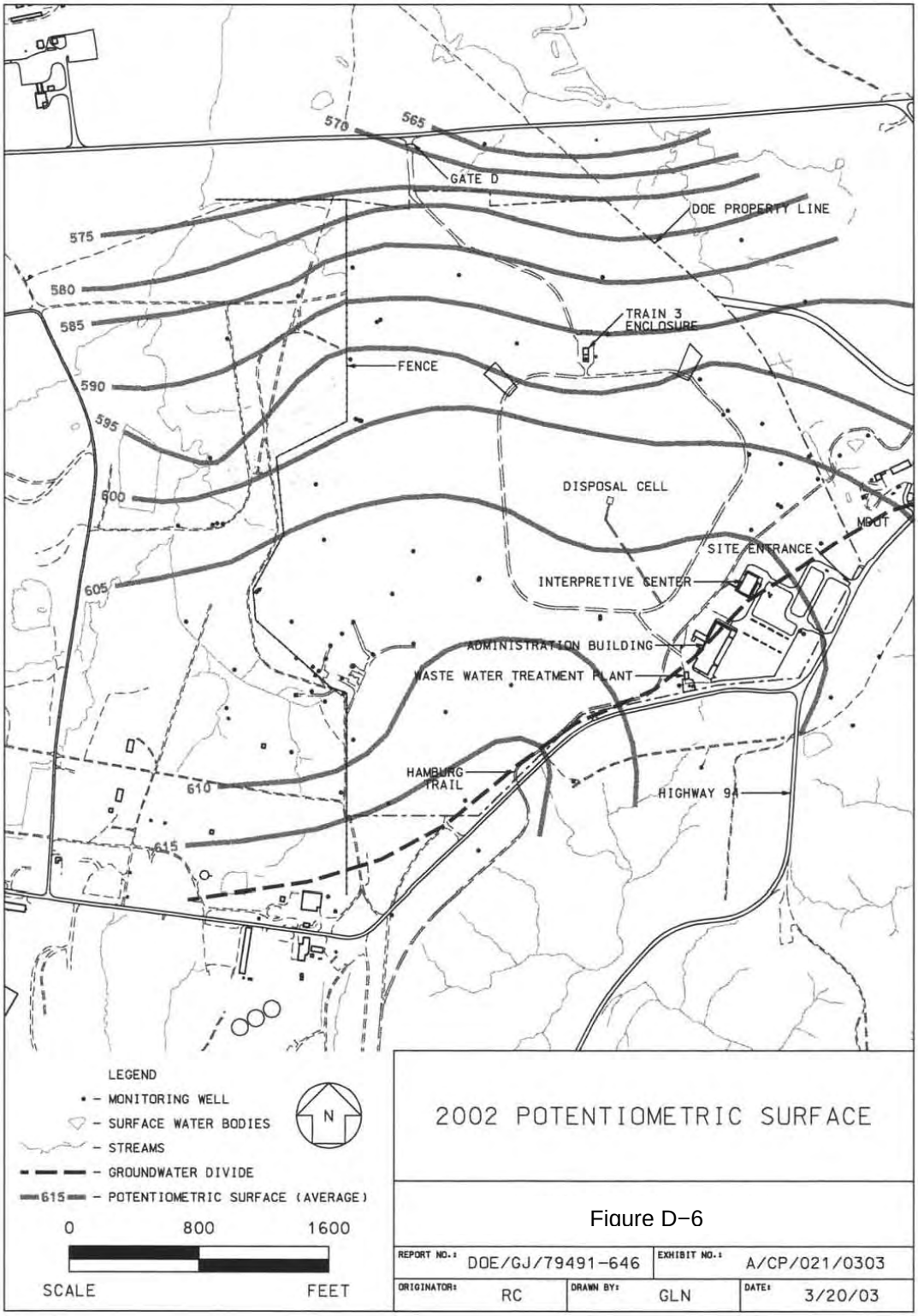

565
570
575
580
585
590
595
600
605
610
615
GATE D
DOE PROPERTY LINE
TRAIN 3 ENCLOSURE
FENCE
DISPOSAL CELL
MDOT
SITE ENTRANCE
INTERPRETIVE CENTER
ADMINISTRATION BUILDING
WASTE WATER TREATMENT PLANT
HAMBURG TRAIL
HIGHWAY 94
LEGEND
• - MONITORING WELL
- SURFACE WATER BODIES
- STREAMS
- GROUNDWATER DIVIDE
615 - POTENTIOMETRIC SURFACE (AVERAGE)
N
0
800
1600
SCALE
FEET
2001 POTENTIOMETRIC SURFACE
REPORT NO.: DOE/GJ/79491-646
EXHIBIT NO.: A/CP/020/0303
ORIGINATOR: RC
DRAWN BY: GLN
DATE: 3/20/03

Figure D-5


570
565
GATE D
DOE PROPERTY LINE
575
580
585
590
595
600
605
610
615
TRAIN 3 ENCLOSURE
FENCE
DISPOSAL CELL
MDOT
SITE ENTRANCE
INTERPRETIVE CENTER
ADMINISTRATION BUILDING
WASTE WATER TREATMENT PLANT
HAMBURG TRAIL
HIGHWAY 94
LEGEND
• - MONITORING WELL
- SURFACE WATER BODIES
- STREAMS
- GROUNDWATER DIVIDE
615 - POTENTIOMETRIC SURFACE (AVERAGE)
N
0
800
1600
SCALE
FEET
2002 POTENTIOMETRIC SURFACE
Figure D-6
REPORT NO.: DOE/GJ/79491-646
EXHIBIT NO.: A/CP/021/0303
ORIGINATOR: RC
DRAWN BY: GLN
DATE: 3/20/03

		YEAR				
LOCATION_	Data	1998	1999	2000	2001	2002
MW-2001	Average of WATER_ELEVATION	588.115	588.2175	587.9475	587.5625	588.0725
	Max of WATER_ELEVATION	588.73	588.58	588.48	587.69	588.43
	Min of WATER_ELEVATION	587.47	587.78	587.73	587.41	587.84
	Count of WATER_ELEVATION	4	4	4	4	4
MW-2002	Average of WATER_ELEVATION	593.214	592.9025	593.41	591.815	591.86
	Max of WATER_ELEVATION	593.99	593.51	594.3	592.68	592.29
	Min of WATER_ELEVATION	592.53	592.41	592.22	591.36	591.61
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2003	Average of WATER_ELEVATION	597.335	597.4875	597.0975	596.765	597.2525
	Max of WATER_ELEVATION	597.63	597.73	597.6	596.99	597.79
	Min of WATER_ELEVATION	596.98	597.19	596.33	596.47	596.79
	Count of WATER_ELEVATION	4	4	4	4	4
MW-2005	Average of WATER_ELEVATION	587.424	587.6	587.4175	587.233333	595.4425
	Max of WATER_ELEVATION	587.74	587.83	587.47	587.33	612.25
	Min of WATER_ELEVATION	587	587.44	587.38	587.16	589.79
	Count of WATER_ELEVATION	5	4	4	3	4
MW-2006	Average of WATER_ELEVATION	599.094	598.2475	597.62	598.545	598.05
	Max of WATER_ELEVATION	599.59	598.6	597.93	598.67	598.05
	Min of WATER_ELEVATION	598.67	598.01	597.22	598.29	598.05
	Count of WATER_ELEVATION	5	4	3	4	1
MW-2010	Average of WATER_ELEVATION	599.565				
	Max of WATER_ELEVATION	599.76				
	Min of WATER_ELEVATION	599.37				
	Count of WATER_ELEVATION	2				
MW-2012	Average of WATER_ELEVATION	602.936	601.0925	600.5925	600.9375	600.68
	Max of WATER_ELEVATION	604.2	601.28	600.72	601.07	600.81
	Min of WATER_ELEVATION	601.87	600.86	600.51	600.82	600.45
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2013	Average of WATER_ELEVATION	604.518	603.8475	603.1675	604.31	603.3725
	Max of WATER_ELEVATION	604.97	604.27	603.59	604.81	603.71
	Min of WATER_ELEVATION	604.15	603	602.73	604.03	602.72
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2014	Average of WATER_ELEVATION	603.934	603.5825	603.2625	603.7825	603.705
	Max of WATER_ELEVATION	604.2	603.84	603.55	604.05	603.91
	Min of WATER_ELEVATION	603.58	603.38	602.71	603.4	603.5
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2017	Average of WATER_ELEVATION	605.15	605.23	604.615	604.675	604.8425
	Max of WATER_ELEVATION	605.36	605.54	604.84	605.3	605.07
	Min of WATER_ELEVATION	604.71	604.85	604.32	604.06	604.61
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2018	Average of WATER_ELEVATION	615.482				
	Max of WATER_ELEVATION	615.82				
	Min of WATER_ELEVATION	614.87				
	Count of WATER_ELEVATION	5				
MW-2019	Average of WATER_ELEVATION	591.878				
	Max of WATER_ELEVATION	592.26				
	Min of WATER_ELEVATION	591.47				
	Count of WATER_ELEVATION	5				
MW-2021	Average of WATER_ELEVATION	589.256	589.1225	589.3025	588.27	588.6675
	Max of WATER_ELEVATION	589.98	589.66	591.44	588.5	589.21
	Min of WATER_ELEVATION	588.42	588.58	588.48	587.98	588.29
	Count of WATER_ELEVATION	5	4	4	4	4

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MW-2022	Average of WATER_ELEVATION	585.07	585.31	584.99	590.95	586.145
	Max of WATER_ELEVATION	585.67	585.65	585.14	603.07	586.44
	Min of WATER_ELEVATION	584.58	585.07	584.71	584.74	586.01
	Count of WATER_ELEVATION	4	4	4	3	4
MW-2023	Average of WATER_ELEVATION	582.964	583.18	583.075	583.1025	583.19
	Max of WATER_ELEVATION	583.19	583.33	583.18	583.2	583.34
	Min of WATER_ELEVATION	582.4	583.11	582.96	582.99	583.08
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2024	Average of WATER_ELEVATION	566.956	567.255	566.67	566.6925	567.2875
	Max of WATER_ELEVATION	567.66	567.87	567	566.94	567.76
	Min of WATER_ELEVATION	566.2	566.88	566.49	566.16	566.83
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2026	Average of WATER_ELEVATION	590.855				
	Max of WATER_ELEVATION	591.18				
	Min of WATER_ELEVATION	590.53				
	Count of WATER_ELEVATION	2				
MW-2027	Average of WATER_ELEVATION	591.95				
	Max of WATER_ELEVATION	592.24				
	Min of WATER_ELEVATION	591.66				
	Count of WATER_ELEVATION	2				
MW-2032	Average of WATER_ELEVATION	582.886	583.01	582.8675	582.09	582.92
	Max of WATER_ELEVATION	583.09	583.49	582.9	582.09	582.92
	Min of WATER_ELEVATION	582.79	582.74	582.82	582.09	582.92
	Count of WATER_ELEVATION	5	4	4	1	1
MW-2033	Average of WATER_ELEVATION	605.096	604.645	604.52	605.08	604.34
	Max of WATER_ELEVATION	605.55	604.85	604.71	605.27	604.69
	Min of WATER_ELEVATION	604.69	604.32	604.27	604.82	603.44
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2034	Average of WATER_ELEVATION	606.302	606.495	605.61	605.63	605.6725
	Max of WATER_ELEVATION	606.81	606.71	605.68	606.6	606.11
	Min of WATER_ELEVATION	605.69	606.02	605.41	604.77	605.13
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2035	Average of WATER_ELEVATION	613.708	613.7275	613.2475	612.636667	615.7125
	Max of WATER_ELEVATION	614.08	613.97	613.36	612.91	615.79
	Min of WATER_ELEVATION	612.92	613.45	613.19	612.49	615.59
	Count of WATER_ELEVATION	5	4	4	3	4
MW-2036	Average of WATER_ELEVATION	610.552	610.755	609.9875	608.7975	609.4725
	Max of WATER_ELEVATION	611.57	610.91	610.21	610.21	609.61
	Min of WATER_ELEVATION	609.57	610.56	609.42	607.43	609.22
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2037	Average of WATER_ELEVATION	610.422	610.6875	610.19	609.42	609.51
	Max of WATER_ELEVATION	612.21	610.8	610.38	609.86	609.78
	Min of WATER_ELEVATION	608.62	610.53	610.09	608.98	609.17
	Count of WATER_ELEVATION	5	4	4	2	4
MW-2038	Average of WATER_ELEVATION	611.146	612.125	613.025	610.0675	609.9025
	Max of WATER_ELEVATION	611.87	614.65	619.63	611.1	610.06
	Min of WATER_ELEVATION	610.45	611.01	610.66	609.02	609.81
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2039	Average of WATER_ELEVATION	612.602	611.8925	612.45	615.13	611.24
	Max of WATER_ELEVATION	613.05	612.86	612.45	615.13	611.39
	Min of WATER_ELEVATION	611.86	609.6	612.45	615.13	611.05
	Count of WATER_ELEVATION	5	4	1	1	4

MW-2040	Average of WATER_ELEVATION	612.508	612.6325	611.933333	611.1675	611.065
	Max of WATER_ELEVATION	612.76	613.04	612.18	611.53	611.32
	Min of WATER_ELEVATION	612.21	612.31	611.71	610.74	610.91
	Count of WATER_ELEVATION	5	4	3	4	4
MW-2041	Average of WATER_ELEVATION	612.384	612.25	616.06		
	Max of WATER_ELEVATION	612.69	612.43	616.06		
	Min of WATER_ELEVATION	612.21	611.97	616.06		
	Count of WATER_ELEVATION	5	4	1		
MW-2042	Average of WATER_ELEVATION	613.822	613.4975	613.28		
	Max of WATER_ELEVATION	614.12	613.97	613.28		
	Min of WATER_ELEVATION	613.58	613.09	613.28		
	Count of WATER_ELEVATION	5	4	1		
MW-2043	Average of WATER_ELEVATION	611.088	613.2925	613.09		
	Max of WATER_ELEVATION	613.8	613.69	613.09		
	Min of WATER_ELEVATION	601.9	612.98	613.09		
	Count of WATER_ELEVATION	5	4	1		
MW-2044	Average of WATER_ELEVATION	613.805				
	Max of WATER_ELEVATION	613.84				
	Min of WATER_ELEVATION	613.77				
	Count of WATER_ELEVATION	2				
MW-2045	Average of WATER_ELEVATION	597.01	596.8625	596.48	599.355	596.65
	Max of WATER_ELEVATION	597.25	597	596.6	605.88	596.94
	Min of WATER_ELEVATION	596.5	596.64	596.4	597.08	596.44
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2046	Average of WATER_ELEVATION	588.842	589	589.105	589.086667	589.01
	Max of WATER_ELEVATION	589.21	589.08	589.22	589.18	589.06
	Min of WATER_ELEVATION	588.25	588.92	589.02	589.02	588.93
	Count of WATER_ELEVATION	5	4	4	3	4
MW-2047	Average of WATER_ELEVATION	590.878	591.045	595.643333	590.9275	591.01
	Max of WATER_ELEVATION	591.21	591.11	604.91	590.97	591.08
	Min of WATER_ELEVATION	590.43	590.93	590.97	590.89	590.92
	Count of WATER_ELEVATION	5	4	3	4	4
MW-2048	Average of WATER_ELEVATION	607.54	607.51	607.485	607.343333	
	Max of WATER_ELEVATION	607.72	607.66	607.64	607.39	
	Min of WATER_ELEVATION	607.08	607.43	607.42	607.3	
	Count of WATER_ELEVATION	5	4	4	3	
MW-2049	Average of WATER_ELEVATION				599.5225	599.365
	Max of WATER_ELEVATION				599.6	599.47
	Min of WATER_ELEVATION				599.43	599.23
	Count of WATER_ELEVATION				4	4
MW-2050	Average of WATER_ELEVATION				601.1825	601.03
	Max of WATER_ELEVATION				601.35	601.13
	Min of WATER_ELEVATION				600.99	600.9
	Count of WATER_ELEVATION				4	4
MW-2051	Average of WATER_ELEVATION				598.94	598.88
	Max of WATER_ELEVATION				598.95	598.99
	Min of WATER_ELEVATION				598.93	598.79
	Count of WATER_ELEVATION				2	4
MW-2055	Average of WATER_ELEVATION					606.795
	Max of WATER_ELEVATION					606.93
	Min of WATER_ELEVATION					606.66
	Count of WATER_ELEVATION					4

MW-3003	Average of WATER_ELEVATION	598.5175	598.4475	598.05	597.5275	597.72
	Max of WATER_ELEVATION	599.22	598.85	598.11	597.86	597.95
	Min of WATER_ELEVATION	597.88	598.01	597.96	597.17	597.43
	Count of WATER_ELEVATION	4	4	4	4	4
MW-3006	Average of WATER_ELEVATION	592.5375	592.57	592.0475	591.1925	591.77
	Max of WATER_ELEVATION	593.5	593.08	592.74	591.45	592.35
	Min of WATER_ELEVATION	591.85	591.94	591.49	590.78	591.22
	Count of WATER_ELEVATION	4	4	4	4	4
MW-3019B	Average of WATER_ELEVATION	606.37				
	Max of WATER_ELEVATION	606.68				
	Min of WATER_ELEVATION	606.06				
	Count of WATER_ELEVATION	2				
MW-3023	Average of WATER_ELEVATION	600.935	601.17	598.3225	599.4375	599.8675
	Max of WATER_ELEVATION	601.74	601.27	600.34	599.96	599.9
	Min of WATER_ELEVATION	600.19	601.07	592.58	598.23	599.83
	Count of WATER_ELEVATION	4	4	4	4	4
MW-3024	Average of WATER_ELEVATION	601.28	601.74	599.9	600.5425	601.115
	Max of WATER_ELEVATION	601.64	602.38	600.77	600.95	601.65
	Min of WATER_ELEVATION	600.84	601.35	597.49	600.24	600.84
	Count of WATER_ELEVATION	4	3	4	4	4
MW-3025	Average of WATER_ELEVATION	610.1375	610.193333	609.235	608.1475	607.865
	Max of WATER_ELEVATION	610.4	610.33	609.52	608.78	608.06
	Min of WATER_ELEVATION	609.48	609.99	608.88	607.33	607.61
	Count of WATER_ELEVATION	4	3	4	4	4
MW-3026	Average of WATER_ELEVATION	607.3675	606.7475	605.8725	605.26	606.0375
	Max of WATER_ELEVATION	608.49	607.22	606.27	605.36	606.53
	Min of WATER_ELEVATION	606.14	606.39	605.05	605.14	605.67
	Count of WATER_ELEVATION	4	4	4	4	4
MW-3027	Average of WATER_ELEVATION	608.49	608.1425	607.9625	606.6825	607.005
	Max of WATER_ELEVATION	609.59	608.46	609.46	607.41	607.31
	Min of WATER_ELEVATION	607.66	607.89	607.31	606.36	606.7
	Count of WATER_ELEVATION	4	4	4	4	4
MW-3028	Average of WATER_ELEVATION	609.27	610.495	610.055	602.2625	609.2775
	Max of WATER_ELEVATION	610.17	610.62	610.19	609.72	609.45
	Min of WATER_ELEVATION	608.42	610.33	609.95	593.11	608.98
	Count of WATER_ELEVATION	3	4	4	4	4
MW-3029	Average of WATER_ELEVATION	609.146667	610.3725	609.9	607.515	609.15
	Max of WATER_ELEVATION	610.04	610.5	610.04	609.59	609.31
	Min of WATER_ELEVATION	608.3	610.21	609.77	604.89	608.84
	Count of WATER_ELEVATION	3	4	4	4	4
MW-3030	Average of WATER_ELEVATION				607.103333	607.425
	Max of WATER_ELEVATION				607.29	607.55
	Min of WATER_ELEVATION				606.87	607.3
	Count of WATER_ELEVATION				3	4
MW-3031	Average of WATER_ELEVATION				608.76	608.6025
	Max of WATER_ELEVATION				608.93	609.01
	Min of WATER_ELEVATION				608.51	608.01
	Count of WATER_ELEVATION				3	4
MW-3032	Average of WATER_ELEVATION				608.93	609.3525
	Max of WATER_ELEVATION				608.93	609.51
	Min of WATER_ELEVATION				608.93	609.11
	Count of WATER_ELEVATION				1	4

MW-3033	Average of WATER_ELEVATION				585.386667	
	Max of WATER_ELEVATION				587.7	
	Min of WATER_ELEVATION				582.38	
	Count of WATER_ELEVATION				3	
MW-3034	Average of WATER_ELEVATION				608.313333	609.245
	Max of WATER_ELEVATION				610.1	609.46
	Min of WATER_ELEVATION				606.07	608.96
	Count of WATER_ELEVATION				3	4
MW-3035	Average of WATER_ELEVATION				607.773333	609.2975
	Max of WATER_ELEVATION				608.97	609.48
	Min of WATER_ELEVATION				605.59	608.99
	Count of WATER_ELEVATION				3	4
MW-3036	Average of WATER_ELEVATION				607.976667	609.2925
	Max of WATER_ELEVATION				609.61	609.46
	Min of WATER_ELEVATION				605.54	609.01
	Count of WATER_ELEVATION				3	4
MW-3037	Average of WATER_ELEVATION					601.956667
	Max of WATER_ELEVATION					602.09
	Min of WATER_ELEVATION					601.78
	Count of WATER_ELEVATION					3
MW-3038	Average of WATER_ELEVATION					609.303333
	Max of WATER_ELEVATION					609.4
	Min of WATER_ELEVATION					609.16
	Count of WATER_ELEVATION					3
MW-3039	Average of WATER_ELEVATION					608.82
	Max of WATER_ELEVATION					608.89
	Min of WATER_ELEVATION					608.76
	Count of WATER_ELEVATION					3
MW-4001	Average of WATER_ELEVATION	602.814	602.1575	601.5775	601.7725	602.48
	Max of WATER_ELEVATION	603.71	602.72	601.89	602.85	603.83
	Min of WATER_ELEVATION	601.8	601.54	601.28	601.1	601.87
	Count of WATER_ELEVATION	5	4	4	4	4
MW-4002	Average of WATER_ELEVATION	575.842	570.5225	568.86	570.436667	577.0675
	Max of WATER_ELEVATION	584.9	576.37	569.15	573.8	587.56
	Min of WATER_ELEVATION	568.16	568.27	568.71	568.75	568.8
	Count of WATER_ELEVATION	5	4	4	3	4
MW-4003	Average of WATER_ELEVATION	614.318	615.08			
	Max of WATER_ELEVATION	615.28	615.08			
	Min of WATER_ELEVATION	612.61	615.08			
	Count of WATER_ELEVATION	5	1			
MW-4004	Average of WATER_ELEVATION	612.094	612.12			
	Max of WATER_ELEVATION	612.66	612.12			
	Min of WATER_ELEVATION	611.56	612.12			
	Count of WATER_ELEVATION	5	1			
MW-4005	Average of WATER_ELEVATION	610.19	610.31			
	Max of WATER_ELEVATION	610.96	610.31			
	Min of WATER_ELEVATION	609.32	610.31			
	Count of WATER_ELEVATION	5	1			
MW-4006	Average of WATER_ELEVATION	602.938	602.1175	601.61	601.5025	602.26
	Max of WATER_ELEVATION	603.74	602.46	601.84	601.75	603.33
	Min of WATER_ELEVATION	602.27	601.64	601.4	601.14	601.66
	Count of WATER_ELEVATION	5	4	4	4	4

MW-4007	Average of WATER_ELEVATION	596.358	596.0175	594.8825	594.4625	595.325
	Max of WATER_ELEVATION	597.25	596.67	595.01	594.91	596.38
	Min of WATER_ELEVATION	595.68	595.15	594.65	593.93	594.48
	Count of WATER_ELEVATION	5	4	4	4	4
MW-4008	Average of WATER_ELEVATION	597.67	598.1			
	Max of WATER_ELEVATION	598.38	598.1			
	Min of WATER_ELEVATION	597.01	598.1			
	Count of WATER_ELEVATION	5	1			
MW-4009	Average of WATER_ELEVATION	594.2	594.73			
	Max of WATER_ELEVATION	595.45	594.73			
	Min of WATER_ELEVATION	593.21	594.73			
	Count of WATER_ELEVATION	5	1			
MW-4010	Average of WATER_ELEVATION	589.39	590.54			
	Max of WATER_ELEVATION	591.04	590.54			
	Min of WATER_ELEVATION	588.02	590.54			
	Count of WATER_ELEVATION	5	1			
MW-4011	Average of WATER_ELEVATION	592.01	591.935	591.9275	591.5875	592.76
	Max of WATER_ELEVATION	592.79	592.45	592.93	591.86	593.3
	Min of WATER_ELEVATION	591.32	591.3	591.17	591.27	591.76
	Count of WATER_ELEVATION	5	4	4	4	4
MW-4012	Average of WATER_ELEVATION	570.8725	571.08			
	Max of WATER_ELEVATION	571.25	571.08			
	Min of WATER_ELEVATION	570.72	571.08			
	Count of WATER_ELEVATION	4	1			
MW-4013	Average of WATER_ELEVATION	560.2375	560.2525	561.0325	561.0625	560.4125
	Max of WATER_ELEVATION	560.38	560.33	563.2	563.35	560.5
	Min of WATER_ELEVATION	560.16	560.22	560.22	560.29	560.36
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4014	Average of WATER_ELEVATION	560.4875	560.6375	560.5975	560.9825	561.23
	Max of WATER_ELEVATION	561.02	561.06	561.05	561.1	561.66
	Min of WATER_ELEVATION	560.21	560.33	560.07	560.8	561.04
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4015	Average of WATER_ELEVATION	581.39	581.47	580.8175	581.74	581.9575
	Max of WATER_ELEVATION	582.51	582.53	580.98	581.98	583.01
	Min of WATER_ELEVATION	580.65	580.87	580.64	581.51	581.34
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4016	Average of WATER_ELEVATION	589.14	589.25			
	Max of WATER_ELEVATION	589.42	589.25			
	Min of WATER_ELEVATION	588.82	589.25			
	Count of WATER_ELEVATION	4	1			
MW-4018	Average of WATER_ELEVATION	598.095	598.08			
	Max of WATER_ELEVATION	598.56	598.08			
	Min of WATER_ELEVATION	597.46	598.08			
	Count of WATER_ELEVATION	4	1			
MW-4019	Average of WATER_ELEVATION	613.105				
	Max of WATER_ELEVATION	613.26				
	Min of WATER_ELEVATION	612.95				
	Count of WATER_ELEVATION	2				
MW-4020	Average of WATER_ELEVATION	604.9875	605.26	604.2475	604.06	604.6225
	Max of WATER_ELEVATION	605.3	605.73	604.43	604.32	604.89
	Min of WATER_ELEVATION	604.4	604.83	604.02	603.59	604.24
	Count of WATER_ELEVATION	4	4	4	3	4

MW-4021	Average of WATER_ELEVATION	607.516667				
	Max of WATER_ELEVATION	607.65				
	Min of WATER_ELEVATION	607.32				
	Count of WATER_ELEVATION	3				
MW-4022	Average of WATER_ELEVATION	596.65	597.105	594.18	593.3225	594.0825
	Max of WATER_ELEVATION	597.22	597.62	594.67	593.49	595.69
	Min of WATER_ELEVATION	595.6	596.54	593.78	592.95	592.81
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4023	Average of WATER_ELEVATION	615.5125	615.37	614.7725	614.5775	614.5025
	Max of WATER_ELEVATION	615.95	615.64	614.94	615.08	615.07
	Min of WATER_ELEVATION	614.7	614.98	614.58	613.87	613.93
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4024	Average of WATER_ELEVATION	605.09	605.3525	604.2375	603.893333	604.5025
	Max of WATER_ELEVATION	605.45	605.86	604.38	604.18	604.84
	Min of WATER_ELEVATION	604.46	604.89	604.08	603.34	604.04
	Count of WATER_ELEVATION	4	4	4	3	4
MW-4025	Average of WATER_ELEVATION	604.9475	604.87			
	Max of WATER_ELEVATION	605.83	604.87			
	Min of WATER_ELEVATION	604.07	604.87			
	Count of WATER_ELEVATION	4	1			
MW-4026	Average of WATER_ELEVATION	459.89	459.9325	459.6	459.68	459.7525
	Max of WATER_ELEVATION	460.06	460.51	459.82	459.83	460.13
	Min of WATER_ELEVATION	459.65	459.51	459.38	459.53	459.15
	Count of WATER_ELEVATION	6	4	2	2	4
MW-4027	Average of WATER_ELEVATION	609.326667	610.5	610.0575	609.38	609.2825
	Max of WATER_ELEVATION	610.23	610.64	610.22	609.97	609.41
	Min of WATER_ELEVATION	608.41	610.42	609.93	608.79	609.03
	Count of WATER_ELEVATION	3	4	4	2	4
MW-4028	Average of WATER_ELEVATION	609.5025	610.6125	609.785	607.6625	609.34
	Max of WATER_ELEVATION	610.18	611.02	610.03	609.72	609.73
	Min of WATER_ELEVATION	608.57	610.38	609.2	605.22	608.98
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4029	Average of WATER_ELEVATION	609.465	610.435	610.0225	608.0775	609.2475
	Max of WATER_ELEVATION	610.15	610.58	610.19	609.7	609.42
	Min of WATER_ELEVATION	608.55	610.35	609.87	605.85	608.95
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4030	Average of WATER_ELEVATION				597.1625	597.21
	Max of WATER_ELEVATION				597.29	597.36
	Min of WATER_ELEVATION				597.06	597.13
	Count of WATER_ELEVATION				4	4
MW-4031	Average of WATER_ELEVATION				608.366667	609.3725
	Max of WATER_ELEVATION				608.66	609.61
	Min of WATER_ELEVATION				608.03	609.24
	Count of WATER_ELEVATION				3	4
MW-4032	Average of WATER_ELEVATION				608.54	609.5
	Max of WATER_ELEVATION				608.88	609.72
	Min of WATER_ELEVATION				608.2	609.25
	Count of WATER_ELEVATION				2	4
MW-4033	Average of WATER_ELEVATION				608.5	609.3
	Max of WATER_ELEVATION				608.72	609.42
	Min of WATER_ELEVATION				608.28	609.06
	Count of WATER_ELEVATION				2	4

MW-4034	Average of WATER_ELEVATION				610.71	611.1525
	Max of WATER_ELEVATION				610.78	611.21
	Min of WATER_ELEVATION				610.64	611.02
	Count of WATER_ELEVATION				2	4
MW-4035	Average of WATER_ELEVATION				623.24	623.8925
	Max of WATER_ELEVATION				623.42	624.08
	Min of WATER_ELEVATION				623.06	623.43
	Count of WATER_ELEVATION				2	4
MW-4036	Average of WATER_ELEVATION					592.51
	Max of WATER_ELEVATION					593.23
	Min of WATER_ELEVATION					591.63
	Count of WATER_ELEVATION					4
MW-4037	Average of WATER_ELEVATION					608.2525
	Max of WATER_ELEVATION					609.61
	Min of WATER_ELEVATION					607.19
	Count of WATER_ELEVATION					4
MW-4038	Average of WATER_ELEVATION					609.51
	Max of WATER_ELEVATION					609.64
	Min of WATER_ELEVATION					609.23
	Count of WATER_ELEVATION					4
MWS-21	Average of WATER_ELEVATION	609.33875	606.25	609.89	608.44	609.4075
	Max of WATER_ELEVATION	610.28	610.47	609.89	610.28	609.68
	Min of WATER_ELEVATION	608.93	602.03	609.89	606.6	609.19
	Count of WATER_ELEVATION	8	2	1	4	4
MWS-3	Average of WATER_ELEVATION	594.303333	598.915			
	Max of WATER_ELEVATION	594.73	603.11			
	Min of WATER_ELEVATION	593.97	594.72			
	Count of WATER_ELEVATION	3	2			
MWS-4	Average of WATER_ELEVATION	602.581429	602.675	601.39	601.556667	602.41
	Max of WATER_ELEVATION	602.94	602.85	601.39	601.94	603.53
	Min of WATER_ELEVATION	601.62	602.5	601.39	601.12	601.84
	Count of WATER_ELEVATION	7	2	1	3	4

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