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Interim Remedial Action Report for the Groundwater Operable Unit of the Weldon Spring Site

March 2005

U.S. Department
of Energy

Office of Legacy Management

Work Performed Under DOE Contract No. DE–AC01–02GJ79491
for the U.S. Department of Energy Office of Legacy Management.

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Interim Remedial Action Report for the Groundwater Operable Unit of the Weldon Spring Site

March 2005

STATE OF MISSOURI
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REGISTERED GEOLOGIST

Work Performed by S.M. Stoller Corporation under DOE Contract No. DE-AC01-02GJ79491
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Acronyms and Abbreviations

AEC	U.S. Atomic Energy Commission
ARAR	applicable or relevant and appropriate requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cm/s	centimeters per second
COC	contaminant of concern
CSR	*Code of State Regulations*
DA	U.S. Department of the Army
DNB	dinitrobenzene
DNT	dinitrotoluene
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EQAPjP	Environmental Quality Assurance Project Plan
ESD	Explanation of Significant Difference
ft	feet
FFA	Federal Facility Agreement
GWOU	Groundwater Operable Unit
IC	institutional control
ICO	in-situ chemical oxidation
in/yr	inches per year
IROD	Interim Record of Decision
LCRS	leachate collection and removal system
LM	Legacy Management
LTS&M	Long-Term Surveillance and Maintenance
MCL	maximum contaminant level
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
MNA	monitored natural attenuation

mg/L	milligram(s) per liter
µg/L	microgram(s) per liter
NEPA	National Environmental Policy Act
NPL	National Priorities List
PCB	polychlorinated biphenyl
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PMC	Project Management Contractor
QAP	Quality Assurance Program
QAPjP	Quality Assurance Project Plan
RD/RA	Remedial Design/Remedial Action
ROD	Record of Decision
RQD	rock quality designation
SOPs	standard operating procedures
TAC	Technical Assistance Contractor
TCE	trichloroethylene
TNB	trinitrobenzene
TNT	trinitrotoluene
USGS	U.S. Geological Survey
WSSRAP	Weldon Spring Site Remedial Action Project
WSUFMP	Weldon Spring Uranium Feed Materials Plant

Abstract

The Interim Remedial Action Report for the Groundwater Operable Unit documents activities that took place at the Weldon Spring Site Remedial Action Project to implement the final remedial action for groundwater at the Chemical Plant site. The interim remedial action report, which is suggested by U.S. Environmental Protection Agency (EPA) guidance, was prepared to document the activities for the Groundwater Operable Unit up to the pre-final inspection.

The final remedy for the Groundwater Operable Unit is monitored natural attenuation (MNA) with institutional controls to limit groundwater use during the period of remediation. This report is considered interim in accordance with EPA guidance. A final remedial action report will be necessary when the MNA goals are attained.

End of current text

1.0 Introduction

This Interim Remedial Action Report documents that the U.S. Department of Energy (DOE) has completed construction activities associated with the remedial action for the Groundwater Operable Unit (GWOU) at the Weldon Spring Chemical Plant site in accordance with the *Closeout Procedures for National Priorities List Sites* (EPA 2000). This report describes the monitored natural attenuation (MNA) monitoring network developed to meet the objectives described in the *Record of Decision for the Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2004a). Remediation of the Weldon Spring Site Remedial Action Project (WSSRAP) was addressed through four operable units, consistent with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements. The GWOU is the fourth of the four operable units. All construction activities identified for the GWOU remedy were completed and groundwater monitoring activities to support MNA also were initiated in July 2004. This report summarizes the activities performed for the GWOU ending with the pre-final inspection performed in July 2004.

1.1 Purpose and Scope

This Interim Remedial Action Report, which is required by the Federal Facility Agreement (FFA) (EPA 1992) between EPA and DOE, documents construction activities that have taken place to implement the remedial action(s) for the GWOU. An interim report is being prepared, as suggested in EPA guidance (EPA 2000), because of the long time period between the pre-final inspection and achieving the goals of the MNA remedial action strategy for groundwater in the Chemical Plant area. A final remedial action report will be prepared when the MNA goals are attained.

EPA guidance recommends a specified format for the remedial action report; however, this report deviates from the recommended format in order to focus on information obtained during the construction phase of the remedial action. For this interim report, background and general operable unit information that addresses various sections of the recommended format have been included in appendices. The organization of this interim report is as follows:

1. Introduction	This section describes the purpose and scope of the plan, a brief description of the site, and the regulatory requirements for the GWOU.
2. Site Hydrogeological Conceptual Model	This section presents a discussion of each of the components of the hydrogeological conceptual model for groundwater flow and contaminant migration at the Weldon Spring Chemical Plant area.
3. Monitored Natural Attenuation Monitoring Network	This section describes the RD/RA design for the MNA monitoring network, construction activities associated with the installation of new wells, and the groundwater quality data from the new wells. This section also presents an evaluation of the adequacy of the RD/RA design given the information from the new wells and provides recommendations to modify the network.
4. Institutional Controls	This section discusses the locations that need institutional controls (ICs) and the requirements for ICs that will need to be established.
5. Pre-Final Inspection	A summary of the pre-final inspection for the GWOU is presented. Deficiencies are summarized and corrective actions are described.

6. Operation and Maintenance Activities	This section describes general activities associated with implementing the MNA program including sampling, data reporting, and annual inspections to verify that the monitoring system is in good condition and that ICs are being enforced.
7. Summary of Project Costs	This section presents a tabular summary of the costs to implement the selected actions and key field studies for the GWOU.
Appendix A – Background Information	Background information which includes the site history, regulatory and enforcement history, environmental documentation, site investigations, land use, and groundwater and spring water use is presented in the appendix.
Appendix B – Construction Activities Associated with Installation of New Wells	Descriptions of the activities taken to implement the MNA monitoring network are given in this appendix. Hydrogeologic data are interpreted using recently collected data.
Appendix C – Chronology of Events	A tabular summary of major events for the GWOU is presented in Appendix C.
Appendix D – Quality Control	A summary of the quality assurance programs applied during construction and sampling activities for the GWOU are presented in Appendix D.
Appendix E – Health and Safety	A summary of the health and safety program applied during construction and sampling activities for the GWOU are presented in Appendix E.
Appendix F – Operable Unit Contact Information	Key contact information for the regulatory agencies and contractors involved in the design and remedial activities are listed in Appendix F.

1.2 Site Description

The Weldon Spring site is in southern St. Charles County, Missouri, approximately 30 miles west of St. Louis, as shown in Figure 1–1. The site consists of two main areas, the Weldon Spring Chemical Plant and the Weldon Spring Quarry; both are located along Missouri State Route 94. Groundwater actions at the Chemical Plant are the focus of this interim report.

The Weldon Spring Chemical Plant is a 217-acre area that operated as the Weldon Spring Uranium Feed Materials Plant (WSUFMP) until 1966. Currently, only three buildings remain within the Chemical Plant property after project completion and site closure (Figure 1–2). The former access control building contains the Weldon Spring Site Interpretive Center, a place where the public can obtain information about the site after the project office closes. The administration building is used for project offices and class space by a local college. The leachate collection and removal system (LCRS) is housed in a building at the north end of the disposal cell.

The disposal cell, which covers approximately 60 acres of the Chemical Plant area, is near the middle of the 217-acre site and will be maintained and monitored by DOE. A perimeter road encircles the disposal cell to allow access from the administration area to the LCRS building and the cell.

Presently there are 92 monitoring wells on and around the Chemical Plant site (Figure 1–3). This includes the four new wells installed in support of the GWOU and four Army-owned wells routinely monitored by DOE. The final monitoring network will consist of 47 DOE-owned wells and two Army-owned wells. The remainder of the existing DOE-owned wells will be retained only for contingency sampling. These wells will be maintained until abandonment is required as a result of deterioration, damage, or other circumstances. Abandonment will be considered only after MNA monitoring has established a downward trend in contaminant concentrations within the area of impact.

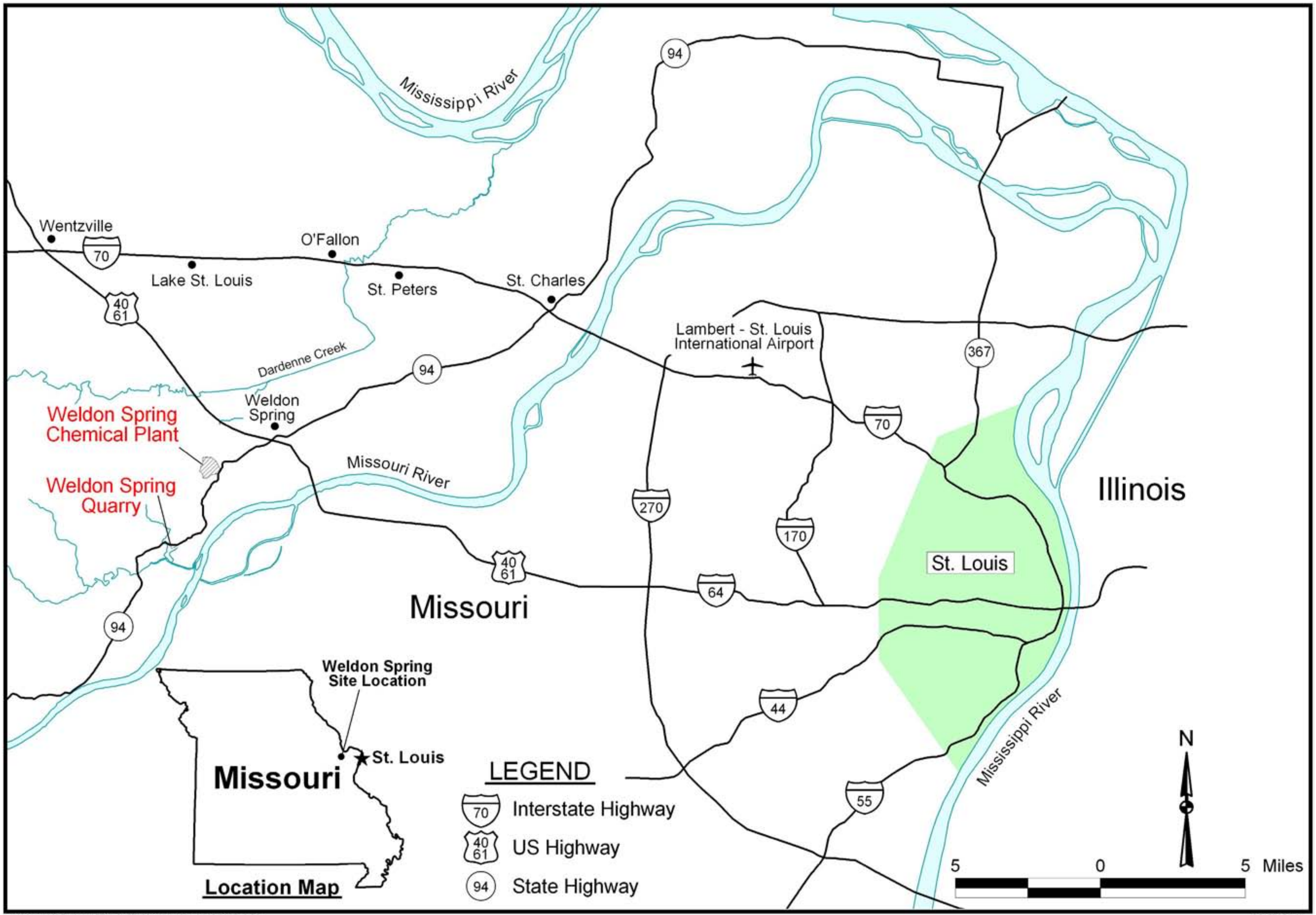

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Figure 1–1. Location of the Weldon Spring Site

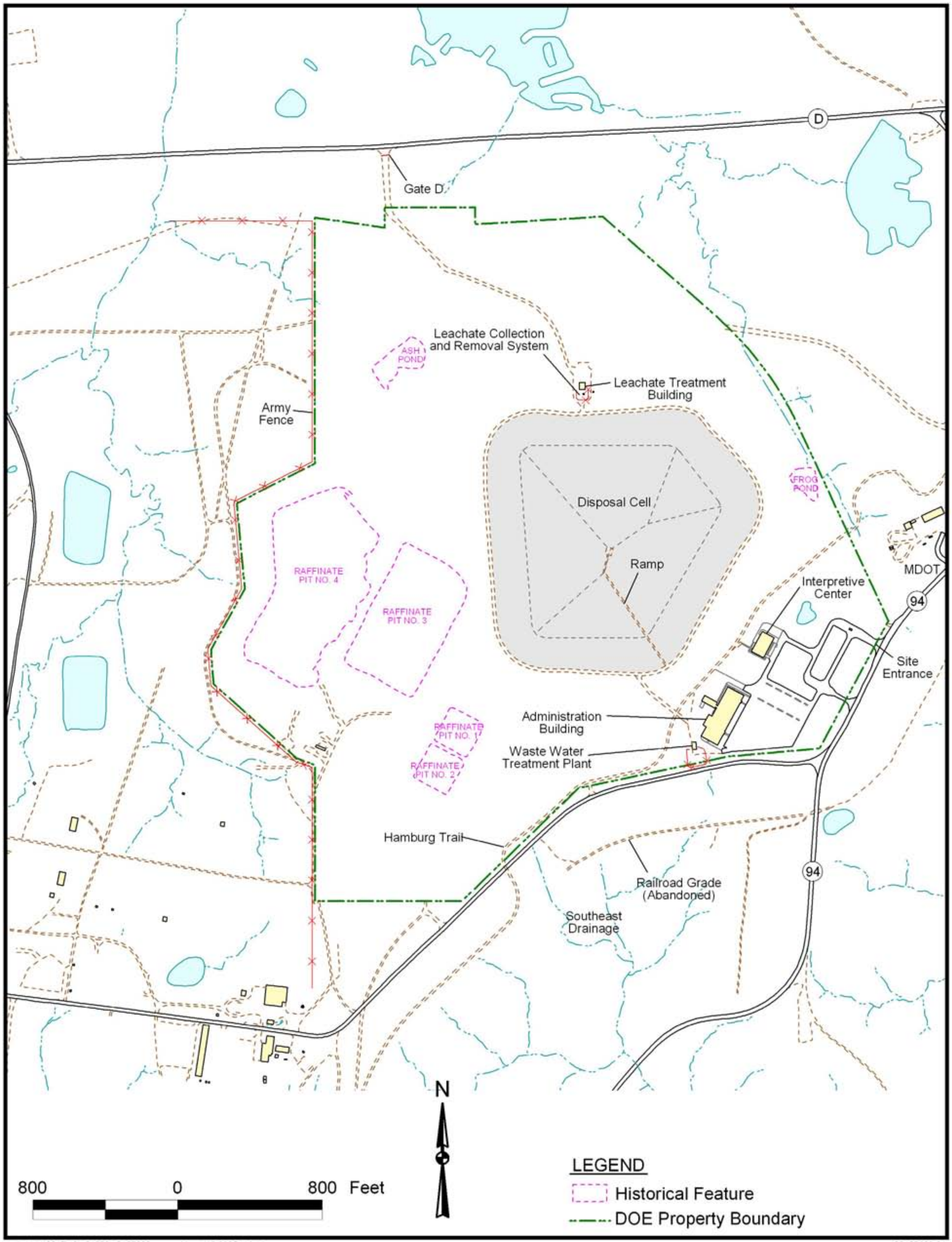

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Figure 1–2. Layout of the Weldon Spring Chemical Plant

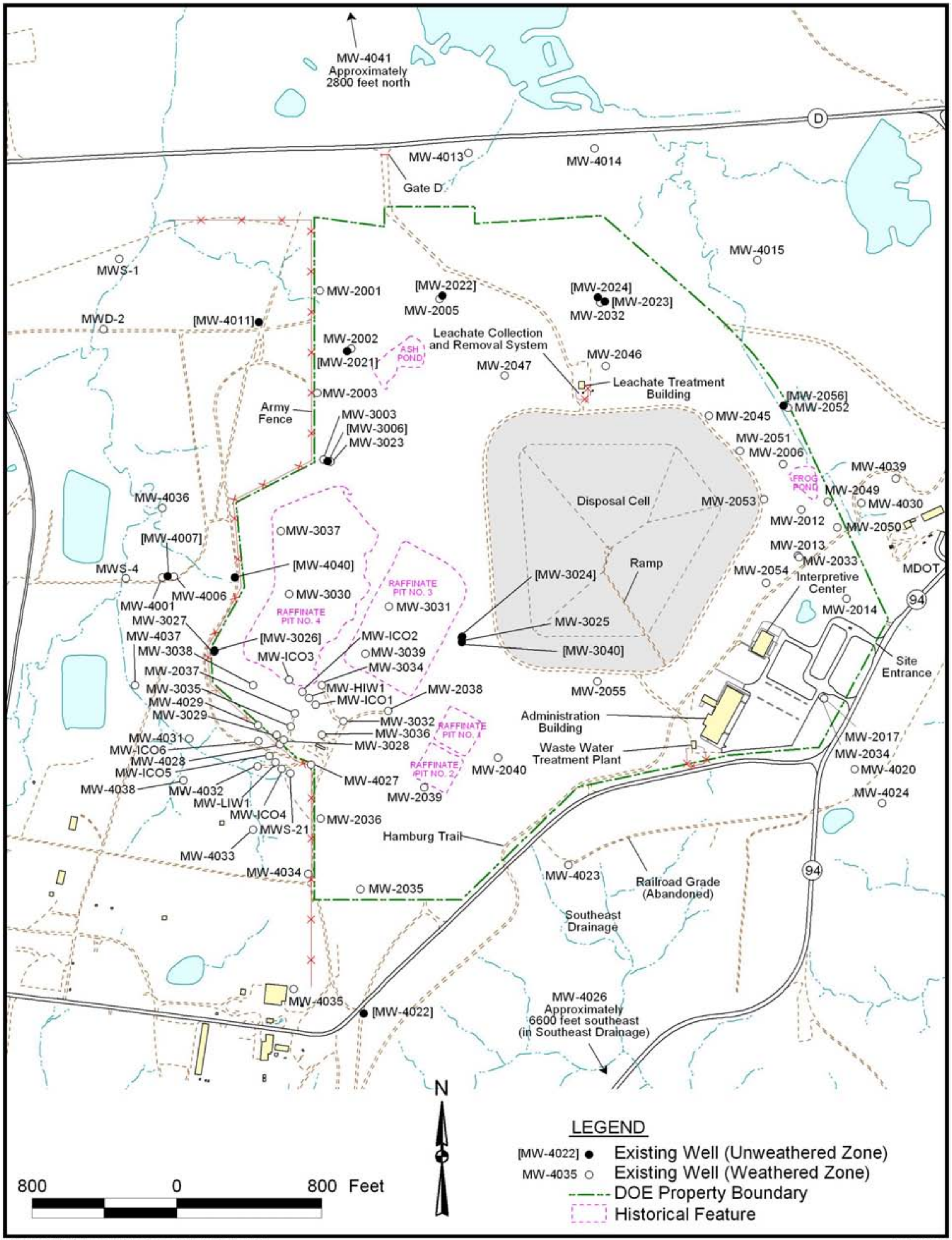

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Figure 1–3. Existing Monitoring Well Network

1.3 Regulatory Requirements

The GWOU is the second of two operable units established for the Chemical Plant area of the Weldon Spring site. The GWOU addresses contamination of the shallow groundwater aquifer at the Chemical Plant and vicinity area. A prior remedy for one GWOU contaminant of concern was selected in the Interim Record of Decision (IROD) (DOE 2000). The IROD addressed the trichloroethylene (TCE) plume and selected in-situ chemical oxidation (ICO) as the remedy. The other contaminants of concern (COCs) (nitrate, nitroaromatic compounds, and uranium) were not addressed at that time. The ICO treatment did not perform adequately under field conditions; therefore, the remediation of TCE was reevaluated along with the remaining COCs.

The final selected remedy of MNA with institutional controls (ICs) to limit groundwater use during the period of remediation specified in the *Record of Decision for the Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (ROD) (DOE 2004a) serves as the remedy selected in the IROD for TCE.

1.3.1 Record of Decision

The final ROD for the GWOU was approved by DOE and the EPA in February 2004. Together, the remedial investigation, baseline risk assessment, feasibility study (including all supplemental studies), proposed plan, and ROD are the required primary documents consistent with the provisions of the FFA (EPA 1992*)* entered into between DOE and EPA.

As presented in the ROD (DOE 2004a), MNA to restore contaminated groundwater in the shallow aquifer was the selected remedial action for all the groundwater COCs. ICs to restrict groundwater and spring water use for drinking water or other uses that might impact the performance of the remedy are also included. The cleanup standards for the remedy are presented in Table 1–1.

Table 1–1. Cleanup Standards for the Groundwater Operable Unit

Contaminant of Concern	**Cleanup Standard**	**Basis of Cleanup Standard**
TCE	5 µg/L	Chemical-specific ARAR based on federal MCL for drinking water.
Nitrate (as N)	10 mg/L	Chemical-specific ARAR based on federal MCL for drinking water.
Uranium	30 µg/L (20 pCi/L)[a]	Chemical-specific ARAR based on federal MCL for drinking water.
2,4-DNT	0.11 µg/L	Chemical-specific ARAR based on State of Missouri water quality standards.
1,3-DNB	1.0 µg/L	Chemical-specific ARAR based on State of Missouri water quality standards.
Nitrobenzene	17 µg/L	Chemical-specific ARAR based on State of Missouri water quality standards.
2,6-DNT	1.3 µg/L [b]	Risk-based concentration equivalent to 10^{-5} for a resident scenario.
2,4,6-TNT	2.8 µg/L	Risk-based concentration equivalent to 10^{-6} for a resident scenario.

[a] 30 µg/L converts to 20 pCi/L based on isotopic ratios of uranium established for the Weldon Spring site.

[b] On the basis of site-specific factors, including technical limitations in achieving cleanup levels greater than a 10^{-5} risk level, the remedial goal for the selected remedy is set at 1.3 mg/L, which is the 10^{-5} risk level.

µg/L = micrograms per liter
mg/L = milligrams per liter
pCi/L = picocuries per liter
ARAR = applicable or relevant and appropriate requirements
MCL = maximum contaminant levels

1.3.2 Remedial Design/Remedial Action Work Plan

The *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit* (RD/RA) (DOE 2004b) was the primary document used in defining the design and implementation of the selected remedial action for the GWOU and was prepared in accordance with the FFA and CERCLA requirements. It provided the design strategy, implementation approach, overall schedule, general cost estimates, and major deliverables associated with the selected remedial action. The construction activities presented in the RD/RA were the installation of several wells to augment the existing monitoring network. EPA approved the combination of the remedial design and the remedial action work plans for this operable unit because it did not involve a major design and construction effort.

End of current text

2.0 Site Hydrogeologic Conceptual Model

2.1 Conceptual Model

The hydrogeologic conceptual model (Figure 2–1) consists of several complex components: thinly bedded limestone, losing and gaining stream segments and sinkholes, preferential flow zones that discharge to springs, pronounced groundwater troughs in the shallow groundwater surface, solution-enlarged joints and fractures, and extensively weathered limestone bedrock. The shallow bedrock aquifer is unconfined and has locally semiconfining conditions as the result of the presence of a leaky confining glacial unit north of the Chemical Plant. The shallow aquifer is conceptualized to be a diffuse flow system with superimposed conduit flow. The matrix in which diffuse flow occurs is a storage reservoir with a low hydraulic conductivity that slowly transfers groundwater to the conduit system. The superimposed conduit system allows for quick movement of water when it is released from the diffuse flow area or is introduced from surface water, such as a losing stream, directly into the conduit system.

Groundwater recharge occurs as infiltration from precipitation through the overburden, from surface water runoff, and historically from surface water impoundments (i.e., Raffinate Pits). The water stored in the pits likely resulted in a greater likelihood of downward movement through the overburden to the fractured limestone. Hydraulic conductivity testing of the overburden materials and the presence of a groundwater mound that existed beneath the Raffinate Pits at the Chemical Plant area indicate that recharge through the overburden was slow; however, it was steady and likely comprised a significant amount. The recharge through losing stream segments is more rapid relative to infiltration through the overburden, as evidenced by the quick discharge response of larger springs to precipitation events.

Groundwater movement in the limestone is controlled principally by horizontal fractures, bedding planes, and solution features (DOE and DA 1997). The lower section of the residuum near the bedrock contact was identified as being more permeable because of the presence of relic chert beds, gravels, and weathered limestone. Preferential horizontal flow occurred along the contact of the residuum and the underlying bedrock, when saturated. This had previously occurred in bedrock lows and beneath the Raffinate Pits prior to their removal.

Vertical groundwater movement within the bedrock occurs and is likely limited to areas that exhibit greater vertical weathering or fracturing (i.e., paleochannels). Downward movement likely occurs more in these localized areas because vertical fractures provide a connection between the weathered and unweathered zones. The downward vertical gradient within the overburden, Burlington-Keokuk Limestone, and Fern Glen Formation (shallow aquifer units) over most of the Chemical Plant area indicates recharge to the shallow aquifer system (Figure 2–2). Upward gradients are prevalent near Burgermeister Spring between the Burlington-Keokuk Limestone and the Fern Glen Formation, and represent the discharge locations of the shallow aquifer prior to Dardenne Creek.

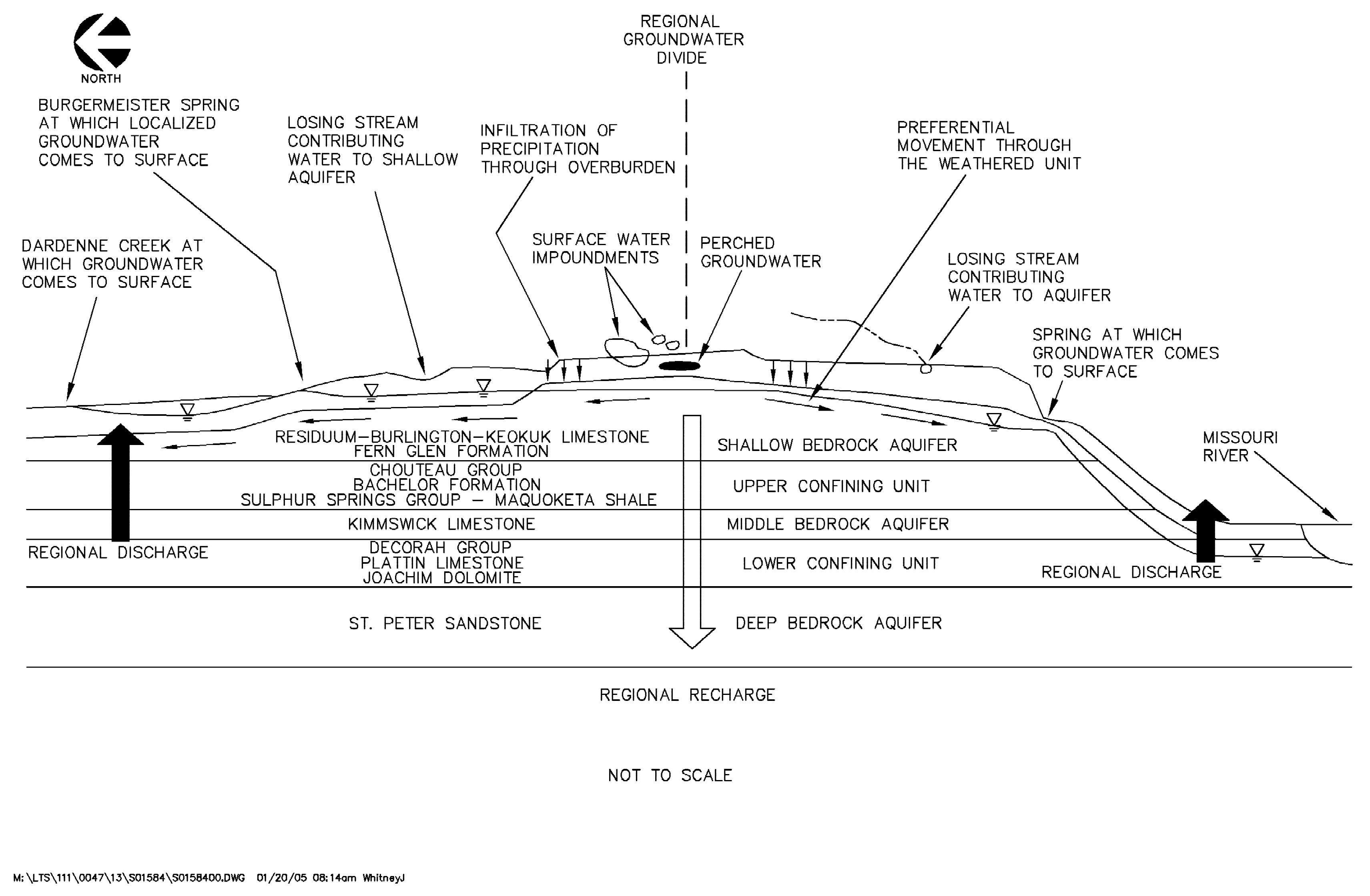

Figure 2–1. Hydrogeologic Conceptual Model for the Weldon Spring Site

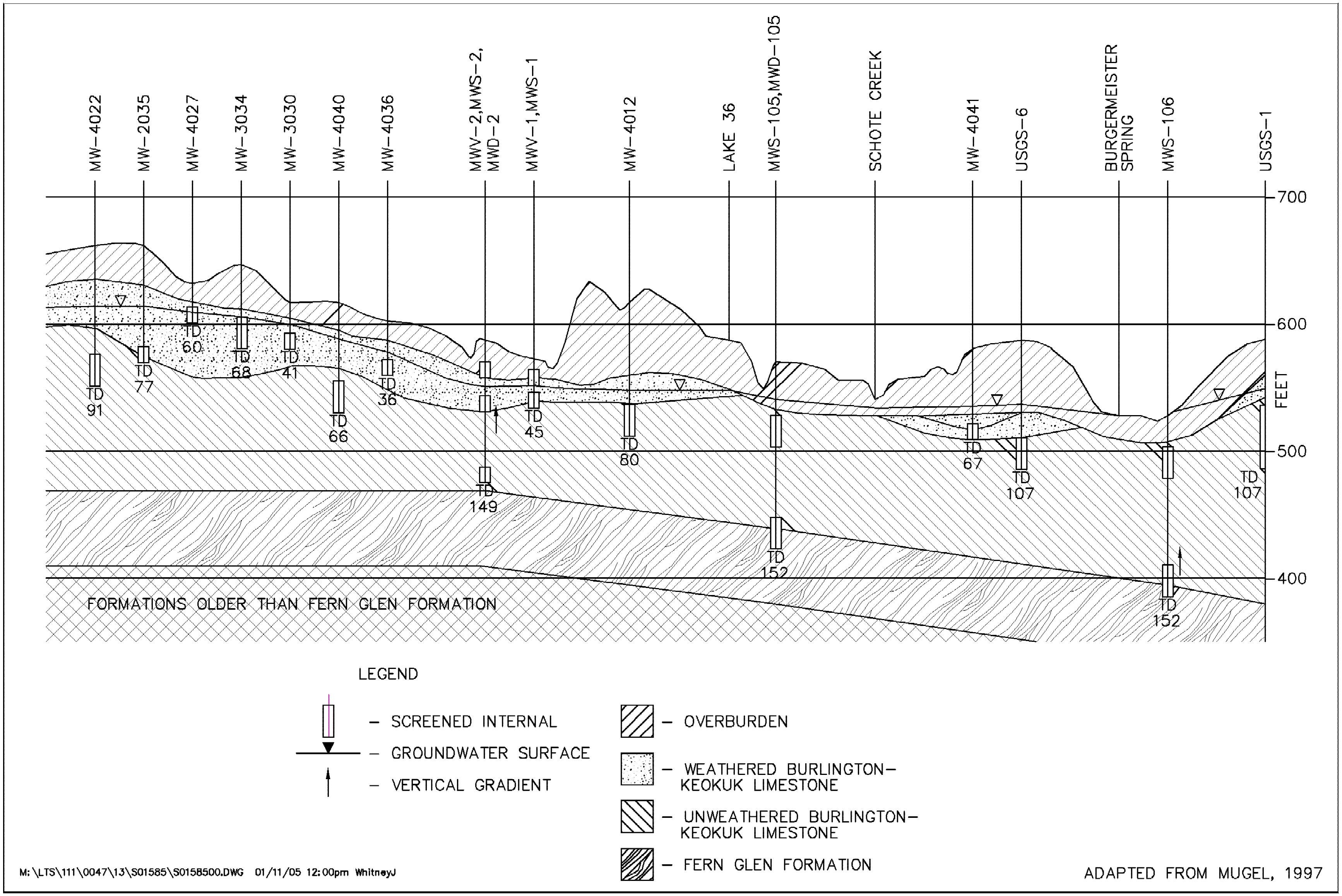

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Figure 2–2. Cross-Section of the Shallow Aquifer in the Weldon Spring Area

2.1.1 Geology

The geology of the Weldon Spring area generally can be divided into unconsolidated surficial material (overburden) and bedrock formations. The units of interest in this report are those that comprise the shallow aquifer (i.e., overburden units, Burlington-Keokuk Limestone, and the Fern Glen Formation). A generalized stratigraphic column of these units is shown in Figure 2–3.

2.1.1.1 Overburden

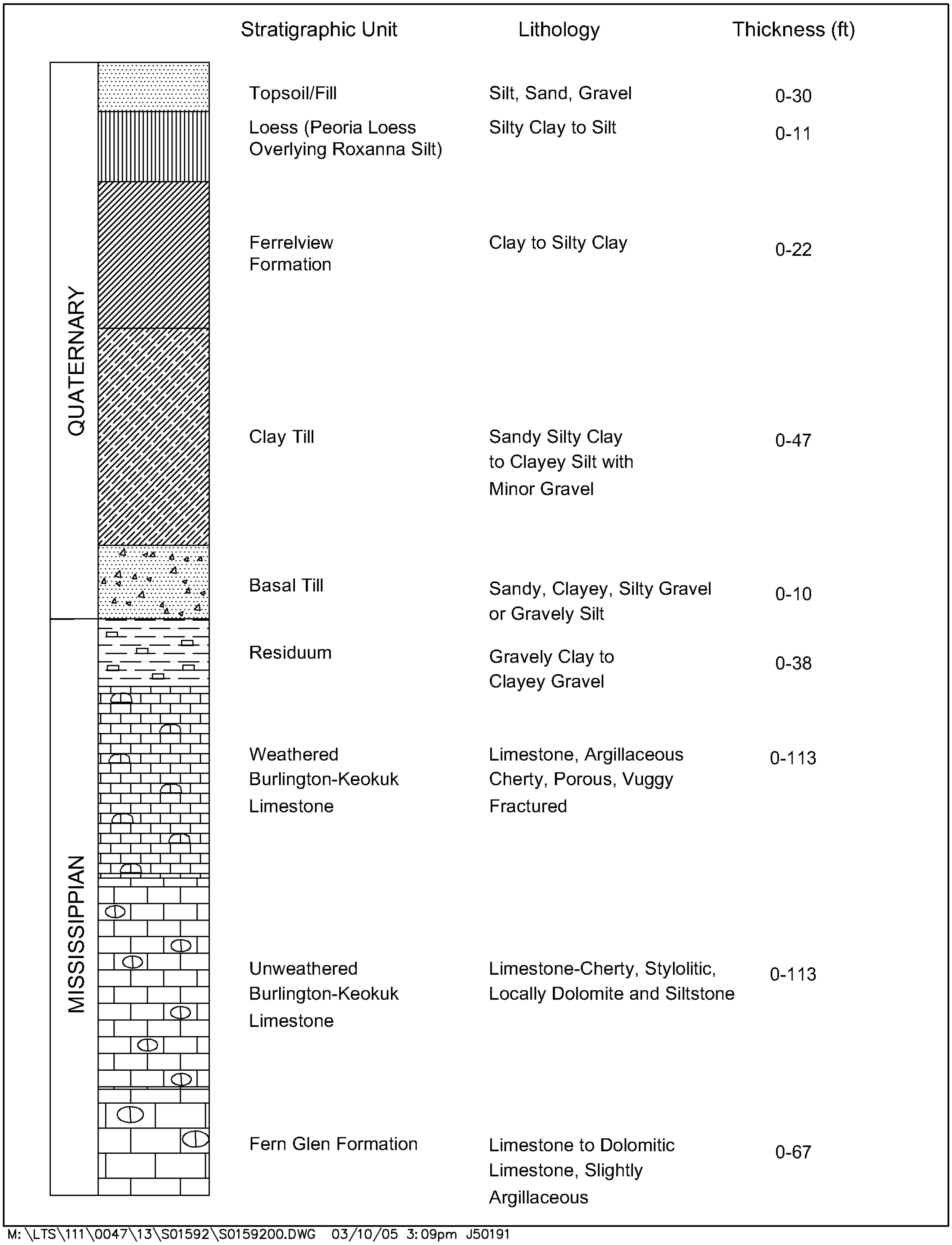
The thickness of the unconsolidated material or overburden ranges from 0 to 70 feet (ft) in the vicinity of the Chemical Plant area (DOE and DA 1997). The actual thickness depends on the topography of the site. Some of the thickest overburden occurs north of the Chemical Plant on the Busch Conservation property. The overburden is thinnest along the topographic high on the southern edge of the Chemical Plant area because of erosion.

The seven principal overburden units found at the Chemical Plant area are (1) fill/topsoil, (2) Peoria Loess, (3) Roxana Silt, (4) Ferrelview Formation, (5) clay till, (6) basal till, and (7) residuum. A more complete description of each overburden unit and a summary of physical characteristics, on the basis of laboratory tests performed on soils from the Chemical Plant and adjacent training area, are presented in the Remedial Investigation (DOE and DA 1997).

The Ferrelview Formation, the till units (basal and clay), and the residuum allow recharge to the shallow aquifer system because of the presence of hairline fractures and permeable zones (DOE and DA 1997). The residuum and till units were saturated in localized portions of the Chemical Plant, generally in bedrock lows near the Raffinate Pits and Ash Pond. On the Busch Conservation area, saturation of these units becomes more predominant, and the units act as a leaky confining unit to the shallow aquifer (Mugel 1997).

2.1.1.2 Bedrock

The Burlington-Keokuk Limestone is the uppermost bedrock unit in the Chemical Plant area. This unit is a fine to coarse-grained, thinly to massively bedded limestone containing 60 percent chert as nodules and interbeds. The approximate thickness of this limestone ranges from 40 to 185 ft at the Chemical Plant area (DOE and DA 1997). On the basis of stratigraphy and the degree of weathering, the Burlington-Keokuk Limestone has been characterized as having two different units or zones: a weathered zone and an unweathered zone. The weathered zone is the uppermost portion of the limestone formation and is characterized as generally having a higher hydraulic conductivity because of increased weathering. The lower unweathered zone is characterized as generally having a lower hydraulic conductivity because of a decrease in weathering. The contact between the weathered and unweathered zones is not distinct, but gradual instead, since the degree of weathering gradually decreases with depth.



Stratigraphic Unit	Lithology	Thickness (ft)
Topsoil/Fill	Silt, Sand, Gravel	0-30
Loess (Peoria Loess Overlying Roxanna Silt)	Silty Clay to Silt	0-11
Ferrelview Formation	Clay to Silty Clay	0-22
Clay Till	Sandy Silty Clay to Clayey Silt with Minor Gravel	0-47
Basal Till	Sandy, Clayey, Silty Gravel or Gravely Silt	0-10
Residuum	Gravely Clay to Clayey Gravel	0-38
Weathered Burlington-Keokuk Limestone	Limestone, Argillaceous Cherty, Porous, Vuggy Fractured	0-113
Unweathered Burlington-Keokuk Limestone	Limestone-Cherty, Stylolitic, Locally Dolomite and Siltstone	0-113
Fern Glen Formation	Limestone to Dolomitic Limestone, Slightly Argillaceous	0-67

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Figure 2–3. Generalized Stratigraphic Column of the Weldon Spring Site

The weathered zone, which ranges in thickness from 10 to 55 ft at the Chemical Plant, is an argillaceous, silty limestone that contains up to 60 percent chert. The zone is micritic to finely crystalline, thickly bedded, fossiliferous, closely fractured, and slightly to severely weathered with abundant iron and manganese oxide staining in the rock matrix and along fractures. Fracture spacing ranges from 0.1 to 1 ft. Angled borings indicate that horizontal bedding plane fractures occur more frequently than vertical fractures by approximately 20 to 1. The weathered zone is moderately to highly fractured with the majority of the rock quality designation (RQD) values in the poor to very poor category (DOE and DA 1997). Solution features are common in the weathered zone and range from pinpoint vugs to small zones of core loss, typically less than 5 ft; however, these features are generally clay filled. Zones of deeper weathering coincide with the location of vertical fractures and pre-glacial drainage features, and create preferential pathways for rapid movement of groundwater. The size, abundance, geometry, and connection of the open fractures and solution features within the bedrock affect the movement of groundwater through the bedrock.

The unweathered zone of the Burlington-Keokuk Limestone is finely to coarsely crystalline, thinly to massively bedded, locally argillaceous, fossiliferous, and slightly weathered to fresh with 20 percent to 40 percent chert, although zones of more intense weathering may occur (DOE and DA 1997). Fresh pyrite is present on some of the fracture surfaces, although this portion of the unit lacks significant fracturing and iron staining. Generally, the RQD values for this unit are in the fair to excellent category. Only one well at the Chemical Plant, which was located along the southern boundary, penetrated the full thickness of this zone. The thickness of the unweathered zone at this location is 127 ft (Mugel 1997).

The Fern Glen Formation typically is a finely crystalline dolomite and, less commonly, limestone with nodular and interbedded chert. The base of the unit typically becomes coarser and exhibits less chert content. Only one well at the Chemical Plant along the southern boundary penetrated this unit. The thickness of the unit in this area is 65 ft (Mugel 1997).

Presently the topography of the area in the vicinity of the Chemical Plant reflects the subsurface topography of the bedrock (Figure 2–4) except in the Busch Conservation area to the north where glacially derived materials were deposited over the existing topography. A bedrock high is present near the southern boundary of the site and coincides with a topographic high. Subsurface data indicate the presence of linear bedrock lows that are likely preglacial drainages in the top of the weathered Burlington-Keokuk Limestone near the northern and western boundaries of the Chemical Plant area (Figure 2–5).

The configuration of the top of the unweathered zone (Figure 2–6) generally is similar to the top of the bedrock. The contact between the two zones dips to the north with a bedrock low extending north from the middle of the site. The presence of discrete paleochannels is not evident in the unweathered zone. The highest elevations for the contact between the two zones generally correspond with the topographic high and the groundwater divide.

2.1.2 Hydrology

There are three regional bedrock aquifers in the vicinity of the Chemical Plant area: a shallow unconfined aquifer (although it may be confined locally), a middle confined aquifer, and a deep confined aquifer. Each aquifer is separated by a thick sequence of bedrock that contains shale and acts as a confining layer, limiting the vertical movement of groundwater into deeper zones.

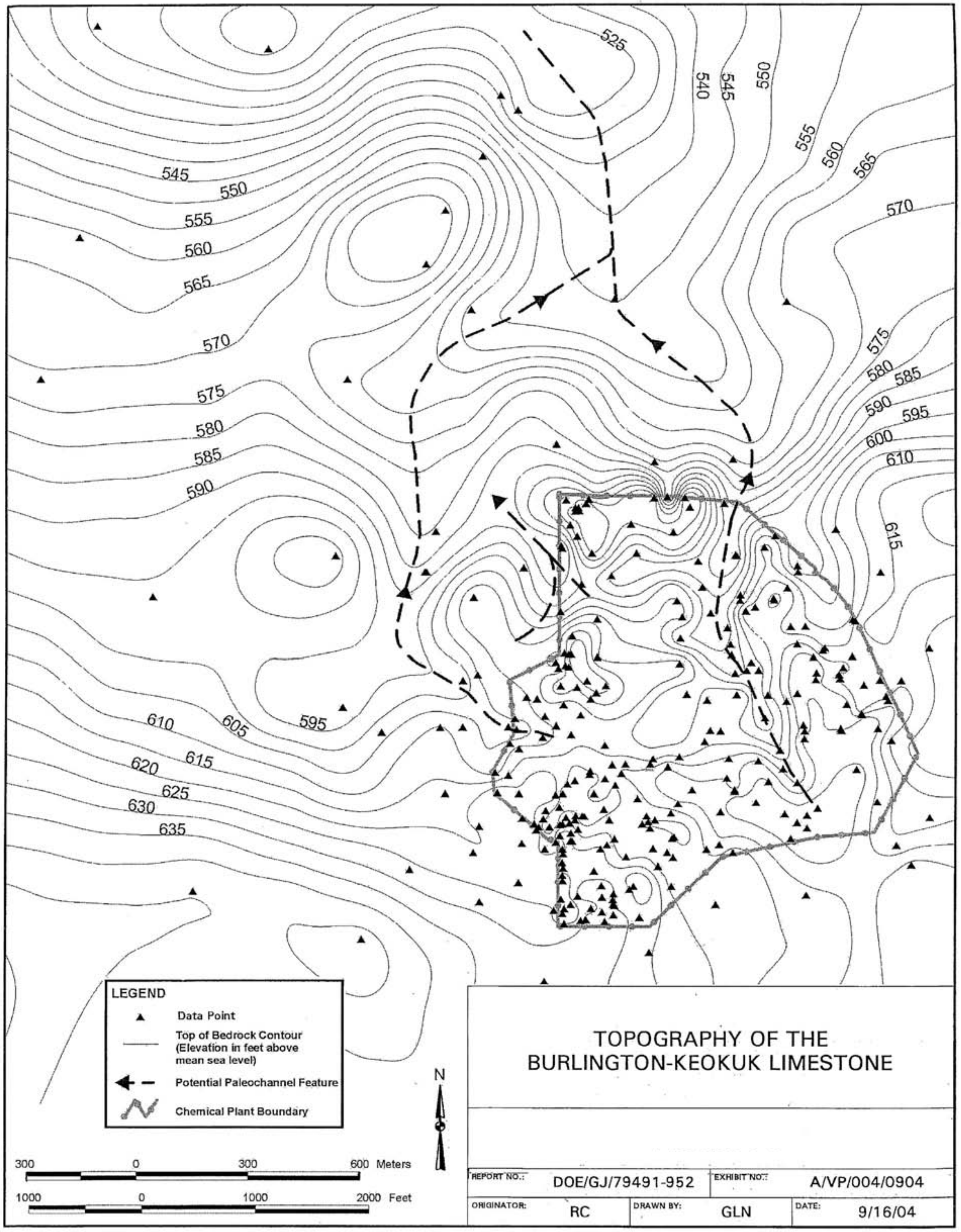

Figure 2–4. Topography of the Burlington-Keokuk Limestone

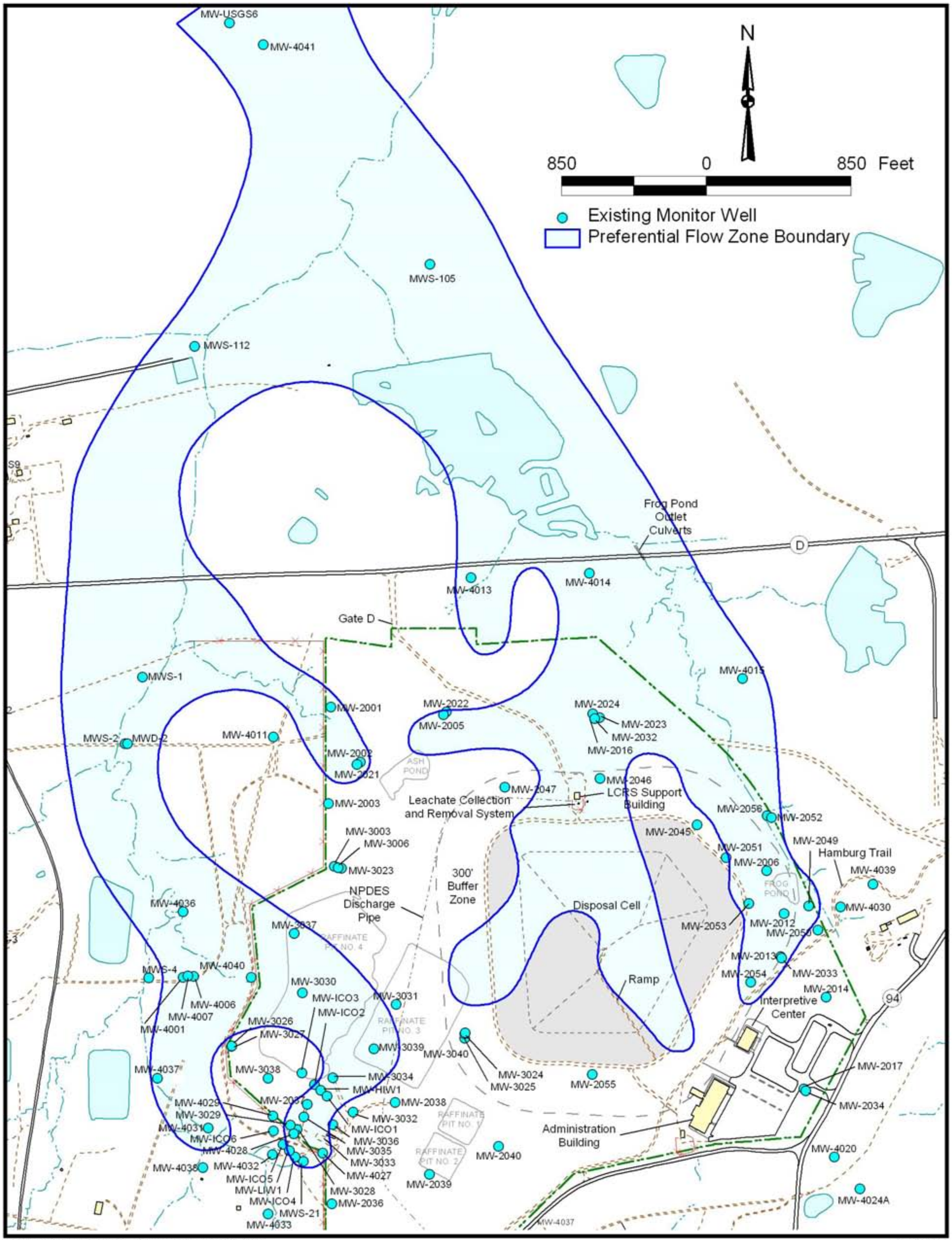

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Figure 2–5. Preferential Flow Paths in the Burlington-Keokuk Limestone at the Chemical Plant Area

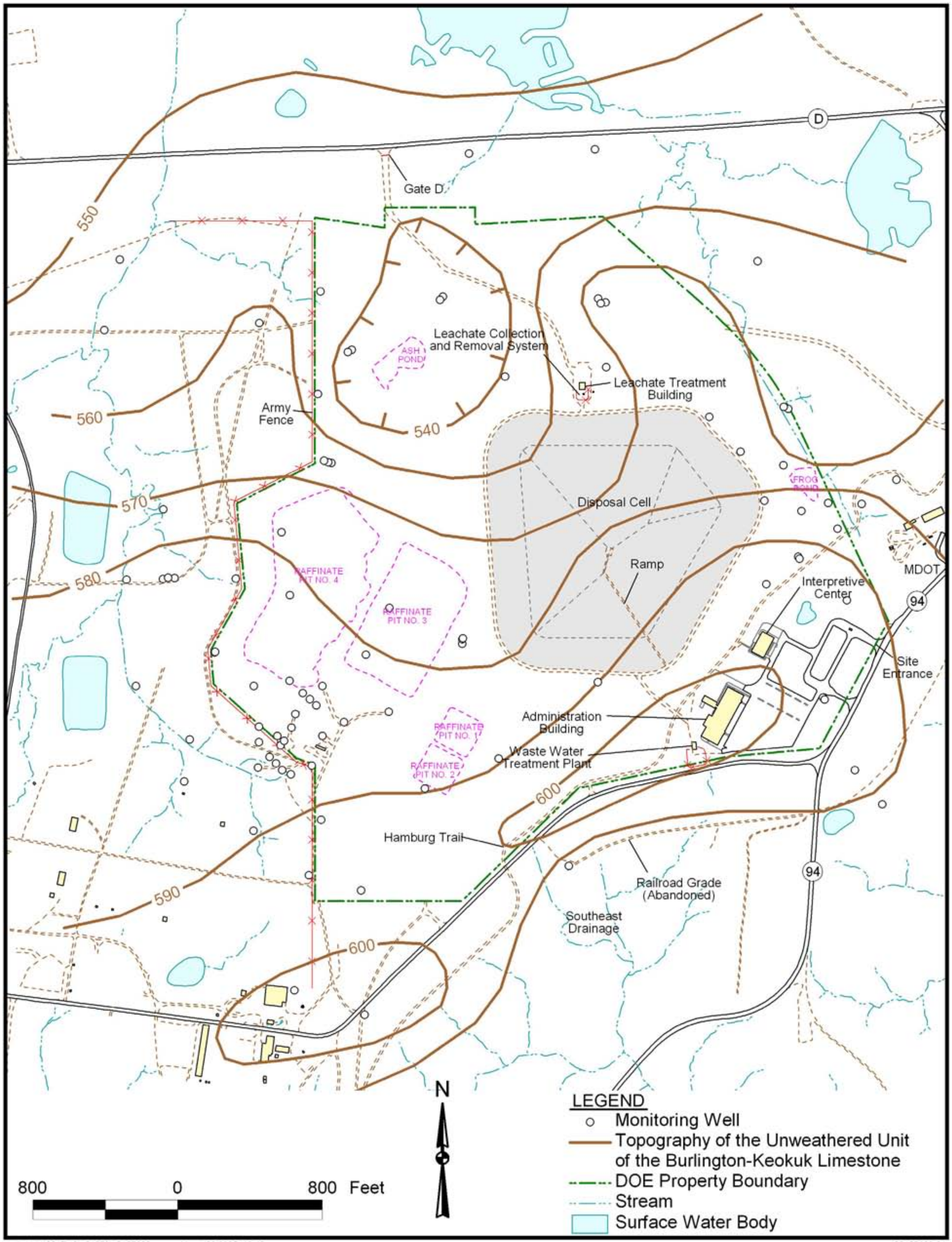

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Figure 2–6. Topography of the Unweathered Zone of the Burlington-Keokuk Limestone

The shallow aquifer has been affected by former activities at the Chemical Plant and is the groundwater system of primary interest. The shallow aquifer is composed of the overburden, where saturated, the Burlington-Keokuk Limestone, and the Fern Glen Formation (limestone unit).

Although the Burlington-Keokuk Limestone is fractured, both horizontally and vertically, and has undergone dissolution that has enlarged the fractures, groundwater flow through the shallow aquifer can be described by the hydraulic head distribution in the aquifer. The assumption is that if the bedrock has a sufficiently high density of interconnected fractures, the bedrock unit will behave as a porous media, and Darcy’s law may apply on a large scale. This assumption can be applied to portions of the Chemical Plant area, although discrete flow in large fractures or solution features in paleochannels must be taken into account in those areas that show evidence of preferential flow. The groundwater flow can be characterized by Darcian diffuse flow with superimposed conduit flow.

2.1.2.1 Aquifer Characteristics

The saturated Burlington-Keokuk Limestone exhibits both primary porosity resulting from the presence of intergranular voids within the rock matrix and secondary porosity due to fracturing and solution activity. The secondary porosity component is a predominant factor because of the extensive fracturing and weathering of the bedrock.

The shallow bedrock aquifer is both anisotropic and heterogeneous. The weathered zone is characterized by significant secondary porosity and permeability derived from fractures, bedding planes, and solution features that can control vertical and horizontal groundwater flow. Data from rock core indicate that horizontal fractures are more predominant than vertical fractures, and thus contribute to preferential horizontal flow. Less weathering and solution activity with depth correlates to lower hydraulic conductivities and slower groundwater movement deeper in the Burlington-Keokuk Limestone.

Typical of most fractured bedrock systems, localized zones of higher conductivity are sometimes encountered within the lower conductivity rock matrix. This is true for the unweathered zone of the Burlington-Keokuk Limestone. Occasional zones of higher conductivity, which are presumably associated with isolated occurrences of more intense fracturing than is observed throughout the majority of the unweathered rock, can provide limited pathways for contaminants to migrate below the gradational contact between weathered and unweathered zones. This is particularly true in areas where vertical fractures in the weathered zoned on the Burlington-Keokuk Limestone extend into the unweathered zone.

Hydraulic conductivity describes the rate at which groundwater can move though an aquifer. Testing performed at the Chemical Plant indicates that the hydraulic conductivity of the weathered and unweathered zones of the Burlington-Keokuk Limestone is highly variable. In general, the unit exhibits decreasing hydraulic conductivity with depth. In the weathered zone, the hydraulic conductivity ranges from 10^{-7} centimeters per second (cm/s) to 10^{-2} cm/s. The upper part of the weathered zone (upper 15 ft) shows a greater variation in hydraulic conductivity than does the lower part. In the unweathered zone, the hydraulic conductivity typically ranges from 10^{-7} cm/s to 10^{-4} cm/s. The highest hydraulic conductivity values occur when a zone of higher fracture frequency or localized weathering is encountered at depth.

Packer testing in the weathered zone indicates thin zones of high conductivity encompassed in a less conductive matrix. The higher hydraulic conductivity in this zone of the Burlington-Keokuk Limestone is influenced by the fracturing. The unweathered zone is characterized by its lack of significant weathering or fracturing; however, zones of higher conductivity can be observed and are associated with zones with higher fracture frequencies.

2.1.3 Shallow Groundwater Surface

In the Chemical Plant area the shallow aquifer is unconfined. However, north of the site, it behaves as a confined aquifer because the potentiometric surface is above the base of the confining layer (glacial drift) (Mugel 1997). Groundwater elevation maps for both the weathered and unweathered zones of the Burlington-Keokuk Limestone (Figure 2–7 and Figure 2–8) have been made by using average groundwater elevations from data collected in 2004.

The potentiometric surface of the shallow aquifer (Figure 2–7), as depicted by using the water levels measured in the weathered zone, shows evidence of a groundwater divide along the southern edge of the Chemical Plant. This map was constructed using average groundwater elevations measured in 2004 for each well. The general groundwater flow direction is to the north and northwest toward Burgermeister Spring. The potentiometric map suggests the topography of the bedrock and the orientation of the paleochannels control the groundwater flow directions.

At the Chemical Plant area, groundwater in the Burlington-Keokuk Limestone north of the divide flows to the north into a karst conduit system that flows toward Burgermeister Spring. Transport through this conduit can be very rapid, as demonstrated by subsurface dye trace studies performed at the Chemical Plant site (DOE and DA 1997). A large portion of groundwater beneath the Chemical Plant area discharges to the surface in the vicinity of Burgermeister Spring. This spring defines the northernmost extent of direct groundwater transport from the site and provides an ideal location for monitoring end-point contaminant concentrations.

Groundwater south of the divide in the Chemical Plant area flows south to southeast toward the Missouri River, through the Southeast Drainage. Presently no groundwater contamination that exceeds the cleanup standards is present south of the groundwater divide; however, contamination greater than the cleanup standards is present in the springs in the Southeast Drainage. The contamination present in the springs in the Southeast Drainage is the result of residual contamination in the subsurface conduits and does not have a groundwater component. Currently, contaminated groundwater impact does not extend south of the groundwater divide. Historically, contaminated water from Raffinate Pits 1 and 2 flowed into the Southeast Drainage. This drainage was used as a discharge point for effluent from the Chemical Plant operations, and because this drainage has losing stream segments in its upper reaches, mixing between groundwater and surface water occurred. Similar to Burgermeister Spring, springs in the Southeast Drainage act as end points of groundwater and provide ideal locations for monitoring contamination.

The groundwater flow direction within the unweathered zone is similar to that in the weathered zone as indicated by the potentiometric map. This figure (Figure 2–8) was constructed using the data from all available unweathered zone wells, including the three new wells installed during 2004.

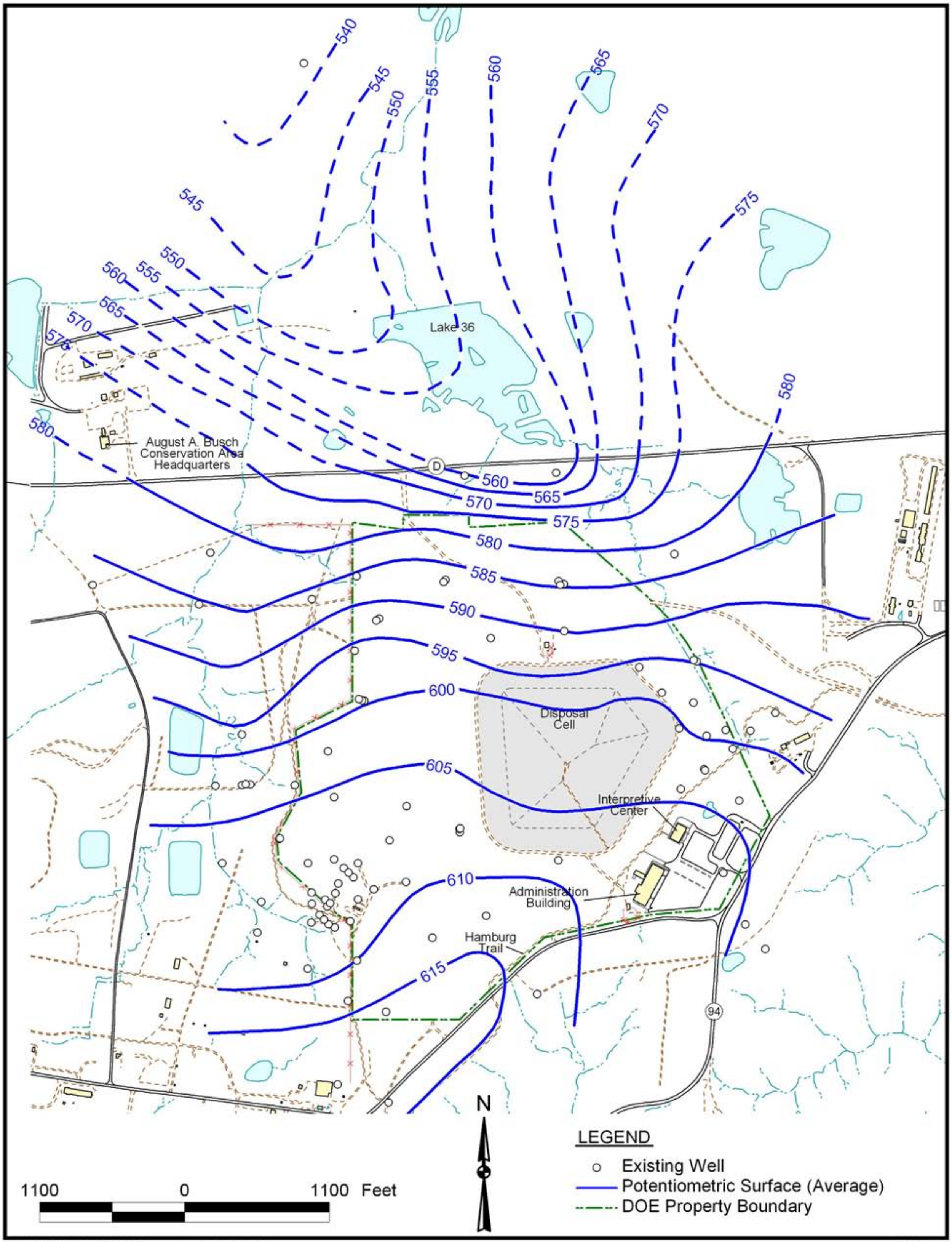

Figure 2–7. Potentiometric Surface of the Shallow Aquifer (Weathered Zone)

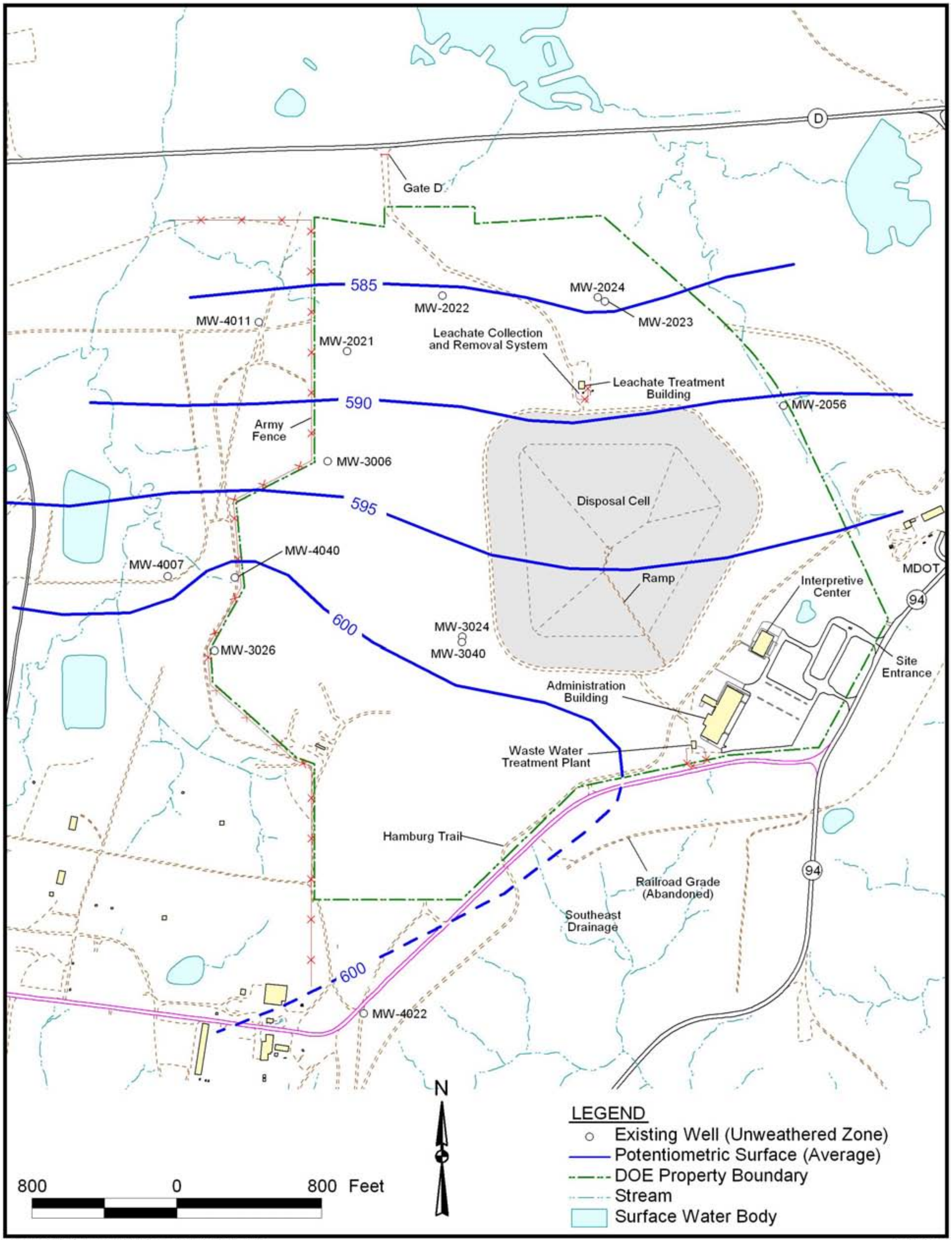

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Figure 2–8. Potentiometric Surface in the Unweathered Zone of the Burlington-Keokuk Limestone

Studies and investigations performed in the Chemical Plant area have indicated that the groundwater in the weathered zone originating from the Chemical Plant area flows north, where predominantly upward hydraulic gradients in the shallow aquifer cause groundwater to discharge to Burgermeister Spring (Kleeschulte and Imes 1994). These recharge areas, which were identified through tracer studies conducted by the Missouri Department of Natural Resources (MDNR 1991), represent sources of spring water that augment surface water sources discussed in the following section.

The conceptual model of groundwater flow from the Chemical Plant to Burgermeister Spring suggests a local flow system wherein mostly vertically downward hydraulic gradients are observed in the area of recharge (i.e., Chemical Plant) and mostly upward vertical gradients are observed north of the site, closer to Burgermeister Spring and Dardenne Creek. This infers the existence of an intermediate location, where the vertical gradients between deeper and shallow portions of the shallow aquifer indicate a transition from recharge to discharge, the hydraulic head differences are relatively small, and both downward and upward gradients may be observed. Evidence for such a transition area located near the northern boundary of the Chemical Plant is provided in potentiometric surface maps prepared for the weathered and unweathered zones in the study area (Figure 2–7 and Figure 2–8). These maps show noticeably larger differences in the heads being observed in the weathered zone than in the underlying unweathered zone in the southern portion of the site. However, with increasing distance toward the north, the observed head difference becomes less, and measured water levels in the two zones tend to be nearly equal at the site’s northern boundary.

2.1.4 Groundwater and Surface Water Interaction

Groundwater discharges from the shallow aquifer can be observed as springs and seeps in or near drainages both north and south of the groundwater divide. The final discharge points for groundwater flow are tributaries of the Mississippi River north of the groundwater divide (namely Dardenne Creek) and the Missouri River south of the divide.

To evaluate the interaction between surface water and groundwater, losing stream segments in the watershed in the vicinity of the Chemical Plant site were identified by performing seepage runs and tracer injections (DOE and DA 1997). The dye tests show two general patterns of subsurface drainage that influence groundwater movement:

- Surface water lost in drainages south of the groundwater divide does not cross into other drainages and emerges in springs within the drainage, and
- Surface water lost in drainages north of the groundwater divide can cross into adjacent surface water drainages and emerges in springs within the adjacent drainage.

The results of surface and subsurface dye tracing studies indicate the presence of a conduit system that connects surface water lost to tributaries of Schote Creek and groundwater from the northern and western portions of the Chemical Plant with Burgermeister Spring. Travel times can be within a few days (DOE and DA 1997).

On the basis of the results of seepage runs and dye tracer studies, the Southeast Drainage appears to be a closed system. Because fairly steep walls surround the stream in the Southeast Drainage, the bottom of the drainage is a likely place for groundwater discharge from the surrounding upland. This groundwater discharge can provide the sustained base flow observed in the lower reaches of the stream.

2.1.5 Aquifer Recharge

Regionally, the principal source of recharge to the shallow aquifer is infiltration of precipitation in areas where glacial drift is not present or the shallow bedrock formations are near the surface (DOE and DA 1997). In the vicinity of the Chemical Plant area, recharge occurs by infiltration through the overburden, which exhibits hairline fractures in some units, and from water entering the aquifer through losing stream segments. Historically, the Raffinate Pits provided localized recharge to the shallow aquifer.

A modeling study was performed by the U.S. Geological Survey (USGS) to quantitatively assess the groundwater flow system in St. Charles County (Kleeschulte and Imes 1994). A regional three-dimensional groundwater flow model was developed to describe groundwater flow between the shallow, middle, and deep aquifers in the county. The results of the steady-state model simulations indicate that 21 percent of the groundwater flow out of the shallow aquifer beneath the Chemical Plant area has the potential to enter the middle aquifer. Approximately 80 percent of the groundwater flow out of the middle aquifer in the same area has the potential to move into the deep aquifer. The quantity of water from the shallow aquifer that enters the deep aquifer is small, and the time required for water to travel between these aquifer systems is expected to be on the order of hundreds of years.

A detailed water-balance was performed in the *Remedial Investigation* (DOE and DA 1997) that incorporated information from a study performed by USGS (Kleeschulte and Imes 1994). Under steady-state conditions, inflow is equal to outflow. Starting with a recharge of 2.5 inches per year (in/yr) to the shallow aquifer and using the results of the three-dimensional groundwater model developed by USGS (Kleeschulte and Imes 1994), it can be estimated that the vertical recharge to the deep aquifer is about 0.6 in/yr in the immediate vicinity of the Chemical Plant.

The above water-balance does not incorporate groundwater losses from the shallow aquifer to Burgermeister Spring via preferential flow. It was estimated that 80 percent of the infiltration from precipitation is lost to Burgermeister Spring. This would lower the net recharge to the shallow aquifer from 2.5 to 1.3 in/yr. The estimated vertical recharge to the deep aquifer is about 0.1 in/yr in the immediate vicinity of the Chemical Plant, taking into account losses to Burgermeister Spring. This represents about 0.3 percent of the total precipitation on the Burgermeister Spring watershed.

2.2 Surface Water Hydrology

The Chemical Plant area is located on an east-west surface water drainage divide between the Missouri and Mississippi River watersheds. At the Chemical Plant area, surface drainage to the south of the divide generally flows through the Southeast Drainage and discharges to the Missouri River. Surface drainage to the north of the divide flows toward Dardenne Creek and its tributaries. Schote Creek, the largest of the tributaries, drains a major portion of the Chemical Plant area. Dardenne Creek flows east to the Mississippi River. Surface drainage north of the Chemical Plant can be lost to losing stream segments and can discharge to nearby springs, primarily Burgermeister Spring.

End of current text

3.0 Monitored Natural Attenuation Monitoring Network

The monitoring network consists of selected existing wells and four newly installed wells. A hydrogeologic conceptual model for the fate and transport of contaminants at the site, as discussed in Section 2.0, was used to develop the monitoring strategy. This section describes construction activities related to the installation of the new wells, provides hydrogeologic and groundwater quality information from the newly installed wells, evaluates the adequacy of the RD/RA monitoring design, and summarizes the final network as modified for the purpose of completing this phase of construction and implementing the remedial action design.

3.1 Summary of Monitoring Program Presented in RD/RA Work Plan

To ensure the performance goals for MNA are being met, a groundwater monitoring program has been developed that uses new and/or existing monitoring wells to evaluate contaminant behavior (Figure 3–1). The MNA monitoring strategy is presented below.

- Objective 1—monitor the unimpacted water quality at upgradient locations in order to maintain a baseline of naturally occurring constituents from which to evaluate changes in downgradient locations. The objective will be met by using wells upgradient of the contaminant plume.
- Objective 2—verify that contaminant concentrations are declining with time at a rate and in a manner that cleanup standards will be met in approximately 100 years as established by predictive modeling. This objective will be met by using wells at or near locations with the highest concentrations of contaminants, both near former source areas and along expected migration pathways. The objective will be to evaluate the most contaminated zones. Long-term trend analysis will be performed to confirm downward trends in contaminant concentrations over time. Performance will be gauged against long-term trends. It is anticipated that some locations could show temporary upward trends as a result of recent source control remediation, ongoing dispersion, analytical variability, or other factors. However, concentrations are not expected to exceed historical maximums.
- Objective 3—ensure that lateral migration remains confined to the current area of impact. Contaminants are expected to continue to disperse within known preferential flow paths associated with bedrock lows (paleochannels) in the upper Burlington-Keokuk Limestone and become more dilute over time. This objective will be met by monitoring various downgradient fringe locations that either are not impacted or minimally impacted. Contaminant impacts in these locations are expected to remain minimal or nonexistent.
- Objective 4—monitor locations underlying the impacted groundwater system to confirm there is no significant vertical migration of contaminants. This will be evaluated by using deeper wells screened and influenced by the unweathered zone of the Burlington-Keokuk Limestone. No significant impacts at these locations should be observed.

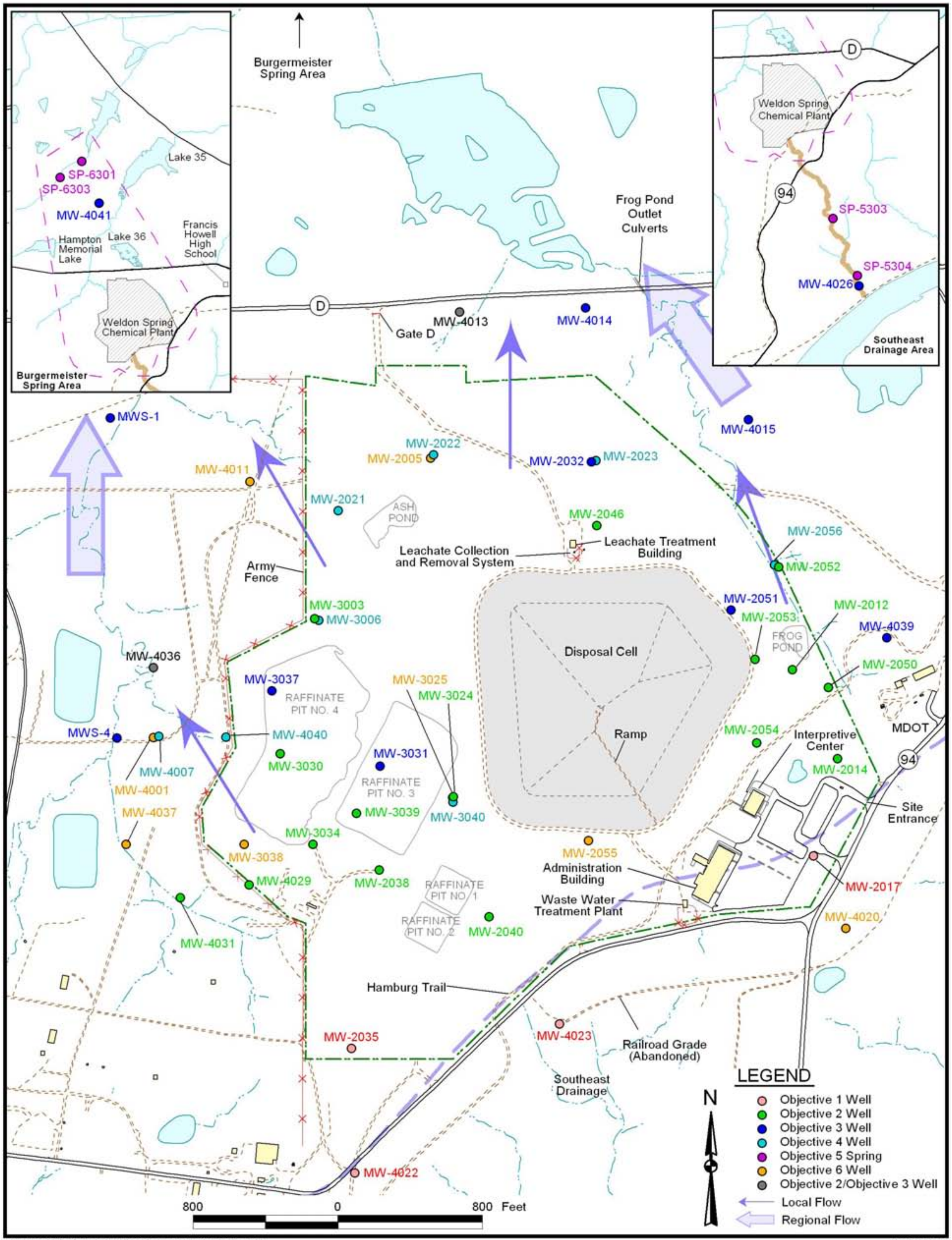

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Figure 3–1. MNA Monitoring Locations (per RD/RA Work Plan)

- Objective 5—monitor contaminant levels at the impacted springs, which are the only potential points of exposure under current land-use conditions. The springs discharge groundwater that includes contaminated groundwater originating from the Chemical Plant area. Current contaminant concentrations at these locations are protective of human health and the environment under existing recreational land uses. Continued improvement of the water quality in the affected springs should continue.
- Objective 6—monitor the hydrologic conditions at the site over time in order to identify any changes in groundwater flow that might affect the protectiveness of the selected remedy. The static groundwater elevation of the monitoring network will be measured to establish that groundwater flow is not changing significantly and resulting in changes in contaminant migration.

As discussed in the RD/RA, the six objectives are addressed under the following four monitoring programs:

Baseline Monitoring (Objective 1)	Monitor upgradient unimpacted locations in order to maintain a baseline of naturally occurring constituents to determine if downgradient conditions may be showing natural changes rather than contaminant-based changes.
Performance Monitoring (Objective 2)	Monitor contaminants of concern (COCs) to confirm downward trends in contaminant concentrations over time. Performance will be gauged against long-term trends at locations within the areas of highest impact for each COC.
Detection Monitoring (Objectives 3, 4, and 5)	Monitor groundwater contaminant levels at various downgradient perimeter locations, in the unweathered zone, and springs. Contaminants are expected to continue to disperse within known preferential flow paths, but become more dilute over time; however, trigger levels have been established that will indicate unanticipated increases at each of these locations.
Hydrologic Monitoring (Objective 6)	Monitor groundwater levels in all available wells to identify changes in flow that might effect the protectiveness of the remedy.

Sampling will be performed to gather baseline data on the new wells and on selected existing wells for inclusion in the MNA program. Baseline sampling was started in July 2004 and will be conducted for a 2-year period.

3.2 Construction Activities Associated with the New Well Installation

Three new wells were installed to supplement the existing monitoring well network (Figure 3–2). Two of these wells were installed in areas of the site where there was not adequate monitoring of the unweathered zone below areas of impact. One new well was installed north of the site to monitor potential offsite migration toward Burgermeister Spring. One additional well also was installed to assess possible impact in the unweathered zone and to assess the integrity of an existing well screened in the unweathered zone. The design rationalization for each of these is presented in the RD/RA Work Plan (DOE 2004b).

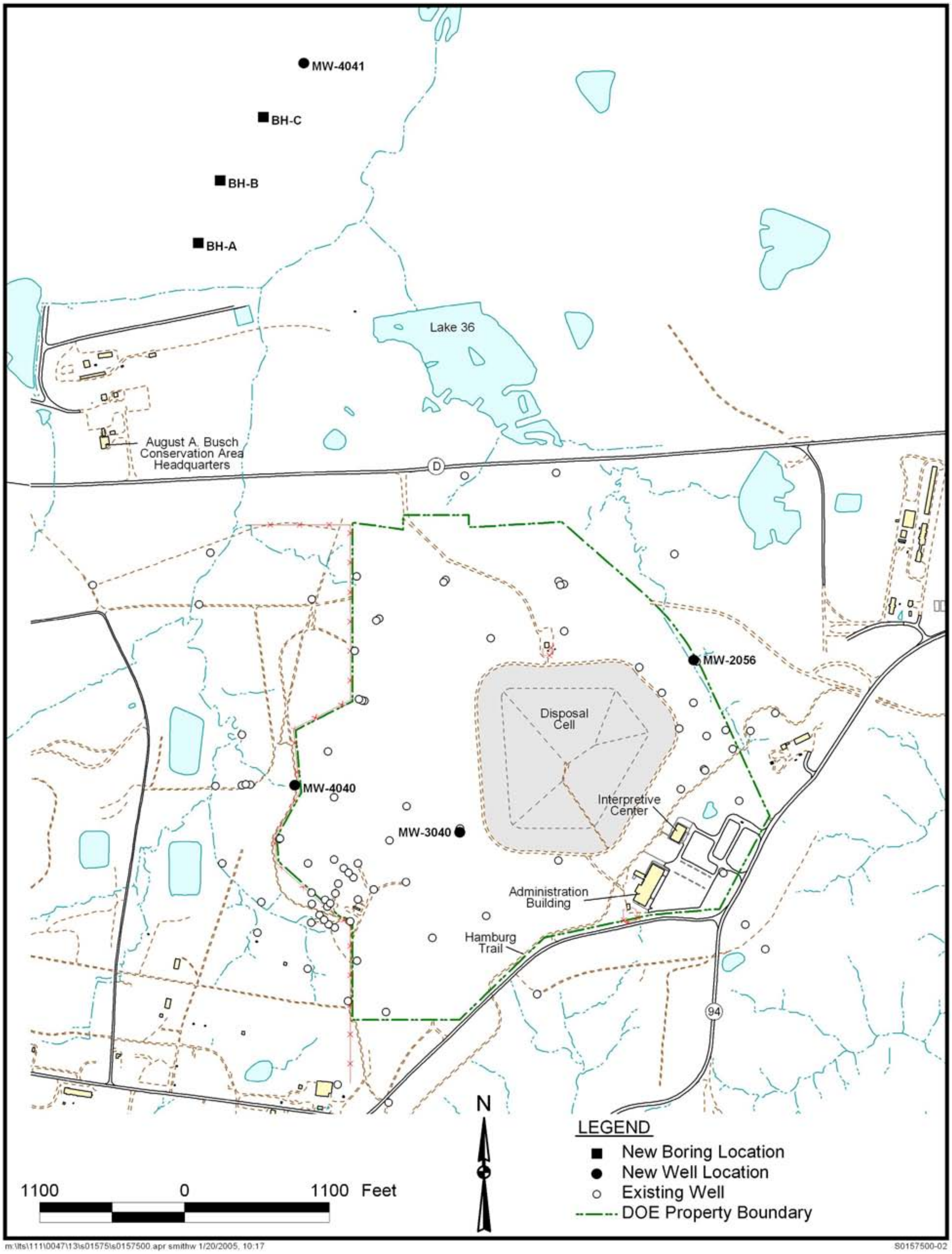


Figure 3–2. New Well Installations

3.2.1 Drilling and Well Installation

Construction activities associated with the MNA remedy consisted of installing four new wells (Figure 3–2) to complete the monitoring network that was designed to monitor MNA performance against the six objectives specified in the ROD. The drilling and well installation requirements were outlined in the RD/RA Work Plan (DOE 2004b). Installation activities included drilling and testing to obtain hydrogeologic data regarding the unweathered zone of the Burlington-Keokuk Limestone and to better define the preferential flow path north of the Chemical Plant site. A detailed account of the drilling and well installation activities is presented in Appendix B.

Three wells targeted the unweathered Burlington-Keokuk Limestone in areas of impact on the site. Well MW−2056 is clustered with MW−2052 in the Frog Pond area immediately downgradient of where nitroaromatic compound concentrations in groundwater exceed cleanup standards. This well is screened in the upper portion of the unweathered Burlington-Keokuk Limestone and was located in order to monitor groundwater quality beneath the preferential flow pathway (paleochannel). Well MW−4040, west of MW−3030 near the property boundary, is within the area of TCE, uranium, nitrate, and nitroaromatic compound contamination in groundwater that exceeds the cleanup standards, but immediately downgradient of the area of highest impact. The well is screened in the upper portion of the unweathered zone and was located to monitor the groundwater quality beneath the paleochannel in this area. Well MW−3040 was installed to monitor the unweathered Burlington-Keokuk Limestone near the existing well cluster of MW−3024 and MW−3025. A review of the hydrologic and contaminant data for MW−3024, and previous reconstruction of this well, led to uncertainty regarding the integrity of the well and the reliability of the contaminant and groundwater level data. This new well will be monitored to assess previous information regarding the unweathered zone in this area.

Well MW−4041 was installed north of the site on the Busch Conservation Area. This well monitors groundwater within the paleochannel that exhibits preferential groundwater flow and transports groundwater from the Chemical Plant site to Burgermeister Spring. The well location was identified based on the topography of the Burlington-Keokuk Limestone and the troughs in the potentiometric surface in this area. Initially, three boreholes (BH−A through BH−C) were drilled to better define the paleochannel in this area. Based on field data, an additional borehole (BH−D) was drilled north of the three original boreholes for better definition of the bedrock topography. Well MW−4041 was constructed at the BH−D location.

3.2.2 Hydrogeologic Results from Installation of New Wells

Geologic and hydrologic information from these new borings and wells were combined with the existing data from the site. In general, the geologic and hydrologic data from these locations were consistent with previous testing.

The results of numerous investigations previously conducted indicate that a subsurface conduit is present between the northern and western portions of the Chemical Plant site and Burgermeister Spring. Dye tracing of two angled borings and one monitoring well during the remedial investigation (DOE and DA 1997) established the subsurface connection, with travel times between the site and the spring ranging from 2 to 7 days. The locations of the paleochannels were determined from the bedrock topography within the Chemical Plant boundary. North of the site, the approximate location of the preferential flow pathway was inferred primarily by troughs in the potentiometric surface.

The bedrock topography north of the site is better established after drilling four borings on the Busch Conservation Area property. The position of the paleofeature is now defined by the top of the bedrock surface, which coincides with the trough in the groundwater surface (Figure 2–4). Boring BH−D exhibited the deepest bedrock elevation and little residuum was encountered. Both of these features are indicative of the paleofeatures in the vicinity of the Weldon Spring Site.

3.2.3 Contaminant of Concern Data from the Newly Installed Wells

The four new wells were initially sampled in June and July 2004 for the groundwater COCs: TCE, nitrate, uranium, 2,4-dinitrotoluene (DNT), 2,6-DNT, 2,4,6-trinitrotoluene (TNT), 1,3-dinitrobenzene (DNB), and nitrobenzene. These new wells have been incorporated into the routine sampling program for the site and additional data will continue to be collected. A summary of the data collected between June and September is presented in Table 3–1 and discussed in the following text.

Table 3–1. Summary of Contaminant Data from New Wells

Well ID	**Sample Date**	**Uranium**	**Nitrate**	**TCE**	**1,3-DNB**	**2,4,6-TNT**	**2,4-DNT**	**2,6-DNT**	**NB**
		pCi/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
MW−2056	6/30/04	0.75	0.25	< 1	< 0.02	< 0.08	< 0.04	< 0.13	< 0.08
	9/13/04	Not Analyzed			< 0.02	< 0.08	< 0.04	< 0.13	< 0.08
MW−3040	7/1/04	80.9	393	< 5	< 0.05	< 0.08	< 0.06	< 0.13	< 0.08
	7/28/04 *	95.2	242	Not Analyzed					
	8/23/04	98.8	254	< 1	Not Analyzed				
MW−4040	6/30/04	178	117	< 5	< 0.02	< 0.08	< 0.04	< 0.13	< 0.08
	7/28/04 *	181	82.2	Not Analyzed					
	8/24/04	206	92.9	< 1	< 0.02	< 0.08	< 0.04	< 0.13	< 0.08
MW−4041	6/30/04	3.3	0.07	< 1	< 0.02	< 0.08	< 0.04	< 0.13	< 0.08
	9/14/04	2.6	0.11	< 1	< 0.02	< 0.08	< 0.04	< 0.13	< 0.08
Cleanup Standard		20	10	5	1.0	2.8	0.11	1.3	17

*Resampling to verify data from previous sampling event.

TCE has not been detected in any of the newly installed monitoring wells. TCE contamination is present only in the vicinity of the former Raffinate Pits and is limited to the weathered zone of the shallow aquifer. TCE also has not been observed in wells screened in the unweathered zone in other portions of the site.

Nitrate was measured at concentrations that exceeded the cleanup standard in the two unweathered zone wells, MW−3040 and MW−4040, installed in the Raffinate Pits area. These two new locations were resampled to verify the elevated nitrate concentrations in the first samples. Subsequent data supported the presence of nitrate greater than the cleanup standard in the unweathered unit beneath the former Raffinate Pits. Historically, the highest concentrations of nitrate have been observed in the vicinity of the Raffinate Pits and Ash Pond, which were the main source areas for this contaminant. Nitrates are mobile in the shallow aquifer and are prevalent in the weathered zone, but are present in the unweathered zone only in the vicinity of the Raffinate Pits.

Uranium has been detected at levels greater than background levels (0.93 pCi/L), but less than the cleanup standard (20 pCi/L) in the new weathered zone well installed north of the Chemical Plant. However, uranium is present in the weathered zone of the shallow aquifer in the Raffinate Pits area at levels that exceed the cleanup standard. The data from the two unweathered zone wells, MW−3040 and MW−4040, installed in the Raffinate Pits area have indicated that uranium is present at levels that exceed the cleanup standard in the unweathered zone in this localized area. Uranium contamination has occurred primarily in the Raffinate Pits area, which was the historical source of uranium in groundwater as it entered the aquifer via infiltration from the Raffinate Pits through the overburden. Adsorption of uranium onto the overburden limited its extent in groundwater in the area of former Raffinate Pits 3 and 4. The long-term source of uranium in the Raffinate Pits has resulted in localized impact in this area.

No impact from nitroaromatic compounds has been indicated by the new unweathered zone wells in either the Frog Pond area or the Raffinate Pits area. No detectable concentrations of nitroaromatic compounds were detected in the weathered well installed north of the Chemical Plant. Nitroaromatic compounds occur in groundwater in the northeastern and southwestern portions of the site, where TNT production lines were located on both the Chemical Plant site and the adjacent Ordnance Works site. Contamination occurs in the weathered zone of the Burlington-Keokuk Limestone with the maximum concentrations being observed in the Frog Pond area.

Data from two of the unweathered zone wells installed at the Chemical Plant (MW−3040 and MW−4040) indicate that uranium and nitrate impact in the Raffinate Pits area extends into the unweathered zone at levels higher than previously observed. Data from other unweathered zone wells at the site, both active and abandoned, indicate that the groundwater in the unweathered zone has shown only slight impact historically. Uranium and nitrate concentrations greater than background have been measured; however, widespread impact and concentrations greater than the respective cleanup standards have not been seen. Detectable concentrations of nitroaromatic compounds have been observed sporadically in the unweathered zone.

The Raffinate Pits provided a long-term contaminant source to groundwater at the Chemical Plant site through infiltration of stored water into the subsurface. The Raffinate Pits were excavated into the deeper overburden units, which have hairline fractures that allow vertical movement of water. Nitrate and uranium are the only contaminants observed in the groundwater in the unweathered zone. This is due to the mobility of nitrate and dissolved uranium in the shallow aquifer, which has oxidizing conditions. Uranium contamination would be higher if not for the attenuation of uranium on the underlying clays, which were excavated during the remediation of the Raffinate Pits area. TCE is not present in the unweathered zone because it was stored in the pits for a shorter period of time than nitrate and uranium. TCE likely was introduced into the Raffinate Pits during one of the efforts by the U.S. Department of the Army (DA) to clean out several of the buildings. Nitroaromatic compound contamination also is not present in the unweathered zone. These compounds were not present in the waters in the Raffinate Pits.

A preferential flow pathway or paleochannel is situated beneath the area where the two largest Raffinate Pits (3 and 4) were constructed. The paleochannel in this area exhibits higher conductivity because of strongly weathered limestone, solution features, and zones of extensive fracturing. Weathering generally is more extensive because of the presence of vertical fractures that facilitated deeper movement of water. Downward transport of contaminants likely occurred in this area because vertical fracturing provided a connection between the weathered and unweathered zones. These areas are probably not large and represent localized impact of the unweathered zone. Also, the additional recharge provided by the water stored in the pits and the saturated conditions beneath part of the pits resulted in a greater likelihood of downward movement through the interconnected fracture system.

Presently, contamination of the unweathered zone is limited to the paleochannel areas. Uranium and nitrate impacts are present in the Raffinate Pits area. Nitrate impact has been observed in the unweathered zone in the Ash Pond area (MW−4011). This well is in close proximity to the paleochannel extending from the northwestern portion of the site (Figure 2–5). The data from the unweathered zone in the Frog Pond area have not indicated impact in this area.

3.3 Evaluation of the Adequacy of the RD/RA MNA Monitoring Network

The present monitoring network meets the ultimate objective of restoring the contaminated groundwater in the shallow unconfined aquifer to cleanup standards. This monitoring program also satisfies the performance goals for MNA, as outlined in the ROD: (1) contaminants will attenuate at a rate sufficient to meet cleanup standards in approximately 100 years; (2) contaminant migration will remain confined to the currently impacted groundwater system; and (3) contaminant levels at the springs will not pose unacceptable risks to receptors and will decline over time.

The groundwater quality data collected during 2004 from the existing wells are consistent with the 2002 data used during the selection process outlined in the RD/RA Work Plan. Therefore, the evaluation of the existing wells is still valid and each well meets its selected monitoring objective.

With respect to the four new wells, monitoring well MW−2056 was installed to meet Objective 4. This well was intended to monitor the groundwater quality in the unweathered limestone beneath the nitroaromatic compound impact area in the Frog Pond. This well was installed adjacent to MW−2052, which is screened in the weathered zone. Initial data from this location indicate there is no impact in the underlying unweathered Burlington-Keokuk Limestone. The elevation of groundwater in MW−2056 (approximately 6.5 ft lower than in MW−2052) is consistent with surrounding wells that also monitor the unweathered zone. Static water level data indicate that the two wells are monitoring intervals that are isolated and the data can be considered representative of two separate zones of the Burlington-Keokuk Limestone. Therefore, well MW−2056 meets the objective for which it was intended.

The second new well, MW−4041, which is installed in the Busch Conservation Area north of the site, is within the paleofeature that extends from the northern portion of the Chemical Plant to Burgermeister Spring. This well was intended to monitor MNA performance as defined in Objective 3. Data from this location indicate uranium levels are slightly above background (3 pCi/L) but are considerably lower than at Burgermeister Spring (33 pCi/L). Because these levels are lower than those at Burgermeister Spring, it is likely that this well does not monitor the specific fracture zone that connects the area of uranium impact in the Raffinate Pits area to this spring. Also, this well does not exhibit nitrate contamination, which further supports the presence of additional migration pathways to this spring. The static water levels measured in MW−4041 extend up into the overburden, indicating semi-confining conditions, as the overlying glacial drift acts as a confining unit (Mugel 1997). This behavior is typical for this area. Although this well does not exhibit the same contaminant concentrations as Burgermeister Spring, it does show impact from site-related contaminants and is located within a preferential flow zone (Figure 2–5) making it a suitable monitoring well for Objective 3.

The third new well, MW−3040 was intended to meet the purposes of Objective 4 and was installed in the unweathered zone to monitor groundwater quality below the Raffinate Pits area. This well was installed adjacent to well cluster MW−3024 and MW−3025. Well MW−3040 was installed because the integrity, and therefore the reliability, of the data obtained from MW−3024 (screened in the unweathered zone) was in question due to extensive damage and previous re-installation within the same borehole. Comparison of data from MW−3024 and MW−3040 indicate MW−3040 has higher uranium and nitrate, and lower TCE concentrations than MW−3024 (Table 3−2). Well MW−3025 data, which monitors the weathered zone, indicate there is nitrate and TCE impact, but little uranium impact. It is likely that MW−3024 is influenced by infiltration of overlying groundwater, which dilutes the uranium concentrations in the unweathered zone, and contributes TCE. The representativeness of the data from MW−3024 is questionable and, therefore, this well should not be included in the MNA monitoring program for Objective 4. Data from MW−3040 indicate that uranium and nitrate impacts extend into the unweathered zone in this area at levels that exceed the cleanup standards. Static water levels measured in MW−3040 (approximately 10 ft lower than in MW−3025) are consistent with the surrounding wells that monitor the unweathered zone. The static water level data indicate that MW−3025 and MW−3040 are monitoring intervals that are isolated and the data from this well cluster can be considered representative of two separate zones of the Burlington-Keokuk Limestone. However, based on the elevated levels of uranium and nitrate, this well does not meet its intended objective (Objective 4).

Table 3–2. Comparison of Contaminant Data in MW−3024, MW−3025, and MW−3040 (2004 Data)

Location	Uranium (pCi/L)	Nitrate (mg/L)	TCE (µg/L)
MW−3024 (UW)	32.4	108	9.6
MW−3025 (W)	2.6	77.3	5.1
MW−3040 (UW)	80.6	393	< 1

W = monitors the weathered zone.
UW = monitors the unweathered zone.

The fourth new well, MW−4040, was intended for Objective 4 and was installed to monitor groundwater quality of the Raffinate Pits area in the upper portion of the unweathered zone. Data from this well indicate that uranium and nitrate impacts extend into the unweathered zone at levels that exceed cleanup standards. The static water levels measured in this well are somewhat higher than expected and the groundwater elevation is not consistent with a nearby well completed in the unweathered zone. The water level in MW−4007, an unweathered zone well in close proximity, is approximately 4 ft lower than that measured in MW−4040. It is likely that the static water levels are being influenced by the groundwater in the weathered unit via the connection of vertical fractures with horizontal fractures or bedding planes in the screened interval of this well. The communication between the two zones would result in higher than expected static water levels. Based on the elevated levels of uranium and nitrate, this well does not meet its intended objective (Objective 4).

In summary, two of the new wells (MW−3030 and MW−4040) installed to complete the MNA network specified in the RD/RA Work Plan do not fulfill their intended purpose of monitoring of Objective 4. The remaining two wells (MW−4041 and MW−2056) fulfill their intended purpose of monitoring of Objectives 3 and 4, respectively.

3.4 Modifications to the RD/RA MNA Network

Based on the discussion presented in Section 3.3, modifications to the RD/RA design are needed in order to put in place a monitoring network that provides adequate data for meeting the objectives for MNA specified in the GWOU ROD. In particular, Objective 4 is not being met as designed with the new unweathered wells. However, given the understanding of the groundwater flow and contaminant migration within the Burlington-Keokuk Limestone, the monitoring strategy as presented in the RD/RA (specifically for meeting Objective 4) over-emphasizes the need to measure localized vertical migration such as those from the Raffinate Pits area. The identification of uranium and nitrate impacts from the new wells furthered the understanding of the dynamics between the preferential flow zones (i.e., locations of vertical fracturing) and surface water impoundments, primarily the Raffinate Pits. The water stored in the pits, in combination with the presence of localized vertical fracturing, likely produced downward movement greater than that in other areas of the site and represents an occurrence that has limited extent.

Based on the above discussion, and still consistent with the site hydrogeological conceptual model (Section 2) that was the basis for the RD/RA MNA strategy, the approach for meeting Objective 4 could be modified by evaluating wells screened deeper than those impacted within the shallow aquifer, but downgradient of source areas that have since been remediated, rather than by selecting wells located within and screened immediately below a known main contaminant source area such as the Raffinate Pits. This modification would still meet the overall intent of Objective 4 given the site hydrogeological model that conceptualizes the shallow aquifer to be a diffuse flow system with superimposed conduit flow. Groundwater movement in the underlying limestone is controlled principally by horizontal fractures, bedding planes, and solution features. Vertical movement occurs but is limited to areas that exhibit greater vertical weathering or fracturing (i.e., paleofeatures). At these localized areas, communication between the weathered and unweathered zones occurs because of the interconnection of these fractures which results in an area of localized impact when vertical fractures occur beneath areas of groundwater impact. At the Chemical Plant, downward vertical gradients through the Burlington-Keokuk Limestone and the Fern Glen Formation indicate recharge to the shallow aquifer. However, just north of the Chemical Plant, upward gradients are prevalent and indicate a localized discharge to Burgermeister Spring and regional discharge of the shallow aquifer to Dardenne Creek (Figure 2–2) (DOE and DA 1997). These upward gradients would limit the contribution of the contaminated groundwater in the shallow aquifer to deeper units (i.e., middle and deep aquifers). Monitoring of the deeper units (Fern Glen) would not be necessary for this reason.

3.5 Summary of the Modifications to the Monitoring Network

The designation of the existing monitoring well network could be reevaluated to determine if new wells and other existing wells better achieve the monitoring objectives. Based on the new data, new wells MW−3040 and MW−4040 could be reassigned to more appropriate objectives than those for which they were originally installed. Both could be categorized as Objective 2 wells that monitor the areas of higher impact, but are within the unweathered zone. The Objective 2 trigger for uranium is presently set at 100 pCi/L (DOE 2004b). This trigger would be re-evaluated and a more appropriate trigger level would be established after the 2-year baseline monitoring period. This trigger would be established in a manner similar to that used for the other contaminants. Existing well MWD−2 could be added to the network as an Objective 4 well to monitor vertical migration of contaminated groundwater within the unweathered zone downgradient of the Raffinate Pits area.

The monitoring locations retained for the modified MNA network and the objectives they satisfy are summarized in Table 3–3 and are depicted on Figure 3–3.

Table 3–3. MNA Monitoring for the GWOU

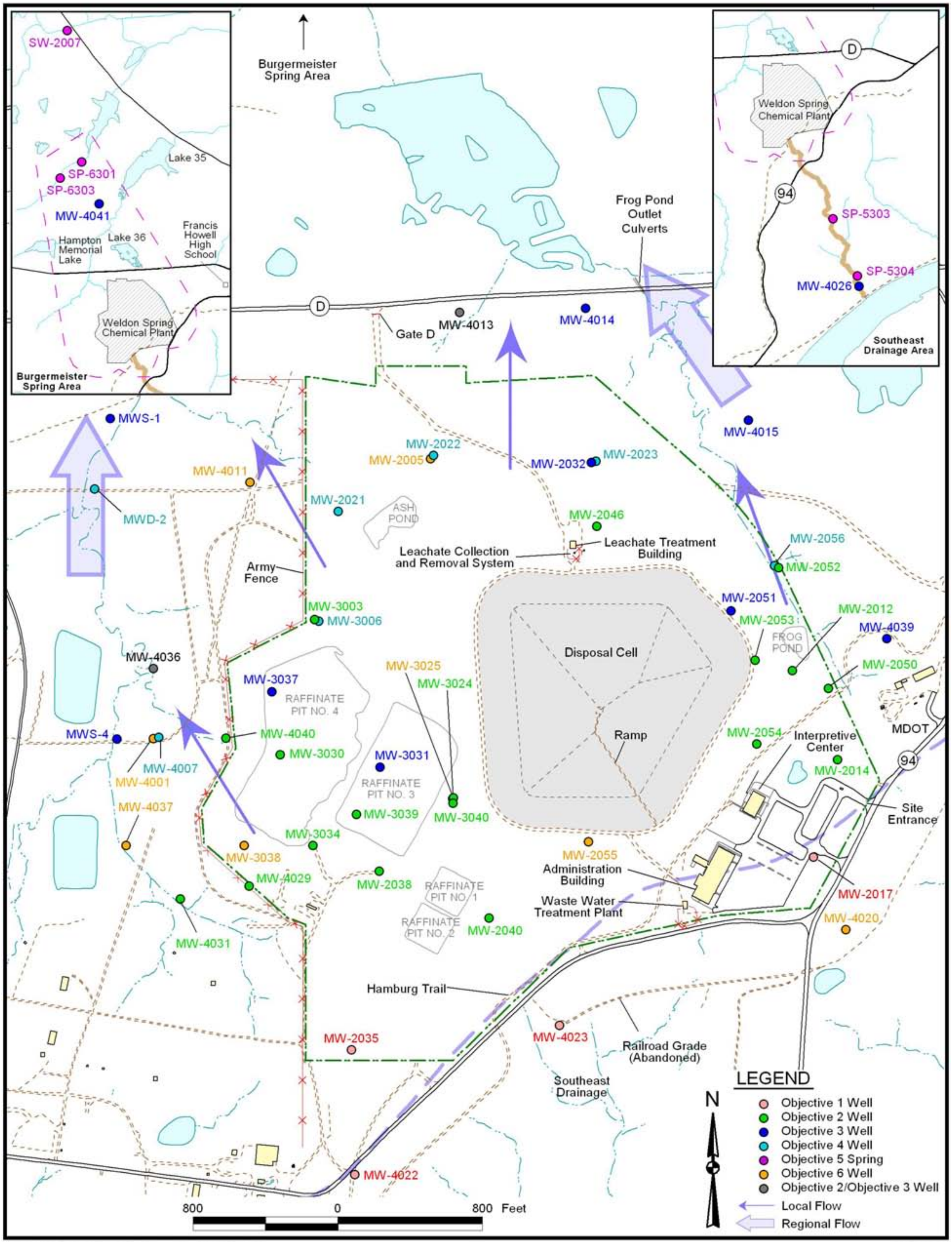
Objective 1	Objective 2	Objective 3	Objective 4	Objective 5	Objective 6
MW−2017	MW−2012	MW−2032	MW−2021	SP5303	MW−2005
MW−2035	MW−2014	MW−2051	MW−2022	SP5304	MW−2055
MW−4022	MW−2038	MW−3031	MW−2023	SP6301	MW−3025
MW−4023	MW−2040	MW−3037	MW−2056	SP6303	MW−3038
	MW−2046	MW−4013	MW−3006	SW−2007[c]	MW−4001
	MW−2050	MW−4014	MW−4007		MW−4011
	MW−2052	MW−4015	MWD-2[c]		MW−4020
	MW−2053	MW−4026			MW−4037
	MW−2054	MW−4036			
	MW−3003	MW−4039			
	MW−3024	MW−4041			
	MW−3030	MWS−1			
	MW−3034	MWS-4			
	MW−3039				
	MW−3040[b]				
	MW−4013[a]				
	MW−4029				
	MW−4031				
	MW−4036[a]				
	MW−4040[b]				

[a] Location is also an Objective 3 location.
[b] Well originally installed for Objective 4, but based on initial data collected the well was reassigned for Objective 2.
[c] Location was added to MNA network based on data collected during well installation activities.

Monitoring wells MW−3040 and MW−4040 will continue to be sampled quarterly until eight data points are collected, as outlined in the RD/RA work plan because they are newly installed wells. The wells will then be sampled semiannually, likely for nitrate (as N) and uranium only, to monitor an area of higher impact (Objective 2). Final determination of the parameters will be made after the collection of eight data points.

Monitoring well MWD−2 initially will be sampled quarterly until eight data points are collected. Sampling of this location was initiated in October 2004. This location will be sampled for nitrate (as N) and uranium, because this location has been selected to monitor for vertical migration of impact in the unweathered zone.

The addition of surface water monitoring in Dardenne Creek (Figure 3–3) is also recommended as an Objective 5 location, given the fact that groundwater in the shallow aquifer discharges to this creek. SW−2007 is located downgradient of Burgermeister Spring (a known point of contaminated groundwater discharge) and along the groundwater flowpath. Water quality data indicate background levels of uranium at this location (SW−2007).



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S0158100-01

Figure 3–3. MNA Monitoring Locations (modified)

4.0 Institutional Controls

Institutional controls (ICs) are being implemented as a component of the selected remedy for the GWOU as described in the ROD (DOE 2004a). The specifics for the ICs to be implemented are presented in the Long-Term Surveillance and Maintenance (LTS&M) Plan (DOE 2004c).

4.1 Area of Groundwater Impact

ICs are needed to limit groundwater usage on property under the jurisdictional control of the DOE and DA and on properties owned by State entities, where the cleanup standards are exceeded. An additional buffer around the area where cleanup standards are exceeded has also been designated for ICs (Figure 4–1). This buffer delineates an area where extraction of the shallow groundwater should be prevented, not because of groundwater quality but because of the possibility of intercepting the groundwater plume as a result of a well's area of influence.

The buffer will extend 1,000 feet (ft) from where the contaminants exceed the cleanup standards. This distance is based on data from two groundwater studies performed at the site during 1998 and 2001. The area of hydraulic capture around a hypothetical well was estimated to be 600 to 1,000 ft. This value is based on information from MW−3028 and is considered conservative, since this well is located in a more transmissive portion of the aquifer (DOE 2004b).

Off-site nitroaromatic contamination southwest of the Chemical Plant is not addressed in this evaluation. This impact originates from DA property and should be addressed by the DA's remedy selection processes. Nitroaromatic contamination originating from within the Chemical Plant boundary and migrating off site is addressed by this remedial action report.

4.2 Subsurface Pathway to Burgermeister Spring

ICs will be implemented to restrict access to groundwater in the subsurface pathway between the Chemical Plant and Burgermeister Spring branch, which includes both Burgermeister Spring (SP−6301) and SP−6303. The results of numerous investigations indicate that a subsurface conduit is present between the unnamed tributary of Schote Creek and Burgermeister Spring (DOE and DA 1997). Overland flow from the northwestern portion of the Chemical Plant is lost in a reach of an unnamed tributary of Schote Creek about 1,000 ft northwest of Ash Pond. Travel time to Burgermeister Spring (SP−6301), which is approximately 6,500 ft downgradient, is estimated to be 48 to 72 hours, depending on previous rainfall. Dye tracing of two angled borings and one monitoring well, which were selected because of high hydraulic conductivity, was performed during the remedial investigation. Three springs in the 6300 drainage were monitored for resurgence of the dye; however, the dye was detected only in Burgermeister Spring. Dye was initially detected in Burgermeister Spring 2 to 7 days after injection.

4.3 Burgermeister Spring and SP−6303

Burgermeister Spring (SP−6301) and SP−6303 are impacted by site related contaminants above the cleanup standard. ICs will be implemented to preclude the residential use of groundwater or spring water in the vicinity of the two springs in the Burgermeister Spring drainage. The boundary where the ICs will be implemented extends downgradient 1,000 ft from the springs (SP−6301 and SP−6303).

4.4 Southeast Drainage Springs

Springs in the Southeast Drainage are impacted by site related contaminants above cleanup standards. ICs also will be implemented along the Southeast Drainage to preclude any groundwater or spring water use. The boundary where the ICs are to be implemented is a 200-ft corridor centered on the existing stream flow. The Southeast Drainage is a closed system with little observable loss to adjacent drainages or the underlying groundwater system (DOE and DA 1997). The 200-ft corridor extends to the edges of this drainage.

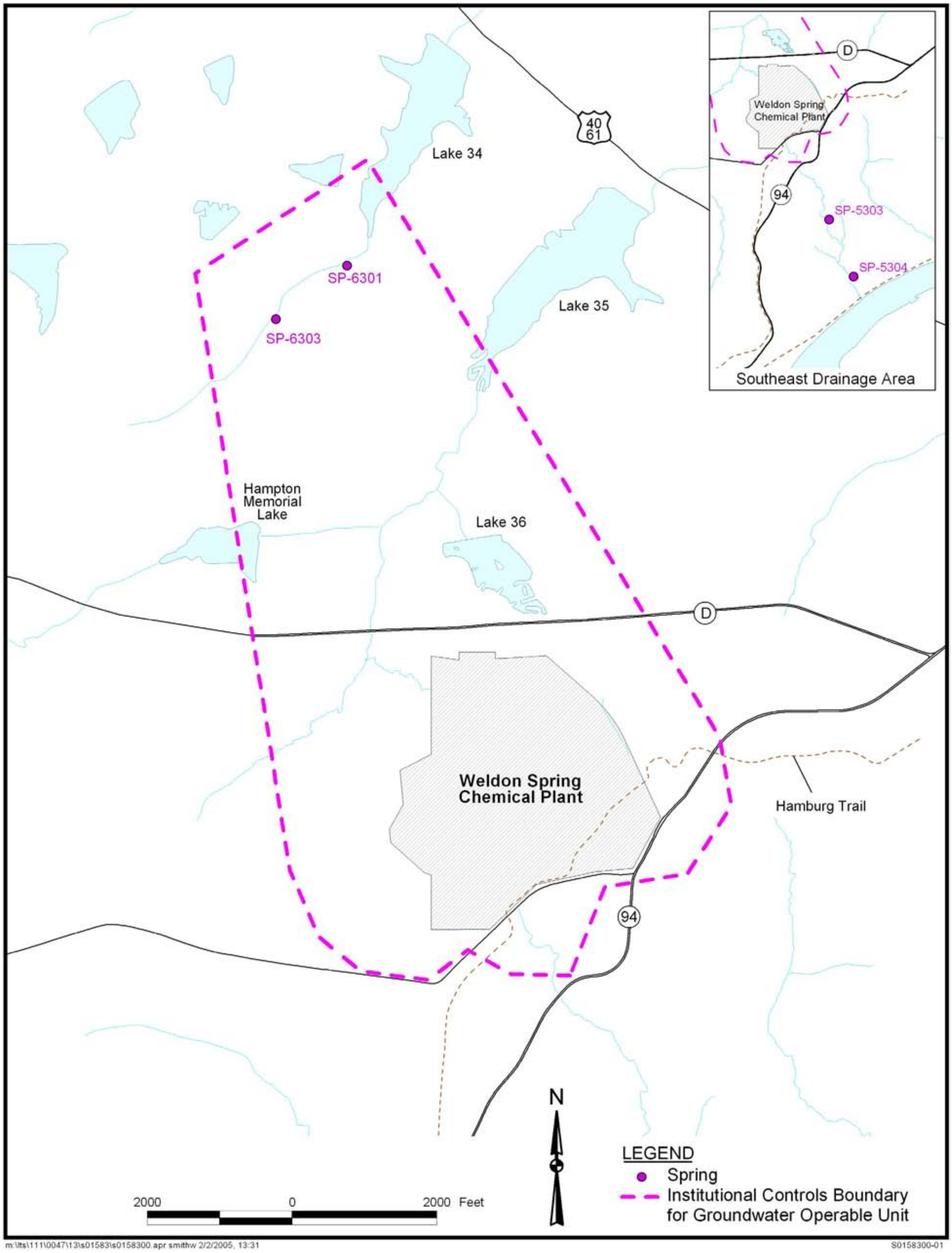

Figure 4–1. Institutional Controls Location Map for the Chemical Plant Area of the Weldon Spring, Missouri, Site

End of current text

5.0 Pre-Final Inspection

A remedial action completion inspection of the GWOU was performed on July 20, 2004, with EPA, Missouri Department of Natural Resources (MDNR), DOE, and S.M. Stoller personnel. This inspection included a review of the well installation activities, field inspection of ICs survey markers, and visual inspections of the new wells and Burgermeister Spring.

The inspection started with an overview of the agenda. Copies of the borehole logs, well completion details, and monitoring well certification records were provided to all attendees. The inspection then proceeded into the field to visually inspect the four new wells and locate several of the survey markers installed to delineate the IC boundary established around the area of groundwater impact and the buffer zone.

The inspection of the wells revealed one finding. Weep holes had not been drilled in the protective casing of the monitoring wells as required under the Well Construction Rules (10 *Code of State Regulations* (CSR) 23-3). It was suggested that screening be placed inside the protective casing at the weep hole to prevent insects from entering the casing. This was noted, but cannot be performed due to the limited spacing of the annulus between the casing and the well. Several minor deficiencies also were noted. The surface drainage around MW−2056 may need to be modified to prevent ponding of water in the vicinity of the well. Also, the drill cuttings at MW−4040 had not been distributed evenly on the ground surface as required in the drilling specifications.

Several survey monuments were found along the Chemical Plant property boundary, on the adjacent DA property, and in the Busch Conservation Area during the inspection. These markers were difficult to locate by using a map only. All the markers were in good condition. It was noted during the inspection, that use of a global positioning system would facilitate quicker location during future inspections.

The inspection concluded with a discussion regarding actual and estimated costs for the well installation. Also, the status of future well abandonment was discussed. It was clarified by DOE that well abandonment likely would commence no sooner than after the 2-year baseline period and likely after downward trends are identified in the higher contamination wells.

The deficiencies noted during the inspection have been corrected. The drill cuttings around MW−4040 were addressed on September 7, 2004. Weep holes were drilled into the protective casings of the four new wells between September 14 and September 16, 2004.

End of current text

6.0 Operation and Maintenance Activities

The details for the GWOU post-construction operation and maintenance activities such as surveillance and maintenance, groundwater monitoring, ICs, and other post-closure activities can be found in the LTS&M Plan (DOE 2004c). The Plan is currently in draft final form. The information in this section provides a summary of the current information in the Plan.

DOE will maintain protectiveness at the Weldon Spring Chemical Plant through a combination of federal ownership, maintaining a local presence, conducting regular inspections, conducting environmental sampling, ICs, and regulatory compliance.

6.1 Annual Site Inspections

DOE will inspect the Weldon Spring Chemical Plant area annually, in accordance with the LTS&M Plan, to confirm that ICs remain effective and to determine if maintenance or additional monitoring is needed. Inspectors will note changes to the Chemical Plant and the surrounding area. Significant changes within an area could include new development that may result in changes to the groundwater system and evidence of inappropriate groundwater extraction. Specific inspection criteria and a checklist are included in the LTS&M Plan.

6.2 Reports

DOE will prepare an annual report, which will include the results of the annual site inspection. The report will be submitted to EPA, MDNR, and stakeholders. The report also will be posted on the LM Program Internet site (www.lm.doe.gov). In the report, DOE also will address maintenance, surveillance, and monitoring results for the previous 12 months. DOE also will prepare a CERCLA 5-year review report in accordance with current EPA guidance for 5-year reviews. The purpose of the 5-year review is to ensure that the remedies remain protective of human health and the environment. The next 5-year review report will be released in 2006.

6.3 Routine Site Maintenance and Operations

During the routine site operations, DOE will inspect all monitoring wells used in the program and arrange for maintenance or repairs, as necessary. Groundwater samplers also will note maintenance needs and ensure the wells are kept secured and in good repair. Monitoring personnel will maintain access to sample locations, which may include maintenance of access routes and vegetation control. Such maintenance on off-site locations will be conducted in accordance with access agreements.

6.4 Groundwater Monitoring

The RD/RA Work Plan (DOE 2004b) specifies the design of the monitoring program for groundwater natural attenuation, which is implemented through the LTS&M Plan (DOE 2004c). Results will be reported annually and summarized in the 5-year review report.

Environmental monitoring for the Weldon Spring site is implemented through the LTS&M Plan. Results will be reported in the annual site environmental report and summarized in the 5-Year review report required under CERCLA. Groundwater monitoring will be conducted using methods and procedures established for the Weldon Spring site.

6.5 Institutional Controls

Review of the ICs for the GWOU will be incorporated into the annual site inspection for the Weldon Spring site as outlined in the LTS&M Plan. DOE will conduct an inspection of the physical locations addressed by the ICs. During annual site inspections, inspectors will look for indications of groundwater or spring water withdrawal or use within the IC boundary for the Chemical Plant groundwater and the Southeast Drainage areas. Periodic reviews of MDNR well registrations also will be conducted to determine if wells have been installed in the vicinity of the Chemical Plant. Also evaluated will be whether the ICs remain effective in protecting human health and the environment, and appropriate action will be taken if evidence indicates the controls are not effective. Property owners and other grantees of real property interest will be contacted annually to ensure cognizant representatives remain aware of ICs on their property. DOE also will check county records to verify that deed restrictions and other IC instruments remain in place.

7.0 Summary of Project Costs

A summary of the actual costs for major elements of the GWOU and estimates provided in the IROD (DOE 2000), the ROD (DOE 2004a), and the RD/RA Work Plan (DOE 2001 and 2004b) are provided in Table 7–1. The actual project costs for those elements that have not been completed (groundwater monitoring and ICs) will be completed upon finalization of this report. The costs presented are final as of the end of July 2004. The costs presented in the table are primarily subcontract costs for performance of fieldwork. Oversight costs for the project management contractors are not included; however, these costs also were not included in the estimates provided in the ROD and the RD/RA Work Plans.

Table 7–1. GWOU Cost Summary

Cost Item	**IROD Estimate**	**Final ROD Estimate**	**RD/RA Estimate**	**Actual Costs**
Additional Groundwater Field Studies	N/A[a]	N/A	N/A	$3.2 M
In-Situ Chemical Oxidation of TCE in Groundwater	$0.5 M	N/A	$1.7 M	$0.63 M[d]
MNA Program (Annual Costs)	N/A	$ 0.15 to 0.45 M	$ 0.22 M	TBD
MNA Program (Capital Costs)	N/A	$ 0.53 M	$ 0.40 M	$0.07 M
ICs	N/A	---[b]	---[b]	$ 0.02 M[c]

[a] Costs for performing the field studies were not included in the IROD since they are not a component of the remedy.
[b] Costs for implementing ICs were estimated to be minimal.
[c] Costs for surveying and establishing survey monuments. Additional costs for ICs to be implemented under the LTS&M Plan are also expected to be minimal.
[d] This cost is for performing pilot scale treatment only. It was determined the treatment did not perform adequately under field conditions.
TBD - to be determined following the 2-year baseline monitoring program.

End of current text

8.0 References

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Appendix A

Background Information

A.1 Background Information

This background discussion on the Groundwater Operable Unit (GWOU) at the Weldon Spring Site Remedial Action Project (WSSRAP) includes the site and regulatory history as well as the extensive environmental documentation process that was performed to arrive at the final groundwater action of monitored natural attenuation (MNA). Information on previous investigations for identification of source areas, nature and extent of groundwater and spring water impact, contaminant fate and transport, and hydrogeology is included. A summary of field studies and previous remedial actions is provided

A.1.1 Site History

From 1941 to 1945, the U.S. Department of the Army (DOA) produced trinitrotoluene (TNT) and dinitrotoluene (DNT) at the Weldon Spring Ordnance Works, which covered 17,233 acres of land that now includes the Weldon Spring site. Two hundred seventeen acres of the former ordnance works property were transferred in May 1955 to the Atomic Energy Commission (AEC) for construction of the Weldon Spring Uranium Feed Material Plan (WSUFMP), now referred to as the Weldon Spring Chemical Plant. Atlas Powder Company and the DA, prior to construction of the WSUFMP, performed several explosives decontamination efforts.

From 1958 until 1966, the WSUFMP converted processed uranium ore concentrates to pure uranium trioxide, intermediate compounds, and uranium metal. A small amount of thorium also was processed. Wastes generated during these operations were stored in the Raffinate Pits. These pits were radiological contaminated with uranium and thorium residues and chemically contaminated with nitrate, fluoride, polychlorinated biphenyls (PCBs), and various heavy metals. The buildings were contaminated with asbestos, hazardous chemical substances, and small quantities of uranium and thorium. Radiological and chemical contaminants (PCBs, nitroaromatic compounds, metals, and inorganic ions) also were found in the soil at many locations.

The WSUFMP was shut down in 1966, and in 1967 the AEC returned the facility to the DA for use as a defoliant production plant to be known as the Weldon Spring Chemical Plant. The DA started removing equipment and decontaminating several buildings in 1968 with some materials being placed into Raffinate Pit 4. However, the defoliant project was canceled in 1969 before any process equipment was installed. The DA retained responsibility for the land and facilities of the Chemical Plant, but the 20.6 hectares (51 acres) tract encompassing the Weldon Spring Raffinate Pits was transferred back to the AEC. The Chemical Plant site was in caretaker status from 1967 through 1985.

Except for a discontinued decontamination effort by the DA in 1968, the Chemical Plant had been closed for 20 years before the U.S. Department of Energy (DOE) took control of the site. During this period, the infrastructure had deteriorated considerably. In the 44 buildings, many windows were broken, walls were separated from floors, floors had begun to break apart, and roofs had deteriorated to the extent that many leaked badly. There was radioactive contamination on various surfaces, PCB contamination of floors, and deterioration of protective coverings for asbestos containing insulation. Radiological and chemical (PCBs, nitroaromatic compounds, metals, and inorganic ions) contaminants were not only found in the buildings but also in soil in many areas around the site.

On the Chemical Plant grounds, 300 utility poles supporting 150,000 linear ft of wiring were rotten, and many had fallen to the ground. There was an additional 33,000 linear ft of piping, some with deteriorating asbestos-containing insulation. Active water mains leaked extensively and added to contaminated water leaving the site and infiltrating into the groundwater. Waste streams generated during Chemical Plant operations were stored in four Raffinate Pits, which leaked into the subsurface impacting the shallow aquifer.

In 1985, DOE designated control and decontamination of the Chemical Plant, Raffinate Pits, and Quarry as a major project. The Project Management Contractor (PMC) for the WSSRAP was selected in February 1986. In July 1986, a DOE project office was established on site, and the PMC, comprised of MK-Ferguson Company and Jacobs Engineering Group, Inc., assumed control of the site on October 1, 1986. The Quarry site was placed on the U.S. Environmental Protection Agency (EPA's) National Priorities List (NPL) in July 1987. DOE redesignated the site as a Major System Acquisition in May 1988. The Chemical Plant and Raffinate Pits were added to the NPL in March 1989. Remedial activities associated with the Chemical Plant and the Quarry were completed between 1991 and 2002.

The project transferred long-term surveillance and maintenance responsibility for the WSSRAP from DOE-Oak Ridge Office to DOE-Grand Junction, Colorado, on October 1, 2002. DOE-GJ office is responsible for the Legacy Management (LM) Program at DOE facilities, providing long-term care for low-level radioactive material disposal sites. The technical assistance contractor for the project is S.M. Stoller, Inc.

A.1.2 Regulatory and Enforcement History

DOE and EPA developed an agreement as to the roles of the various participants and the regulatory requirements of the remediation. The key assumption driving the project was that the National Environmental Policy Act (NEPA) would be the primary law governing the final disposition of the wastes. Prior to 1986, DOE facilities were exempt from the cleanup requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The only regulatory process for remediation available for former DOE sites was NEPA. In 1986, CERCLA was amended by the Superfund Amendments and Reauthorization Act of 1986. The Chemical Plant and Quarry were subsequently placed on the NPL. This new regulatory process required DOE and EPA to agree on how remediation decisions would be made. During the site preparation phase, they agreed on expedited removal actions to stem the slow dispersal of contaminants off site and to protect on-site workers from various hazardous materials.

In addition, EPA and DOE entered into a Federal Facilities Agreement (FFA) (EPA 1992). This 1986 agreement was amended in 1992 and is consistent with CERCLA, Section 120. The amended FFA includes agreements to ensure that the environmental impacts associated with past and present activities at the Weldon Spring site are thoroughly investigated and that appropriate remedial action is taken, as necessary, to protect public health and the environment. Along with CERCLA, this FFA also facilitates the exchange of information among EPA, DOE, and the State of Missouri, and contains procedures for resolving disputes, assigning penalties for nonconformance, and ensuring public participation in the remedial action decision-making process.

A.1.3 Environmental Documentation

It was decided in 1993 to prepare separate environmental documentation regarding remediation of groundwater beneath the Chemical Plant site. Prior to this the groundwater was being addressed as part of the Chemical Plant Operable Unit. It also was decided at that time that DOE and the DA would work jointly to address the groundwater issues for both sites. The remedial investigation was conducted in 1995 and included a joint sampling effort of all wells in the Chemical Plant and ordnance works areas by DOE and the DA. The *Remedial Investigation for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area of the Weldon Spring Site* (DOE and DA 1997a) and the *Baseline Risk Assessment for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area of the Weldon Spring Site* (DOE and DA 1997b) were finalized in July 1997. The contaminants of potential concern were identified as nitrate, sulfate, chloride, lithium, molybdenum, nitroaromatic compounds, uranium, trichloroethylene (TCE), and 1,2-dichloroethylene. Contamination in groundwater is generally confined to the shallow, weathered portion of the uppermost bedrock unit, the Burlington-Keokuk Limestone.

The feasibility study for remedial action for the GWOU at the Chemical Plant and Ordnance Works areas was initiated in 1997 (DOE and DA 1998). This study evaluated potential options for addressing groundwater contamination at both sites. The preferred alternative was long-term monitoring of groundwater in conjunction with in situ treatment of portions of the shallow aquifer impacted by TCE. In 1998, a long-term pumping test was performed at the Chemical Plant to evaluate potential groundwater remediation methods for TCE contaminated groundwater (MKF and JEG 1998). Results indicated that the transmissivity of the aquifer in the area of TCE impact was higher than expected; however, due to the geology in the area, dewatering of the aquifer occurred. Evaluation of conventional pump-and-treat technologies indicated that this would not be the most effective method for possible remediation of this area. These data were evaluated in the *Supplemental Feasibility Study for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 1999a) and utilized in preparation of the *Proposed Plan for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 1999b).

The Proposed Plan was submitted to the public and the regulatory agencies on August 3, 1999. A first public comment period was from August 3 through September 1999. After a public meeting on August 25, 1999, at the Weldon Spring site, the comment period was extended from November 2, 1999, through January 6, 2000, in response to public requests.

When the plan was issued, the Missouri Department of Natural Resources (MDNR) did not concur with the proposal. To resolve these issues, the EPA facilitated an issue-resolution process. Specifics of process are provided in the *Interim Record of Decision for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2000).

On June 12, 2000, DOE announced there would be an additional public comment period so there would be further opportunity to review the plan along with the documents generated during the issue resolution. This additional public comment period was originally scheduled to end on July 14, 2000, but was later extended through August 15, 2000, in response to requests for more time. Numerous public comment letters were received that expressed concern over the proposal to not actively treat all the groundwater contaminants of concern. In response to these comments, DOE reconsidered the initial decision to move forward and decided to postpone the final ROD.

DOE proposed active remediation of the TCE impacted groundwater at the Chemical Plant site as presented in the proposed plan and to conduct further field studies to re-examine the effectiveness and practicability of further active remediation for the remaining contaminants of concern. An interim ROD relating to the remediation of TCE contaminated groundwater at the Chemical Plant site was signed by DOE and EPA on September 29, 2000. This *Interim Record of Decision for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2000) authorized treatment of TCE in groundwater utilizing in situ chemical oxidation methods.

In 2003, the *Supporting Evaluation for the Proposed Plan for Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2003a) was prepared in conjunction with the *Proposed Plan for Final Remedial Action for the GWOU* (DOE 2003b). The purpose of the Supporting Evaluation was to reevaluate the feasibility of groundwater removal, in-situ chemical oxidation (ICO), and MNA technologies and options on the basis of recent information collected from the ICO pilot-phase treatment and the additional groundwater field studies.

The *Proposed Plan for Final Remedial Action* was submitted to the public and the regulatory agencies on August 4, 2003. A public comment period was from August 4 through September 3, 2003. A public meeting was held on August 13, 2003, at the Weldon Spring site to present an overview of the preferred alternative and explain the process that led to its selection. Representative from MDNR, Missouri Department of Conservation (MDC), EPA, and the public were present.

The *Record of Decision for Final Remedial Action for the Groundwater Operable Unit at the Chemical Plan Area of the Weldon Spring Site* (DOE 2004a) was signed by DOE on January 29, 2004, and EPA on February 20, 2004. The selected remedy of MNA with ICs to limit groundwater use during the period of remediation addresses cleanup of all contaminants of concern (COCs) in groundwater and springs at the Chemical Plant area. The selected remedy also serves as a change to the Interim ROD, which addressed TCE groundwater contamination. In-situ treatment of TCE did not perform adequately in the field and MNA is now considered the appropriate final remedy for TCE as well as the other groundwater contaminants.

A.1.4 Site Investigations

A number of investigations have been performed to determine the nature and extent of contamination at the Chemical Plant. These investigations are included in this document because they define the source areas and possible constituents for groundwater impact. Investigations also have been performed to define the geological, hydrological, and contaminant profiles of the aquifer system in the Chemical Plant area.

A.1.4.1 Chemical Plant Contaminant Investigations

Investigations of the nature and extent of soil contamination at the Chemical Plant Site were conducted during the late 1980’s and early 1990’s. Included in the investigations at the Chemical

Plant were the four Raffinate Pits, Ash Pond, Frog Pond, the coal storage area, soils near former processing facilities, and soils near the former TNT production lines. The findings were published in the *Remedial Investigation for the Chemical Plant Area of the Weldon Spring Site* (DOE 1992).

Soil at the Chemical Plant generally contained low levels of radionuclides such as uranium, thorium, and radium; some heavy metals such as arsenic and lead; and inorganic ions such as sulfate. Characterization data indicated that uranium (U-238) generally was distributed at low levels across the Chemical Plant surface soils, but a few discrete areas of relatively high concentrations occurred at the north dump, the south dump, and around the process buildings. Elevated levels of radium (Ra-226 and Ra-228) were detected in a few scattered areas around the process buildings, and elevated levels of thorium (Th-230) were detected in scattered locations around the Raffinate Pits and in the south dump.

The Raffinate Pits contained several hundred to several thousand picocuries per gram (pCi/g) of uranium, radium, and thorium isotopes. Chemical analysis of the sludge showed relatively homogeneous material in all of the pits except Pit 4, which also contained a large number of discarded drums, containers, and debris from the DA's earlier partial decontamination. The sludge contained concentrations greater than background for all the metals and anions included in the analysis. The pH of greater than 7 maintained low concentrations of heavy metals in the water. These four pits, Frog Pond, and Ash Pond all contained radionuclides, primarily thorium and uranium, metals such as arsenic and chromium, and inorganic anions such as nitrate, fluoride, and sulfate. Even though characterization of Frog Pond showed radiological contamination, there is no known record of contaminated material being stored or buried in this area.

A.1.4.2 Chemical Plant Hydrogeologic Investigations

Numerous hydrogeological investigations have been performed since 1987 at the Chemical Plant area to develop a hydrogeological conceptual model for the GWOU. The investigations that focused on characterizing the shallow aquifer system and identifying potential flow paths for contaminant migration included installation of monitoring wells, logging of the bedrock and overburden, measuring static water levels, surface and subsurface dye trace testing, aquifer testing, and pilot scale remedial actions.

A.1.4.3 Chemical Plant Groundwater Contaminant Investigations

Groundwater sampling and analysis have been ongoing at the Chemical Plant area since 1987 to identify the nature and extent of groundwater impact as well as contaminant fate and transport mechanisms. A joint sampling effort was conducted with the Army during 1995 in support of the remedial investigation for both the Chemical Plant and the neighboring Ordnance Works area.

Several area and/or contaminant specific investigations were performed recently to further determine the nature and extent of groundwater impact. These investigation focused on areas that were not accessible prior to Chemical Plant remediation (i.e., Raffinate Pits area) or were exhibiting changing conditions due to remedial actions (i.e., nitroaromatic compounds in the Frog Pond area) (DOE 2004b and 2004c).

A.1.4.4 Field Studies

The removal of groundwater by conventional (vertical) extraction wells was evaluated in the Feasibility Study (DOE and DA 1998), but was not deemed to be viable because of field limitations that were indicated by the hydrogeological data available at that time. At the request of MDNR, DOE conducted additional groundwater field studies in 2001 to determine the contaminant removal rates using a conventional system. Also, MDNR requested that several enhancements, such as using artificial recharge in conjunction with groundwater extraction, or using an angled well for extraction, be evaluated to determine if contaminant removal rates could be improved. The purpose of the field study was to obtain data for use in deciding whether these variations could significantly improve removal rates over those achieved by a conventional system. A detail discussion of the field studies is presented in the *Completion Report for the Additional Groundwater Field Studies in Support of the Groundwater Operable Unit* (MKF and JEG 2002).

The results of the field studies conducted in 2001 indicated that modifications to the conventional pump and treat systems did not increase the mass of contaminants removed over those removed by a conventional vertical well system with no artificial recharge. Consequently, the amount of water extracted from the area as a result of artificial recharge would not reduce the remediation time frames for TCE, nitrate, uranium, or nitroaromatic compounds. Another modification, the use of an angled well, likewise failed to produce results comparable to those achieved by the vertical extraction well. These results reflect the difficulty involved in siting productive wells in the complex geology of the site.

A.1.4.5 Remedial Actions

The *Interim Record of Decision* (IROD) (DOE 2000) established ICO of TCE as the remedial action to address TCE contamination in the groundwater in the Raffinate Pits area. This technology was selected because of all the technologies evaluated, it offered the best potential for quickly reducing TCE levels, and it would be cost effective. However, it also was recognized, that uncertainties associated with the complex hydrogeology of the site likely would affect the effectiveness and implementability of the ICO process.

To implement the IROD remedial action, bench-scale tests by several vendors were performed to determine the effectiveness of ICO in treating TCE at the site and evaluate several of the ICO processes. It was determined from the bench-scale testing that both of the processes evaluated (permanganate and hydrogen peroxide) could destroy the TCE in the site groundwater; however, uncertainty still existed regarding the implementation on a full-scale.

Pilot-phase ICO was performed in 2002 to evaluate the effectiveness of the ICO process under actual field conditions and to assess the feasibility of implementing a full-scale system. The pilot-phase activities were performed at two locations, representing the upper and lower limits of the hydraulic condition in the bedrock aquifer within the area of higher TCE concentrations. A detailed discussion of the field activities is presented in the *Pilot-Scale Testing Completion Report on In-Situ Chemical Oxidation of TCE in Groundwater* (ATC 2002). A summary of the groundwater sampling performed subsequent to the pilot-phase project is discussed in the *Completion Report for the Groundwater Sampling Performed in Support of the Pilot Phase ICO Project* (DOE 2004d).

The pilot-phase ICO temporarily reduced TCE concentrations in the area of influence. The sodium permanganate solution was distributed to a distance of about 100 feet from the injection point, with the dispersion of the permanganate favoring a downgradient direction toward the paleochannel features of the site. Uniform distribution of the injection chemicals was not achieved. In addition, increased chromium, mercury, silver, and manganese concentrations were observed in areas where sodium permanganate appeared. Although the metals concentrations were expected, sodium permanganate was still present at some locations 1 year after the completion of the pilot-phase ICO. The ICO treatment did not affect uranium or nitrate concentrations at the site.

The results of the pilot-phase ICO could not be applied directly to the whole TCE area because of the non-uniform, heterogeneous nature of the site hydrogeology. The limitations imposed by site hydrogeology on the design for full-scale implementation, coupled with concerns about the potentially large increase in metal concentrations in groundwater and the persistence of the chemical aquifer, were the primary factors that contributed to the overall decision not to go forward with full-scale implementation of ICO.

A.1.5 Land Use

The Weldon Spring site is in St. Charles County, which in 2000 had a population of approximately 283,833. The largest city in the county is St. Charles, which is approximately 15 miles northeast of the site and has a population of about 58,156. The two communities closest to the site are Weldon Spring and Weldon Spring Heights; both located about 2 miles to the northeast. The combined population of these two communities in 2000 was 5,349. No private residences exist between these two communities and the site. Urban areas occupy about 6 percent of county land, and non-urban areas occupy 90 percent; the remaining 4 percent are dedicated to transportation and water uses (DOE 2004e).

The Weldon Spring Training Area, which is adjacent to the Chemical Plant site, is currently used for field training and outdoor maneuvers by the U.S. Army reserve, the Missouri Army National Guard, and other military and police units. An estimated 3,300 local Army reservists and 3,400 other reserve units use the training area each year. The Department of the Army intends to continue using the area for training activities.

A large portion of the former Ordnance Works area, which consisted of 17,232 acres, was converted into conservation areas. The August A. Busch Memorial Conservation Area, located north of the Chemical Plant, occupies 6,987 acres. South of the Chemical Plant site is the Weldon Spring Conservation Area, which occupies 7,356 acres. Both areas are managed by the Missouri Department of Conservation and are open throughout the year for recreational use. These areas receive an estimated 1.2 million visitors each year.

The Missouri Highway and Transportation Department Weldon Spring maintenance facility located adjacent to the north side of the Chemical Plant employs about 10 workers. Francis Howell High School, about 0.6 mile east of the Chemical Plant area, employs approximately 150 faculty and staff (including employees at the Francis Howell Administration Annex) and is attended by about 1,500 students (DOE 2004a). About 741 acres of land east of the Chemical

Plant site are owned by the University of Missouri. The northern third of this land has been developed into a high-technology research park.

The 217-acre Chemical Plant area is expected to remain under control and ownership of DOE. As currently planned, only three buildings will remain within the Chemical Plant proper after project completion and site closure. These include the Interpretive Center, Administration Building, and Leachate Collection and Removal System building.

The Weldon Spring Training Area, which is adjacent to the Chemical Plant, is managed by the DA and will continue to be used for field training for the foreseeable future. The Missouri Department of Conservation will continue to maintain the remaining surrounding conservation areas for recreational use for the long-term.

A.1.6 Groundwater and Spring Water Use

As a whole, the shallow aquifer beneath the boundaries of the Chemical Plant area and the adjacent former Ordnance Works area is currently not used for drinking water or for irrigation. However, on the basis of EPA guidance for groundwater classification, site groundwater is classified as potentially useable from a water quality standpoint (MKF and JEG 1990). No active private wells are located within 1 mile of the Chemical Plant. One well, which is used for irrigation at the Missouri Research Park, is within 2 miles, but it is crossgradient of the site and therefore does not have the potential for impact. No domestic wells are known to be active within the Chemical Plant area, the adjacent Ordnance Works area, or the Busch Conservation area. The closest domestic water wells are 2.1 miles to the north-northeast. These wells are estimated to be 325 to 350 feet deep. Although these wells produce water from the shallow aquifer, the potential of impact from contaminated groundwater originating at the Chemical Plant site is low. Groundwater field studies have supported that the preferential flow direction for groundwater from the site is to the northwest toward Burgermeister Spring and the 6300 Drainage (DOE and DA 1997a). If active wells screened in the Burlington-Keokuk Limestone were present between the site and this drainage, the likelihood for impact would be high.

A municipal water supply is currently available to serve the residential and commercial needs of the area communities. Thus, for the foreseeable future, it is unlikely that the impacted groundwater beneath the Chemical Plant area would be used for household purposes. In addition, the impacted shallow portion of the aquifer in the Chemical Plant area is characterized by low yields. The deeper, unaffected, higher yielding aquifers would more likely serve as a groundwater source in the unlikely event groundwater use were to occur. Despite the unlikelihood of the impacted groundwater being used for household purposes, in accordance with EPA guidelines and for purposes of making the remedial action determination, this shallow groundwater is a potentially usable resource.

Several springs and seeps receive groundwater discharge near the Chemical Plant area. Burgermeister Spring, which is 1 mile northwest of the Chemical Plant area, is a major discharge point for migrating groundwater. Two large springs are located in the bottom portion of the Southeast Drainage. Recreational visitors to the Busch Conservation Area have access to these springs. Access to spring water will remain similar to current conditions, consistent with recreational land use.

A.1.7 References

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Appendix B

Construction Activities

B.1 Construction Activities

Construction activities under the Groundwater Operable Unit (GWOU) consisted of drilling and testing to support the hydrogeologic investigation and monitoring well installation. These activities began in April 2004 and were completed by July 2004. The scope of the work initially involved installing three new wells to supplement the existing monitoring well network. Two of the wells targeted the unweathered Burlington-Keokuk Limestone and were located in areas of the site where monitoring of this unit below areas of impact is not adequate. Well MW−2056 is clustered with MW−2052 in the Frog Pond area and is within the leading edge of the nitroaromatic compound plume and the preferential flow pathway in this area. Well MW−4040 is located west of MW−3030 near the property boundary and is within the leading edge of the trichlorethylene (TCE), uranium, nitroaromatic compound, and nitrate plumes. It also is within the preferential flow pathways in this area.

One new weathered zone well, MW−4041, is north of the site on the Busch Conservation Area. The purpose of this well is to monitor groundwater within the preferential flow pathway that transports groundwater from the Chemical Plant site to Burgermeister Spring. The location of this well was based on the topography of the top of the Burlington-Keokuk Limestone and the troughs in the potentiometric surface in this area. Initially three boreholes (BH−A through BH−C) were drilled to better define the paleochannel in this area. Based on field data, an additional borehole (BH−D) was drilled north of the three original boreholes for better definition. Well MW−4041 was constructed at the BH−D location.

Well MW−3040 was installed to monitor the unweathered Burlington-Keokuk Limestone near the existing well cluster of MW−3024 and MW−3025. A review of the hydrologic and contaminant data, and previous reconstruction of unweathered well MW−3024, led to uncertainty regarding the integrity of the well and the reliability of the contaminant and groundwater level data. This new well will be monitored to assess previous information regarding the unweathered zone in this area.

These new wells were initially sampled between June 30 and July 1, 2004. The results of these sampling events are summarized in Section 4, as well as the interpretation of the data regarding contaminant nature and extent.

B.1.1 Drilling and Sampling

Seven boreholes were drilled and tested during the effort (see Figure 3−2). The drilling began on April 26 and the last well was completed on May 20, 2004. Roberts Environmental Drilling Inc. of Millstadt, Illinois, was subcontracted to perform all drilling, aquifer testing, well installation, and well development. Geologic field oversight was provided by Paul Patchin and Alan Benfer, both of Washington Group International of Boise, Idaho.

All boreholes were drilled and cored using an all terrain CME-750 drill rig. A truck-mounted CME-75 was initially used on the first borehole, but had mechanical problems and was replaced by an all-terrain drilling rig, which allowed better access to the well locations given the wet conditions. Hollow stem augers with an inside diameter (ID) of 4-1/4 inches and outside diameter (OD) of 7-1/4 inches were used to drill the boreholes to the top of the limestone bedrock.

Soil samples were collected during the drilling of the first three boreholes (BH−A through BH−C) located in the Busch Conservation Area to characterize the overburden material. Soil samples were not collected in BH−D as this location was initially bored to obtain top of rock data only. Soil samples were not collected in the overburden for the three boreholes drilled on the Chemical Plant site unless needed to confirm the top of bedrock. For those that were sampled, the samples were collected continuously using an 18-inch split spoon with an ID of 1 inch. The sampler was driven 18 inches below the auger bit using an automatic 140-pound hammer falling 30 inches. The number of blows required to drive each 6-inch interval was recorded, and the last two 6-inch drives were summed and expressed in blows per foot on the borehole log. Soils were retrieved from the split spoon and described according to the Unified Soil Classification System.

Core drilling of the bedrock was performed in all of the boreholes using an NQ wireline split core barrel with a 3-inch inside diameter. All rock cores were described according to site procedures. Borehole logs for all the boreholes are contained in this appendix.

Borehole BH−B was abandoned in accordance with 10 CSR 23. Boreholes BH−A and BH−C required variances from the regulations because the original core hole could not be located due to collapse near the overburden/bedrock interface. Roberts Environmental Drilling Inc. requested an alternative method of plugging from the bedrock to approximately 2 ft below the ground surface with group and topping with clean compacted soil. MDNR-DGLS approved this method and the boreholes were abandoned in accordance with the variance (Variance No. 2550).

B.1.2 Packer Testing

Packer testing was performed in each borehole to measure the hydraulic conductivity in discrete intervals of the bedrock. Methods described in the *Groundwater Manual* (DOI 1977) were used to perform the tests. During the drilling of each borehole, packer testing was performed in the limestone bedrock as the borehole was advanced. The testing utilized a single packer assembly. Following core drilling of the interval to be tested, it was then flushed with water through the end of the core barrel to clean out the fine cuttings created during the drilling process. The packer assembly was placed down and through the end of the drill pipe, extending past the drilling bit attached to the outer core barrel. The packer assembly had an inflatable packer within the core barrel and a second packer that extended just outside the end of the core barrel. One packer sealed the drill rods while the other sealed the borehole. The open hole below the lowermost packer was pressurized by pumping water directly into the test interval through the drill pipe and into a water pipe extending through the packers. Test pressure and flow rates were measured at the surface with a pressure gauge and water meter, respectively, and recorded. Generally four or five tests of differing pressures were performed at each interval, which were generally 10 ft in length.

The calculated hydraulic conductivity (K) results from the testing are given in Table B−1. Test sheets from the field packer testing are included in this appendix.

Table B−1. Summary of Packer Test Results

Location	Test Interval (ft bgs)	Test Number	Test Pressure (psi)	K (cm/sec)	Average K (cm/s)
MW−2056	19.0 – 29.7	1	5	4.1×10^{-4}	5.0×10^{-4}
		2	10	4.3×10^{-4}	
		3	15	5.4×10^{-4}	
		4	10	5.5×10^{-4}	
		5	5	5.6×10^{-4}	
	24.0 – 34.7	1	5	2.0×10^{-4}	4.0×10^{-4}
		2	15	3.9×10^{-4}	
		3	25	4.9×10^{-4}	
		4	15	5.1×10^{-4}	
		5	5	3.7×10^{-4}	
	35.0 – 44.7	1	10	7.2×10^{-6}	2.5×10^{-6}
		2	20	No Take	
		3	30	2.4×10^{-6}	
		4	20	No Take	
		5	10	No Take	
	45.0 – 54.7	1	10	No Take	7.5×10^{-6}
		2	30	4.9×10^{-6}	
		3	50	2.3×10^{-5}	
		4	30	No Take	
	55.0 – 64.7	1	15	1.8×10^{-5}	3.6×10^{-5}
		2	35	4.8×10^{-5}	
		3	55	4.4×10^{-5}	
		4	35	6.9×10^{-5}	
		5	15	No Take	
	65.0 – 74.9	1	20	No Take	$<1.0 \times 10^{-7}$
		2	40	No Take	
		3	60	No Take	
MW−3040	44.5 – 55.0	1	15	No Take	4.7×10^{-4}
		2	30	No Take	
		3	45	5.6×10^{-4}	
		4	30	No Take	
		5	15	No Take	
	55.0 – 64.0	1	10	2.1×10^{-5}	3.5×10^{-5}
		2	30	3.9×10^{-5}	
		3	50	5.1×10^{-5}	
		4	30	3.7×10^{-5}	
		5	10	2.5×10^{-5}	
	64.0 – 74.0	1	20	3.2×10^{-5}	2.6×10^{-5}
		2	40	2.5×10^{-5}	
		3	60	3.0×10^{-5}	
		4	40	2.5×10^{-5}	
		5	20	1.8×10^{-5}	
	74.0 – 82.2	1	30	No Take	$< 1.0 \times 10^{-7}$
		2	50	No Take	
		3	70	No Take	

Table B−1 (continued). Summary of Packer Test Results

Location	**Test Interval (ft bgs)**	**Test Number**	**Test Pressure (psi)**	**K (cm/sec)**	**Average K (cm/s)**
MW−3040 (continued)	82.0 – 94.0	1	25	No Take	1.1×10^{-5}
		2	50	9.7×10^{-6}	
		3	75	3.9×10^{-5}	
		4	50	4.9×10^{-6}	
		5	25	No Take	
	94.0 – 104.0	1	30	2.9×10^{-4}	2.9×10^{-4}
		2	60	2.7×10^{-4}	
		3	90	2.5×10^{-4}	
		4	60	2.9×10^{-4}	
		5	30	3.3×10^{-4}	
	104.0 – 114.0	1	45	8.8×10^{-7}	8.9×10^{-7}
		2	70	6.5×10^{-7}	
		3	95	1.4×10^{-6}	
		4	70	6.5×10^{-7}	
		5	45	8.8×10^{-7}	
MW−4040	33.0 – 39.0	1	10	No Take	$< 1.0 \times 10^{-7}$
		2	15	No Take	
		3	25	No Take	
		4	10	No Take	
	38.0 – 49.0	1	10	8.9×10^{-7}	1.6×10^{-6}
		2	20	1.9×10^{-6}	
		3	30	2.5×10^{-6}	
		4	20	1.9×10^{-6}	
		5	10	8.9×10^{-7}	
	50.0 – 65.0	1	20	4.3×10^{-7}	6.4×10^{-7}
		2	30	1.0×10^{-6}	
		3	45	1.0×10^{-6}	
		4	30	3.3×10^{-7}	
		5	20	3.3×10^{-7}	
MW−4041	57.5 – 67.0	1	20	No Take	7.2×10^{-6}
		2	40	3.7×10^{-6}	
		3	60	2.7×10^{-5}	
		4	40	5.2×10^{-6}	
		5	20	No Take	
BH−A	38.0 – 48.0	1	10	3.0×10^{-4}	4.6×10^{-4}
		2	20	4.7×10^{-4}	
		3	30	4.6×10^{-4}	
		4	20	4.9×10^{-4}	
		5	10	5.7×10^{-4}	
	49.0 – 59.0	1	20	1.8×10^{-5}	4.4×10^{-6}
		2	30	No Take	
		3	40	No Take	
		4	30	No Take	
		5	20	No Take	
	59.0 – 69.0	1	20	5.2×10^{-6}	2.1×10^{-6}
		2	40	3.4×10^{-5}	
		3	60	3.6×10^{-5}	
		4	40	2.2×10^{-5}	
		5	20	1.0×10^{-5}	

Table B−1 (continued). Summary of Packer Test Results

Location	Test Interval (ft bgs)	Test Number	Test Pressure (psi)	K (cm/sec)	Average K (cm/s)
BH−A (continued)	69.0 – 79.0	1	20	No Take	3.5 x 10^{-6}
		2	40	5.0 x 10^{-6}	
		3	60	1.2 x 10^{-5}	
		4	40	No Take	
		5	20	No Take	
	79.0 – 89.0	1	20	1.4 x 10^{-5}	8.8 x 10^{-6}
		2	40	2.7 x 10^{-6}	
		3	60	1.4 x 10^{-5}	
		4	40	1.3 x 10^{-5}	
		5	20	No Take	
BH−B	32.0 – 38.0	1	10	1.8 x 10^{-5}	7.7 x 10^{-6}
		2	20	2.0 x 10^{-5}	
		3	30	No Take	
		4	20	No Take	
		5	10	No Take	
	38.0 – 48.0	1	20	1.0 x 10^{-5}	5.2 x 10^{-6}
		2	30	4.0 x 10^{-6}	
		3	40	4.2 x 10^{-6}	
		4	30	7.8 x 10^{-6}	
		5	20	No Take	
	48.0 – 58.0	1	20	No Take	< 1.0 x 10^{-7}
		2	30	No Take	
		3	40	No Take	
		4	50	No Take	
	58.0 – 64.0	1	30	No Take	< 1.0 x 10^{-7}
		2	40	No Take	
		3	50	No Take	
BH−C	68.7 – 77.0	1	20	5.8 x 10^{-5}	6.5 x 10^{-5}
		2	40	6.3 x 10^{-5}	
		3	60	3.8 x 10^{-5}	
		4	40	6.8 x 10^{-5}	
		5	20	1.0 x 10^{-4}	
	78.7 – 87.0	1	20	5.8 x 10^{-5}	4.8 x 10^{-5}
		2	40	4.7 x 10^{-5}	
		3	60	4.0 x 10^{-5}	
		4	40	2.5 x 10^{-5}	
		5	20	6.9 x 10^{-5}	

No Take = no measurable volume of water could be introduced into the formation at the specified pressure.

B.1.3 Well Installations

Three wells (MW−2056, MW−3040, and MW−4040) were drilled and completed in the unweathered portion of the Burlington Keokuk Limestone (see Figure 3−2) to supplement the unweathered zone monitoring well network. The remaining well, MW−4041, was drilled and completed in the overburden/weathered portion of the Burlington-Keokuk Limestone to monitor a paleochannel feature north of the Chemical Plant. The boreholes and wells were drilled, tested, and constructed at locations summarized in Table B−2.

Table B−2. Monitoring Well Construction Summary

Location	Coordinates		Elevations (MSL[a])		Screened Interval (ft bgs[b])	Total Depth[c] (ft)
	Northing	Easting	Ground	Top of Casing		
MW−2056	1043939.0	756027.0	622.2	624.9	73.0 – 83.0	83.0
MW−3040	1042632.8	754252.0	654.3	656.8	95.0 – 105.0	119.0
MW−4040	1042990.8	753001.3	631.7	633.9	55.0 – 65.0	65.0
MW−4041	1048463.8	753070.9	581.0	583.1	55.0 – 65.0	67.0
BH−A	1047099.2	752267.3	609.2	NA	NA	89.1
BH−B	1047574.4	752434.7	609.6	NA	NA	74.0
BH−C	1048053.2	752763.0	604.6	NA	NA	87.0

[a] Elevation above mean sea level.
[b] Feet below ground surface.
[c] Total depth of the deepest advancement of the borehole irrespective of well construction.
NA = Not applicable.

The wells consisted of 2-inch 316 stainless steel wire-wrapped screen (0.0010-inch slot) with 10/20 silica sand filter pack. A 2-inch blank riser was attached to the screen to approximately 3 feet above ground surface. For the unweathered Burlington-Keokuk wells, a 6-inch ID protective casing was grouted into the borehole following the reaming of the borehole to 10 inches. The casing was installed to prohibit the downward movement of contaminated groundwater in the overlying weathered zone. Hydrated bentonite chips generally were utilized as the well seal and bentonite grout was used as the annulus seal. Surface completions consisted of a 5-foot lockable protective cover, set into a 2-ft diameter concrete pad extending 2 ft below the ground surface. A brass identification plate was set into the concrete and the well number stamped into the plate. Where possible the locking well cover was threaded to the 6-inch protective casing. Four steel protective posts (4-in diameter by 6 ft long) were placed to a depth of 3 feet into the ground around the well and cemented in place. Upon completion of the well surface, all wells were surveyed for location and elevation of top of well casing and ground surface. Surveyed coordinates and elevations are included on the borehole logs and well completion diagrams for the monitoring wells.

B.1.4 Well Development

Following a minimum of 48 hours after well completion, all wells were developed using a pump and surge technique combined with overpumping. Physical parameters such as temperature, conductivity, pH, and turbidity were measured until all were consistent, the minimum well volume was removed, and turbidity conditions met the specifications. During development, wells completed in the unweathered zone of the Burlington-Keokuk Limestone exhibited slow recharge (generally less than 1 gallon per minute) and were difficult to clear up. Table B−3 summarizes the development information for wells installed during this effort.

Table B−3. Well Development Summary

Location	Screened Interval	Static Water Level		Volume Removed (gallons)	Observations/Comments
		Before Development	After Development		
MW−2056	73.0 – 83.0	31.2	34.2	45	Very slightly turbid
MW−3040	95.0 – 105.0	57.5	59.2	42	Very slightly turbid Sustained approx. 0.25 to 0.5 gpm
MW−4040	55.0 – 65.0	32.7	33.8	28	Slightly Turbid Very slow recharge
MW−4041	55.0 – 65.0	40.3	42.6	174	Slightly turbid Sustained approx. 1 gpm

gpm = gallons per minute

B.1.5 Hydrogeologic Observations

The results from the packer testing followed trends noted from previous testing at the site such as decreasing permeability with depth with the highest permeability typically resident in the strongly weathered portion of the Burlington Keokuk Limestone.

The drilling of boreholes BH−A, BH−B, BH−C, and MW−4041 (BH−D) was performed to better define a potential paleochannel that was believed to extend north from the site into the Busch Conservation Area. The first two holes drilled encountered relatively shallow bedrock and delineated a bedrock high that was not previously defined. The paleochannel became evident to the northeast with the drilling of the last two boreholes. Well MW−4041 was placed at BH−D location because it exhibited the deepest bedrock elevation and little residuum was encountered that is indicative of the paleofeatures. The site bedrock topography map was updated with the data from this drilling program. The bedrock topography north of the site is much better defined and the morphology is indicative of more deeply incised drainages.

B.1.6 References

U.S. Department of Interior (DOI), 1977. *Groundwater Manual, A Water Resources Technical Publication*, prepared by the Bureau of Reclamation.

End of current text

Borehole Logs and Well Diagrams

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER BH-A
SHEET 1 OF 2
NORTH (Y) : 1047099.2
EAST (X) : 752267.3
TOC ELEVATION
GROUND ELEVATION 609.2
STICKUP
HYDR CONDUCTIVITY (cm/sec) K= 4.6x10^{-4} (Packer Test)

WELL STATUS/COMMENTS Exploratory Borehole
LOCATION BUSCH WILDLIFE AREA
DRILLING CONTRACTOR ROBERTS ENVIRONMENTAL Inc.
DRILL RIG MAKE & MODEL CME-750 HSA/NQWL
HOLE SIZE & METHOD 7-1/4" HSA-27.5' NQ-89.1'
ANGLE FROM HORIZONTAL & BEARING Vertical
DRILL FLUIDS & ADDITIVES Water core
CASING TYPE, DEPTH, SIZE None
DATE START 05-03-04
DATE FINISH 05-05-04

DEPTH (FT.) FROM GROUND ELEV. TO:
BOTTOM OF HOLE (TD) 89.1
BEDROCK 27.5
WATER LEVELS & DATES ▽ ▼

LITHOLOGY BY ALLEN BENFER

SAMPLE/RUN Number	PERCENT Recovery (0–100)	N# or RQD
SPT-1	12/18"	13
SPT-2	12/18"	13
SPT-3	18/18"	11
SPT-4	18/18"	13
SPT-5	18/18"	41
SPT-6	18/18"	40
SPT-7	6/6"	50
RUN-1	9/84"	0
RUN-2	18/60"	14
RUN-3	37/37"	87
RUN-4	59/72"	27
RUN-5	115/120"	86
RUN-6	68/72"	68

SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
CL	1.0 - 7.0'. CLAY, medium plasticity, stiff, moist, brown and pale brown, some iron oxide, some root hairs, MnOx (black), CL FERRELVIEW CLAY	QFv
CH	7.0 - 11.0'. CLAY, high plasticity, hard, ~10% sand and fine gravel, (white), clay is reddish brown & gray mottled together, moist, by 9.0' only a trace of sand and gravel but abundant FeOx, CH FERRELVIEW CLAY	QFv
CH GRVL	11.0 - 27.5'. CLAY, high plasticity, with ~20% fine angular chert gravel increasing with depth, reddish brown and black (MnOx), moist, hard, CH RESIDUUM @17.0' Switched to NQWL coring, partial water return (reddish), drilling fast, poor recoery (mostly chert and some red clay - Residuum)	pPr
LMS CHRT	Top oflimestone bedrock @ 27.5 ft. 27.5 - 36.8'. LIMESTONE and CHERT, approx 60/30, interbedded and finely divided together. Overall limestone is very weathered, finely crystalline, yellow brown, mod. hard, vuggy with minor small voids, FeOx common, several loss zones, some stylolites. Chert exhibits wavy bedding, hard, light colored. STRONGLY WEATHERED BURLINGTON-KEOKUK LIMESTONE UNIT 36.8 - 49.7'. LIMESTONE with CHERT, approx. 50/50, Limestone is highly weathered and eroded, soft to mod. hard, vuggy, yellow brown with clay along some fractures. Chert is nodular.	Mbksw

DEPTH feet	ELEVATION feet
5	605
10	600
15	595
20	590
25	585
30	580
35	575
40	570
45	565

WELL DIAGRAM

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

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER BH-A

SHEET 2 OF 2

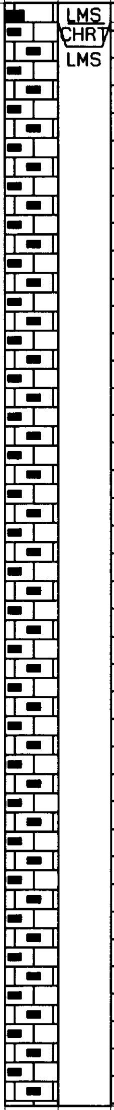
NORTH (Y): 1047099.2

EAST (X): 752267.3

WELL STATUS/COMMENTS Exploratory Borehole

LOCATION BUSCH WILDLIFE AREA

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery 0 100	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	WELL DIAGRAM	ELEVATION feet
						LMS CHRT LMS	49.7 - 66.4'. LIMESTONE, yellow brown to pale brown, moderately weathered, with stylolites, with approx. 20% chert primarily as nodules. Limestone exhibits oxidation on fractures, is medium bedded to massive, finely to coarsely crystalline, med. hard to hard, fossiliferous, decreasing weathering with depth. WEATHERED BURLINGTON-KEOKUK LIMESTONE UNIT	Mbksw		560
54		RUN-7	28/60"	18						555
59		RUN-8	115/120"	66						550
64										545
							66.4 - 83.2'. LIMESTONE, massive, generally finely crystalline, slightly weathered, styolitic, minor chert, oxidized fractures, 25% gray chert from 69.1-72.0', occasional voids to 2", fossiliferous, chert bed from 82.3-83.2' (gray to light gray).	Mbkw		
69		RUN-9	120/120"	69						540
74										535
79		RUN10	38/38"	44						530
		RUN11	82/82"	81						
84							83.2 - 89.1'. LIMESTONE, very slightly weathered, fine to coarsly crystalline, fossiliferous, several stylolites, hard minor iron staining, light gray (near unweathered contact).			525
89										520
							Total depth 89.1', 5-05-04. Hole abandoned to the surface with high-solids bentonite grout.			
94										515
99										510
104										505



CONSTANT HEAD SINGLE PACKER TEST RESULTS
38.0 - 48.0-FT. K = 4.6E-4 cm/sec
49.0 - 59.0-FT. K = 2.3E-6 cm/sec
59.0 - 69.0-FT. K = 2.1E-5 cm/sec
69.0 - 79.0-FT. K = 3.5E-6 cm/sec
79.0 - 89.0-FT. K = 8.8E-6 cm/sec

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

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER BH-B

SHEET 1 OF 2

NORTH (Y): 1047574.4

EAST (X): 752434.7

WELL STATUS/COMMENTS Exploratory Borehole

LOCATION BUSCH WILDLIFE AREA

DRILLING CONTRACTOR ROBERTS ENVIRONMENTAL Inc.

DRILL RIG MAKE & MODEL CME-750 HSA/NQWL

TOC ELEVATION

HOLE SIZE & METHOD 7-1/4" HSA-28.5' NQ-74.0'

ANGLE FROM HORIZONTAL & BEARING Vertical

DEPTH (FT.) FROM / GROUND ELEV. TO:

BOTTOM OF HOLE (TD) 74.0

GROUND ELEVATION 609.6

DRILL FLUIDS & ADDITIVES Water core

CASING TYPE, DEPTH, SIZE None

BEDROCK 28.5

STICKUP

DATE START 04-29-04

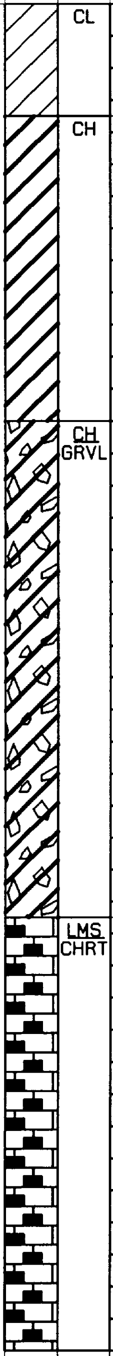
DATE FINISH 05-03-04

WATER LEVELS & DATES ▽ ▼

HYDR CONDUCTIVITY (cm/sec) $K= 7.7x10^{-6}$ (Packer Test)

LITHOLOGY BY ALLEN BENFER

SAMPLE/RUN Number	PERCENT Recovery (0–100)	N# or RQD	SOIL/ROCK class
SPT-1	10/18"	5	CL
SPT-2	12/18"	10	CH
SPT-3	18/18"	23	
SPT-4	18/18"	18	
SPT-5	9/9"	50	
SPT-6	12/18"	29	CH GRVL
SPT-7	14/18"	28	
SPT-8	6/12"	87	
SPT-9		69	
SPT-10	18/18"	36	
SPT-11		43	
SPT-12	6/6"	50	
RUN-1	114/114"	73	LMS CHRT
RUN-2	60/60"	76	



DESCRIPTION AND REMARKS

0.0 - 3.5'. CLAY, medium plasticity, firm, moist, mottled reddish- brown, black, and light brown, abundant iron oxide and MnOx root hairs ROXANA SILT

3.5 - 6.0'. CLAY, high plasticity, stiff, trace sand and fine gravel, mottled reddish brown & light gray, moist, trace carbonized hair roots. CH FERRELVIEW CLAY

6.0 - 13.0'. CLAY, high plasticity, with ~10% sand and fine gravel, very stiff, mottled yellow brown, black (MnOx), and light gray, moist, FeOx common, CH CLAY TILL

13.0 - 28.5'. CLAY, highly plastic with up to 40% angular chert gravel (white), clay is reddish brown, very stiff to hard, damp, CH RESIDUUM

Predominantly chert gravel at 25.5'.

Rods bouncing. Top of rock at 28.5. Switch to NQWL Core.

28.5 - 48.0'. LIMESTONE and CHERT, approx 60/30, interbedded and finely divided together. Limestone is moderately to severely weathered, yellow brown, soft to med. hard, finely crystalline, FeOx common, MnOx specks, some clay coating on fractures. Chert as beds and nodules, very hard, light colored. STRONGLY WEATHERED BURLINGTON- KEOKUK LIMESTONE UNIT

---Vuggy at 30'

---8-inch void at 32.5'

---Mostly CHERT from 35 - 38', bluish gray, limestone less weathered.

STRAT. UNIT

- QRx
- QFv
- Qct
- pPr
- Mbksw

WELL DIAGRAM

DEPTH feet	ELEVATION feet
5	605
10	600
15	595
20	590
25	585
30	580
35	575
40	570

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

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER
BH-B

SHEET 2 OF 2

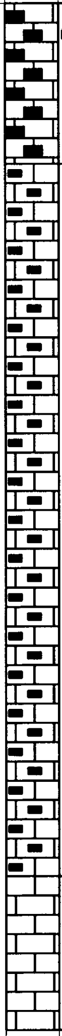
NORTH (Y): 1047574.4

EAST (X): 752434.7

WELL STATUS/COMMENTS
Exploratory Borehole

LOCATION
BUSCH WILDLIFE AREA

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery 0 100	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	WELL DIAGRAM	ELEVATION feet
		RUN-3	60/60"	40		LMS CHRT		Mbksw		565
47		RUN-4	118/120"	89		LMS	47.0 - 69.2'. LIMESTONE with CHERT, approx. 60/40, Limestone is moderately to slightly weathered, hard, thinly bedded and interbedded with chert, FeOx and clay along some fractures, shaley zones a few inches thick, finely to coarsely crystalline, fossiliferous (increasingly with depth), MnOx and stylolites common. WEATHERED BURLINGTON-KEOKUK LIMESTONE UNIT	Mbkw		560
52										555
57		RUN-5	72/72"	92						550
62		RUN-6	120/120"	54						545
67										540
72						LMS	69.2 - 74.0'. LIMESTONE, with minor interbedded CHERT. Limestone is argillaceous, grayish brown, finely crystalline, very fossiliferous and stylolitic. Chert is light gray. UNWEATHERED BURLINGTON-KEOKUK LIMESTONE UNIT	Mbkuw		535
77							Total depth 74.0', 5-03-04. Hole abandoned to the surface with high-solids bentonite grout.			530
82										525
87										520



CONSTANT HEAD SINGLE PACKER TEST RESULTS
32.0 - 38.0-FT. K = 7.7E-6 cm/sec
38.0 - 48.0-FT. K = 5.2E-6 cm/sec
48.0 - 58.0-FT. K = <1.0E-7 cm/sec
58.0 - 64.0-FT. K = <1.0E-7 cm/sec
68.7 - 77.0-FT. K = 6.5E-5 cm/sec
78.7 - 87.0-FT. K = 4.8E-5 cm/sec

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

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER BH-C

SHEET 1 OF 2

NORTH (Y): 1048053.2

EAST (X): 752763.0

TOC ELEVATION

GROUND ELEVATION 604.6

STICKUP

HYDR CONDUCTIVITY (cm/sec) K= 6.5x10^{-5} (Packer Test)

WELL STATUS/COMMENTS Exploratory Borehole

LOCATION BUSCH WILDLIFE AREA

DRILLING CONTRACTOR ROBERTS ENVIRONMENTAL Inc.

DRILL RIG MAKE & MODEL CME-75 HSA/NQWL

HOLE SIZE & METHOD 7-1/4" HSA-43.5' NQ-87.0'

ANGLE FROM HORIZONTAL & BEARING Vertical

DRILL FLUIDS & ADDITIVES Water core

CASING TYPE, DEPTH, SIZE None

DATE START 04-26-04

DATE FINISH 04-28-04

DEPTH (FT.) FROM GROUND ELEV. TO:

BOTTOM OF HOLE (TD) 87.0

BEDROCK 43.5

WATER LEVELS & DATES ∇ ▼

LITHOLOGY BY ALLEN BENFER

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery 0 100	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	WELL DIAGRAM	ELEVATION feet
	SPT-1		10	CL	0.0 – 3.5'. CLAY, medium plasticity, firm, damp to moist, mottled light brown and black, trace FeOx, CL FERRELVIEW CLAY	QFv		
5	SPT-2		7		3.5 – 5.5'. CLAY, as above, increase in reddish FeOx and considerable MnOx (black), firm, CL FERRELVIEW CLAY			600
	SPT-3		8	CH	5.5 – 9.0'. CLAY, high plasticity, with ~10% fine limestone gravel, firm, mottled orange brown and gray, moist, CH BASAL FERRELVIEW CLAY			
10	SPT-4		12		9.0 – 15.5'. CLAY, high plasticity, trace fine gravel, orange brown, with light gray and black streaks filling fractures, moist, stiff, 1/8" to 1/2" rounded and angular clasts. CH CLAY TILL	Qct		595
	SPT-5		14					
15	SPT-6		15					590
	SPT-7		16		15.5 – 18.0'. CLAY, low plasticity, silty, massive, rounded gravel (rose-colored) moist, stiff, CL CLAY TILL			
20	SPT-8		31	CH GRVL	18.0 – 43.5'. CLAY, high plasticity, reddish brown, moist, with ~40% angular gravel (chert and weathered limestone), moist, very stiff, CH RESIDUUM	pPr		585
	SPT-9		55+					
	SPT-10		27					
25	SPT-11		57					580
	SPT-12		31					
30	SPT-13		25		Residuum as above but with~50% angular chert gravel increasing with depth.			575
	SPT-14		28					
35	SPT-15		21		Very moist at 36'with some chert sand.			570
40	SPT-16		50					565
	SPT-17		18		Refusal. Top of rock at 43.5. Switch to NQWL Core. No water return.			
45	SPT-18 RUN-1	75/90"	50	LMS CHRT	43.5 – 48.0'. LIMESTONE and CHERT, approx 60/30, interbedded and finely divided together. Limestone is moderately to severely weathered, gray to tan, locally argillaceous, vuggy (pinpoint to 1"), signficant solution voids throughout section, some massive quartz, some clay along fractures, some iron oxide, STRONGLY WEATHERED BURLINGTON-KEOKUK LIMESTONE UNIT	Mbksw		560

▮ Sample Interval ☐ No Sample Taken ∇minimum ▼maximum ▼average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER BH-C

SHEET 2 **OF** 2

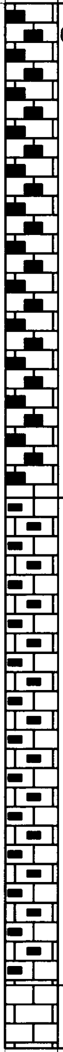
NORTH (Y): 1048053.2

EAST (X): 752763.0

WELL STATUS/COMMENTS Exploratory Borehole

LOCATION BUSCH WILDLIFE AREA

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery 0 100	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	WELL DIAGRAM	ELEVATION feet
	▮	RUN-2	10/96"	0		LMS CHRT	---Water circulation returns at 50.5' --@ 51.5 Bit dropped to 54.5'and lose circulation. Run 2 recovered only 0.8' of chert with trace of clay.	Mbksw		555
54	▮						---Void from 55.0 - 55.5' ---Void from 56.5 - 58.0' ---Void from 58.5 - 59.0'			550
59	▮	RUN-3	5/54"	0			---Void from 59.5 - 63.5' Run 3 recovered only 0.4' of light colored chert with some brown clay.			545
64	▮	RUN-4	13/42"	20			---Void from 63.75 - 65.25' Run 4 recovered 1.1' of mostly lightly colored chert with minor slightly weathered limestone.			540
	▮	RUN-5	56/60"	70		LMS	67.0 - 84.7'. LIMESTONE with CHERT, interbedded. Limestone is slightly weathered, thinly bedded and occasionally wavey bedded, stylolitic with MnOx coating, finely crystalline, becoming more fossiliferous with depth, occasional vugs, minor FeOx. WEATHERED BURLINGTON-KEOKUK LIMESTONE UNIT	Mbkw		
69	▮									535
	▮	RUN-6	55/60"	77						
74	▮									530
	▮	RUN-7	60/60"	86						
79	▮									525
	▮	RUN-8								
84	▮									520
	▮					LMS	84.7 - 87.0'. LIMESTONE, fresh, medium crystalline, light gray, highly fossiliferous, hard with minor bluish-gray chert. UNWEATHERED BURLINGTON-KEOKUK LIMESTONE UNIT	Mbkuw		
89							Total depth 87.0', 4-28-04. Hole abandoned to the surface with high-solids bentonite grout. CONSTANT HEAD SINGLE PACKER TEST RESULTS 68.7 - 77.0-FT. K = 6.5E-5 cm/sec 78.7 - 87.0-FT. K = 4.8E-5 cm/sec			515
94										510
99										505
104										500



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

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER MW-2056

SHEET 1 OF 2

NORTH (Y): 1043939.0

EAST (X): 756027.0

TOC ELEVATION 624.9

GROUND ELEVATION 622.2

STICKUP 2.7

HYDR CONDUCTIVITY (cm/sec) K= $5.0x10^{-4}$ (Packer Test)

WELL STATUS/COMMENTS ACTIVE

LOCATION NW. OF DISPOSAL CELL; PERIMETER WELL

DRILLING CONTRACTOR ROBERTS ENVIRONMENTAL Inc.

DRILL RIG MAKE & MODEL CME-750 HSA/NQWL; I-R TH-60 AIR ROTARY

HOLE SIZE & METHOD 7-1/4" HSA-15' NQ-75' 6" AIR-83'

ANGLE FROM HORIZONTAL & BEARING Vertical

DEPTH (FT.) FROM GROUND ELEV. TO:

BOTTOM OF HOLE (TD) 83.0

BEDROCK 15.0

WATER LEVELS & DATES ∇ ▼

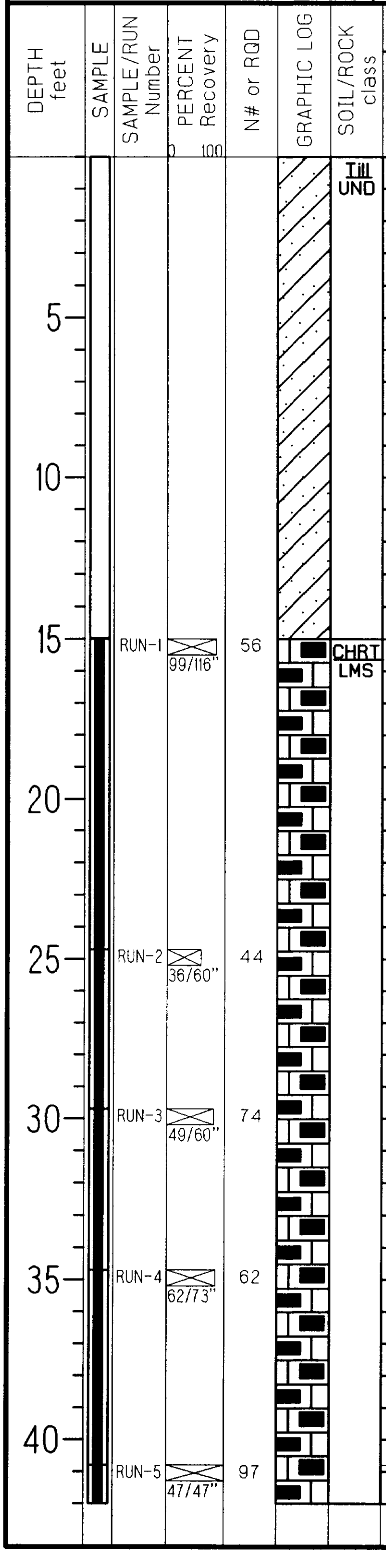
DRILL FLUIDS & ADDITIVES Water core; Air ream

CASING TYPE, DEPTH, SIZE 2" 316 SS Mon. Well

DATE START 05-7-04

DATE FINISH 05-14-04, Mon. Well

LITHOLOGY BY ALAN BENFER



DESCRIPTION AND REMARKS

Soil not sampled or logged from the surface to 15.0-ft.

CHERT AND LIMESTONE, chert (60%) is yellowish brown to light gray, hard. Limestone is highly weathered, moderately soft, solutioned, partial water return. Strongly Weathered Burlington-Keokuk Limestone

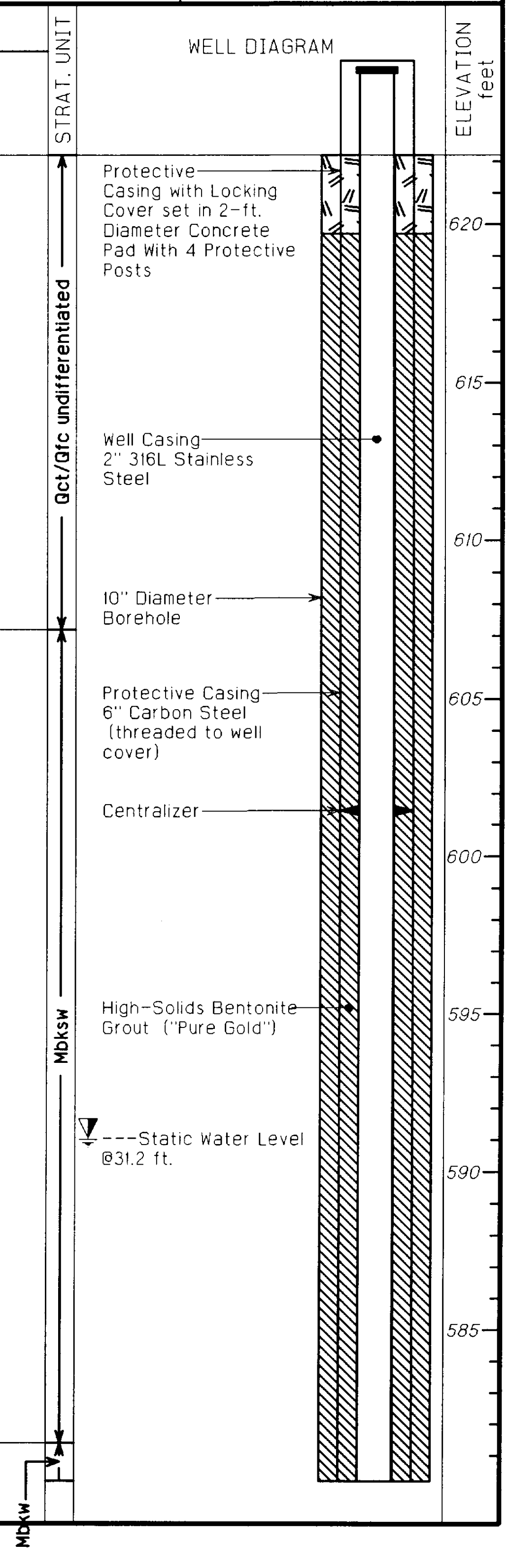
18.7 - 22.5 ft. solutioned zones with some stylolites

--6-inch void @ 27,5 ft., limestone is highly weathered, weak, solutioned, yellow brown.

29.7 - 37.0 ft. Increasing chert, limestone is mod. weathered argillaceous, mod. soft, yellow-brown, minor solutioning, thin-bedded, interbedded with the chert.

@37.0-40.8 ft. Approx. 40% Limestone, highly weathered, weak, local solutioning along fractures, yellow brown. STRONGLY WEATHERED BURLINGTON KEOKUK LIMESTONE

@40.8'- 42.6'. mostly CHERT, gray to blue-gray with 30% weathered LIMESTONE, yellow brown, minor solutioning



▮ Sample Interval ☐ No Sample Taken ∇minimum ▼maximum ∇average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER MW-2056

SHEET 2 OF 2

NORTH (Y): 1043939.0

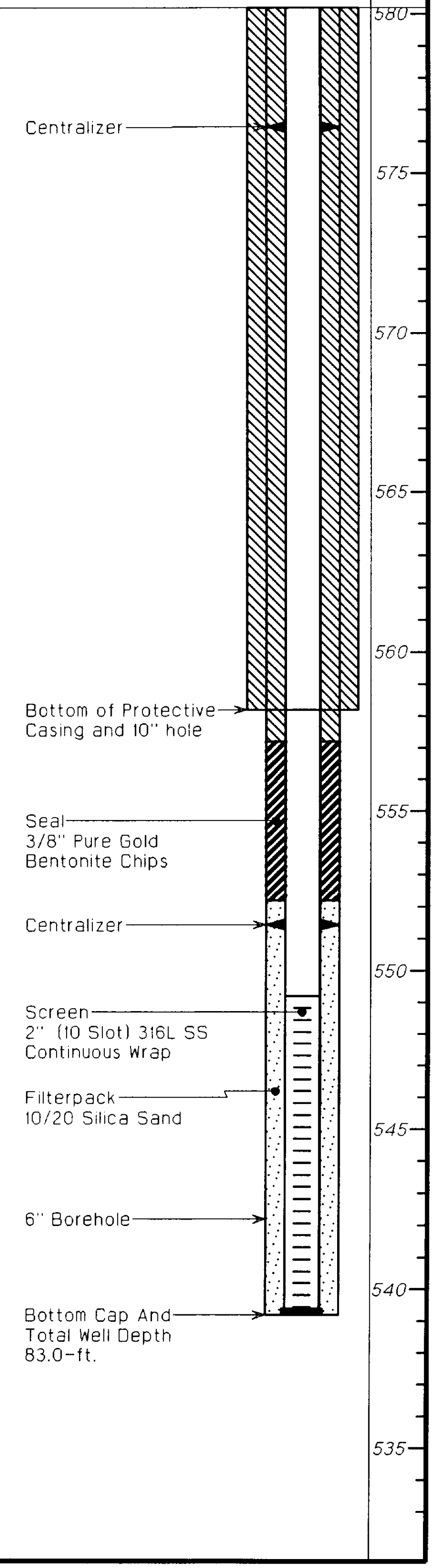
EAST (X): 756027.0

WELL STATUS/COMMENTS ACTIVE

LOCATION NW. OF DISPOSAL CELL; PERIMETER WELL

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery 0 100	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
				CHRT LMS	@ 42.6'-44.7'. CHERT up to 12" thick, massive, minor mod. weathered LIMESTONE, hard, gray to light brown, with thin carbonaceous zone at 44.3'	Mbkw
47	RUN-6	120/120"	92		@ 44.7'- 49.0'. 50% CHERT, bluish gray, 50% LIMESTONE, light brown, mod. weathered, blocky appearance, abundant quartz from 44.7 to 45.7', thin wavey carbonaceous banding at 50.3'	
				LMS CHRT	@49.0'- 51.3'. Predominantly LIMESTONE, light brown, fine-grained, mod. weathered, with nodules of blue-gray CHERT.	
52					@ 51.3'- 54.7'. LIMESTONE, light brown, with blue-gray CHERT, abundant stylolites from 51.7 - 52.4', minor solutioning at 54.6'.	
	RUN-7	22/23"	58		@ 54.7'- 60.0'. CHERT, hard, white to blue-gray, with interbedded light brown LIMESTONE. Chert and limestone are slightly weathered, chert with fresh and oxidized pyrite at 57.8' and 58.4 - 59'.	
57	RUN-8	92/97"	69			
62					@ 60.0'- 63.5'. Massive LIMESTONE, hard. very slightly weathered, gray, mostly crystalline and fossiliferous, some fine-grained, with stylolites coated with MnOx, little chert.	
67	RUN-9	120/120"	76		@ 63.5'- 67.7' LIMESTONE, crystalline, hard, gray to light brown, very slightly weathered, oxidized and fresh pyrite @ 66.4', no chert. WEATHERED/UNWEATHERED BURLINGTON KEOKUK LIMESTONE CONTACT @ 67.7'	
72				LMS	67.7'-74.7' LIMESTONE, gray, hard, unweathered, trace MnOx on some fractures, massive, coarsly crystalline and fossiliferous, several stylolites. UNWEATHERED BURLINGTON KEOKUK LIMESTONE	Mbkuw
77					Total cored depth 74.7', 5-11-04. Hole reamed to 10" diameter to 64.0' and a 6" casing was installed and grouted. Hole then reamed to 6" from 64.0' to 83.0' and a 2" monitoring well was constructed.	
82					CONSTANT HEAD SINGLE PACKER TEST RESULTS 19.0 - 29.7-FT. K = 5.0E-4 cm/sec 24.0 - 34.7-FT. K = 3.9E-4 cm/sec 35.0 - 44.7-FT. K = 2.0E-6 cm/sec 45.0 - 54.7-FT. K = 7.0E-6 cm/sec 55.0 - 64.7-FT. K = 3.6E-5 cm/sec 65.0 - 74.9-FT. K = <1.0E-7 cm/sec	
87						

WELL DIAGRAM

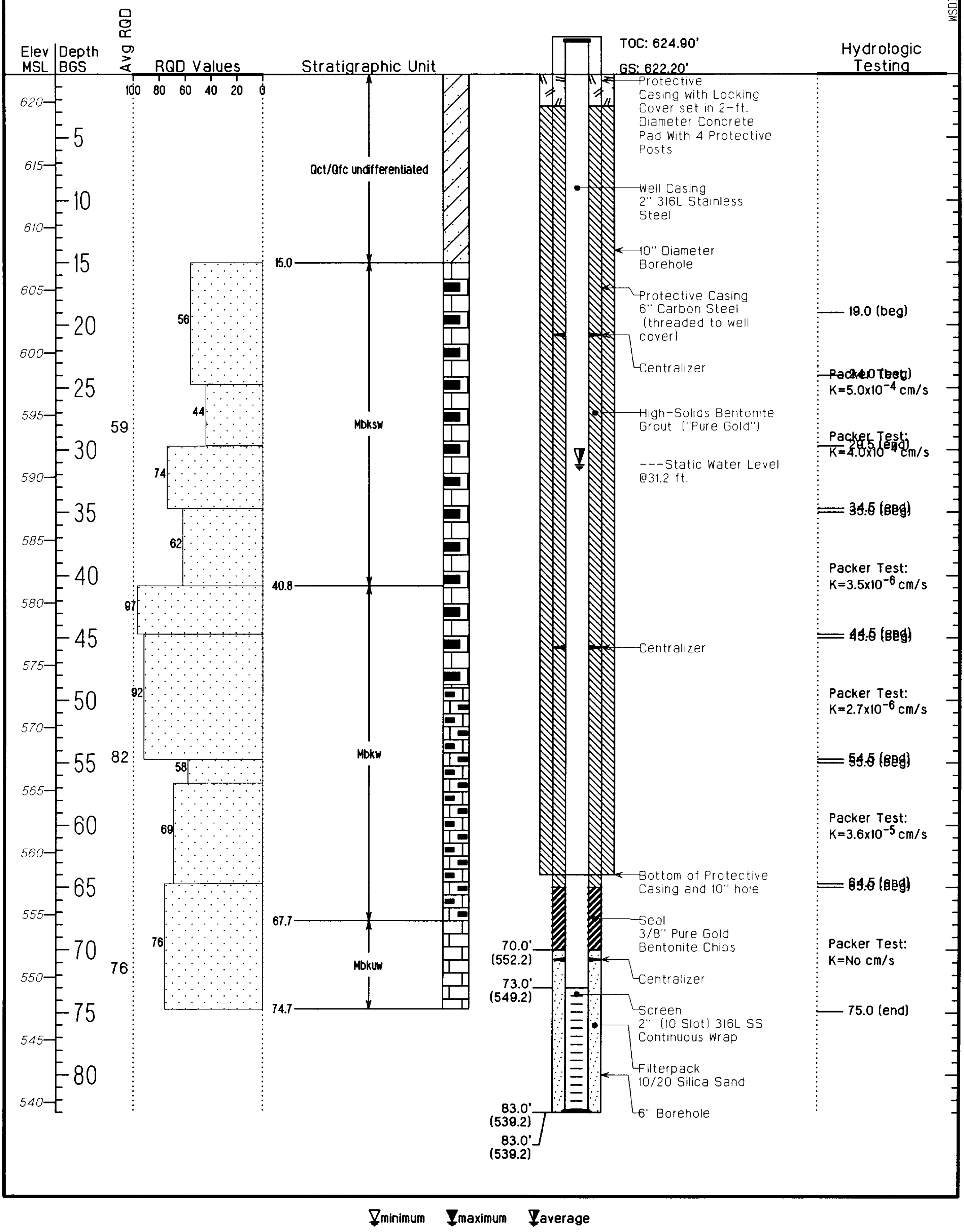


◨ Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

BOREHOLE DIAGRAM

Page 1 of 1

MW-2056



WELDON SPRING SITE REMEDIAL ACTION PROJECT

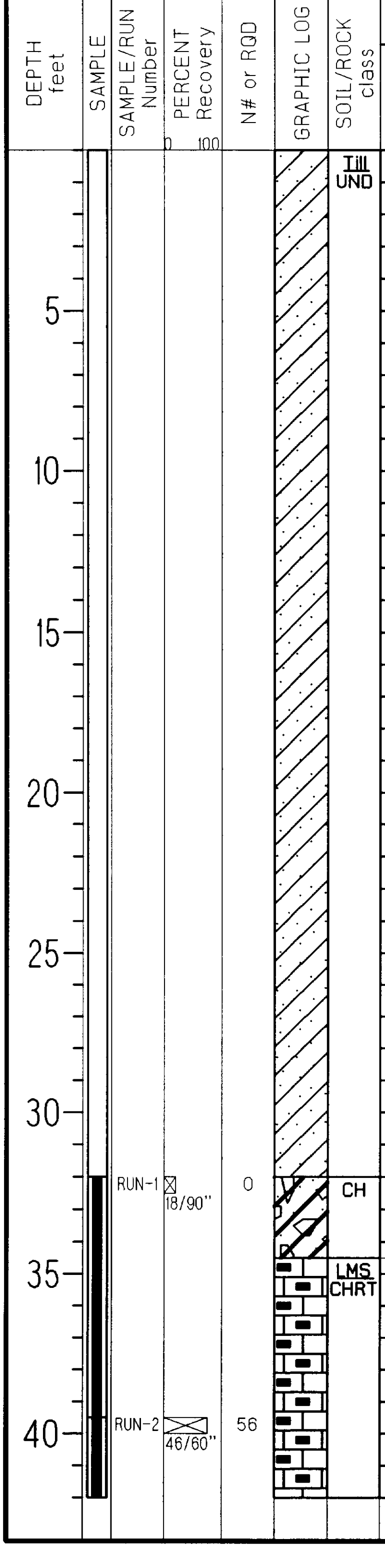
BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

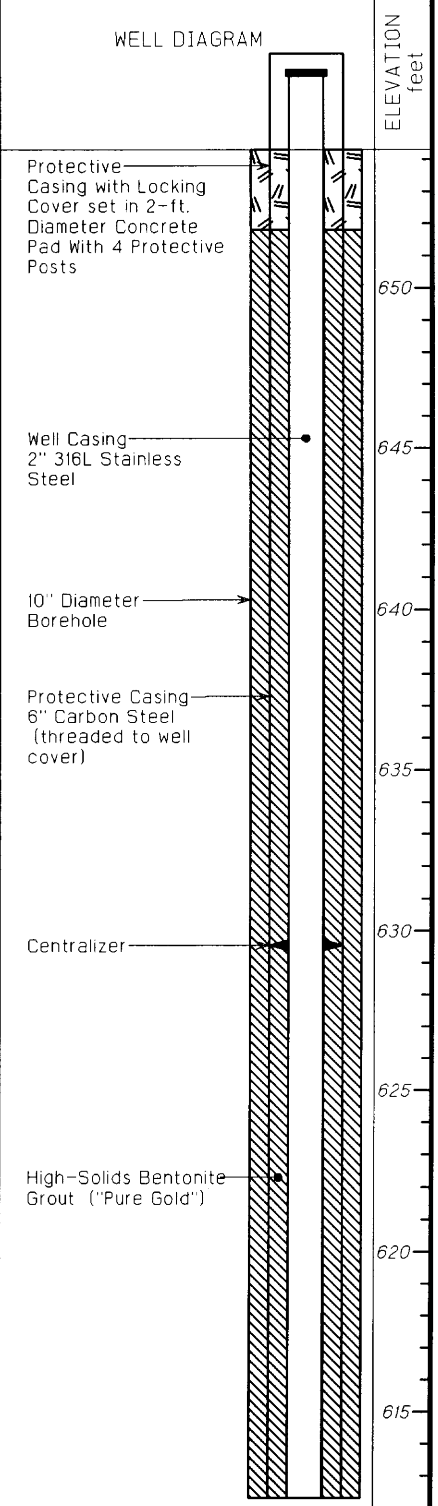
HOLE NUMBER MW-3040
SHEET 1 OF 3
NORTH (Y): 1042632.8
EAST (X): 754252.0
TOC ELEVATION 656.8
GROUND ELEVATION 654.3
STICKUP -2.5
HYDR CONDUCTIVITY (cm/sec) K= 5.5x10^{-6} (Packer Test)

WELL STATUS/COMMENTS ACTIVE
LOCATION S. OF DISPOSAL CELL; PERIMETER WELL
DRILLING CONTRACTOR ROBERTS ENVIRONMENTAL Inc.
DRILL RIG MAKE & MODEL CME-750 HSA/NQWL; I-R TH-60 AIR ROTARY
HOLE SIZE & METHOD 7-1/4" HSA-32' NQ-119' 6" AIR-105'
ANGLE FROM HORIZONTAL & BEARING Vertical
DRILL FLUIDS & ADDITIVES Water core; Air ream
CASING TYPE, DEPTH, SIZE 2" 316 SS Mon. Well
DATE START 05-11-04
DATE FINISH 05-19-04, Mon. Well
DEPTH (FT.) FROM GROUND ELEV. TO:
BOTTOM OF HOLE (TD) 119.0
BEDROCK 34.5
WATER LEVELS & DATES ▽ ▼

LITHOLOGY BY ALAN BENFER/PAUL PATCHIN



SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
			Till UND	Soil not sampled or logged from the surface to 32.0-ft. Start coring at 32.0'	Qct/Qfc undifferentiated
RUN-1	18/90"	0	CH	@ 32' Start NQ coring, no water return. CLAY, high plasticity, reddish brown with 5-inch length of chert and highly weathered limestone fragments, yellow brown, RESIDUUM	
			LMS CHRT	No water return, possible that the residuum clay blocked off the core barrel and some rock was ground away. Estimate TOP OF ROCK at 34.5 ft.	Mbksw
RUN-2	46/60"	56		39.5 - 40.7'. CHERT GRAVEL from residuum at top of run. STRONGLY WEATHERED BURLINGTON-KEOKUK LIMESTONE UNIT	
				40.7 - 42.9'. Mostly CHERT as nodules, gray and orange-brown.	



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

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER MW-3040

SHEET 2 **OF** 3

NORTH (Y): 1042632.8

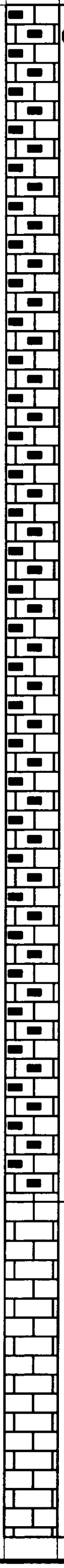
EAST (X): 754252.0

WELL STATUS/COMMENTS ACTIVE

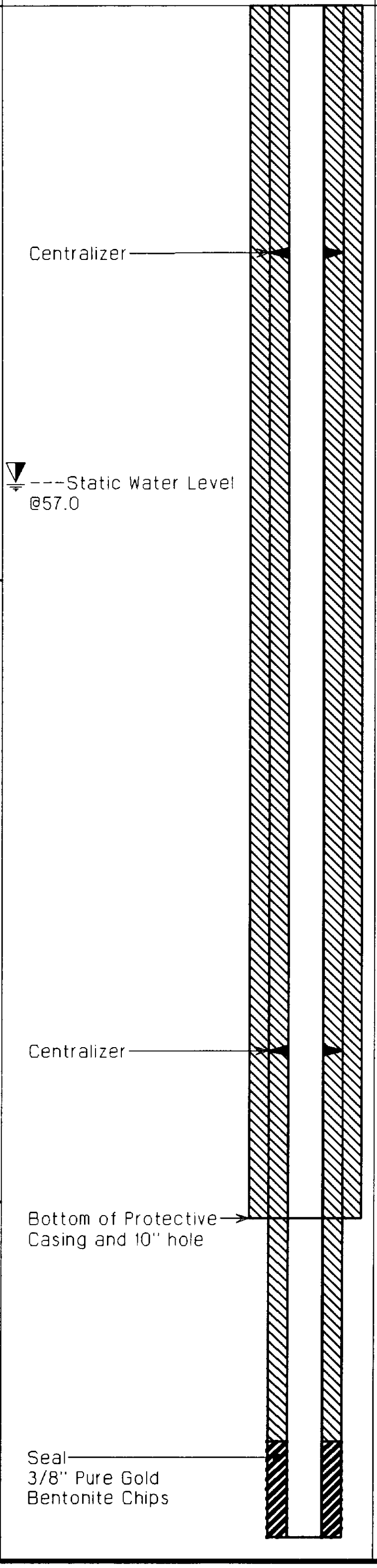
LOCATION S. OF DISPOSAL CELL; PERIMETER WELL

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery 0 100	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	ELEVATION feet
	▮				LMS CHRT	42.9 - 47.0'. CHERT with minor Limestone, orange-brown, limestone is highly weathered, moderately soft, strongly solutioned 43.9-44.4', occasional clay seam.		
	▮	RUN-3	36/60"	42				610
47	▮					47.0' STRONGLY WEATHERED LIMESONE, soft, with black MnOx specks, weak, orange-brown, with minor Chert, gray and orange-brown, approx 50/50 limestone to chert with several stylolites from 55 ft.	Mbksw	
	▮	RUN-4	24/24"	50				605
52	▮	RUN-5	38/71"	31				
	▮							600
57	▮	RUN-6	50/79"	16		Several loss zones in Run 6, many fractures, mostly CHERT, gray to blue gray with some mottled white and light brown, some with microfractures, approx. 20% LIMESTONE, highly weathered.		595
	▮					60.0' Increasing LIMESTONE, light brown to orange brown, some solutioning, most fractures up to 1". WEATHERED BURLINGTON KEOKUK LIMESTONE UNIT	Mbkw	
62	▮	RUN-7	103/120"	44		64.0 - 71.7'. CHERT and LIMESTONE approx. 50/50, finely divided, speckled appearance. Limestone is light brown moderately weathered, some solutioning, fine-grained. Chert is gray to blue-gray. Quartz crystals @ 67.5'		590
67	▮							585
72	▮					71.7'- 79.5'. Interbedded LIMESTONE and CHERT, limestone is moderately weathered, light brown, with shaley zones, fine-grained, Chert is blue-gray. White quartz and soft brown limestone 72.3-72.8.		
	▮	RUN-8	89/98"	100		74.6'. Limestone and chert becoming less weathered (slightly weathered) with depth.		580
77	▮					WEATHERED/UNWEATHERED BURLINGTON-KEOKUK CONTACT @79.5'		575
	▮				LMS	79.5'. LIMESTONE, fine-grained, slightly weathered, gray, minor oxidation, minor chert. UNWEATHERED BURLINGTON-KEOKUK LIMESTONE UNIT	Mbkuw	
82	▮	RUN-9	79/82"	86		82.2'- 87.0'. LIMESTONE, hard, fine-grained, slightly weathered, oxidation on fracture surfaces, some stylolites, approx. 20% blue-gray chert.		570
87	▮					87.0'- 89.0'. LIMESTONE, light brown, slightly weathered, fine-grained, interbedded with blue-gray chert.		
	▮	RUN-10	60/60"	92		89.0'- 95.8'. LIMESTONE, very slightly weathered, fossiliferous, oxidation on fractures, light gray, several stylolites.		565

GRAPHIC LOG



WELL DIAGRAM



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

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER MW-3040

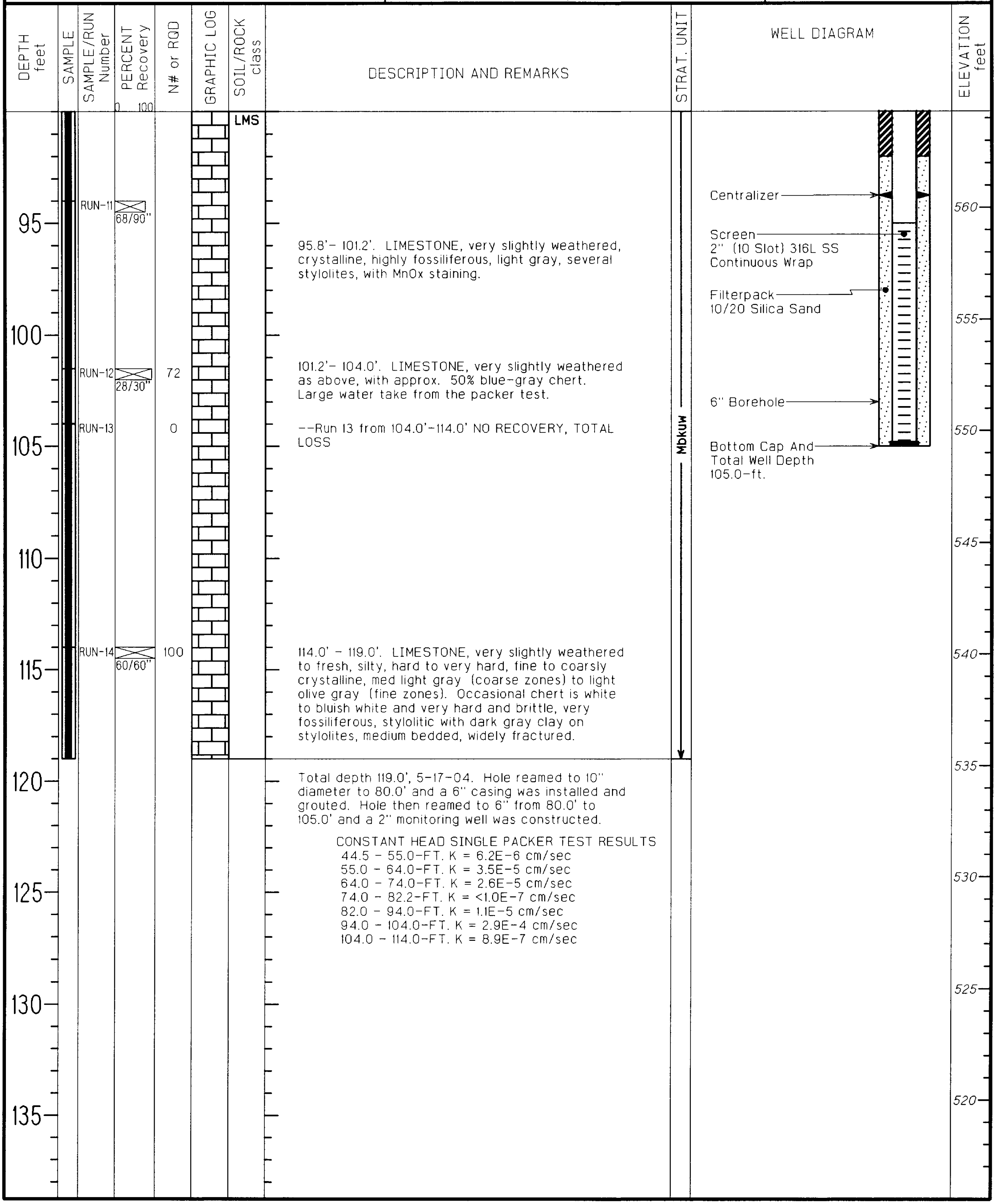
SHEET 3 OF 3

NORTH (Y) : 1042632.8

EAST (X) : 754252.0

WELL STATUS/COMMENTS ACTIVE

LOCATION S. OF DISPOSAL CELL; PERIMETER WELL



95.8'- 101.2'. LIMESTONE, very slightly weathered, crystalline, highly fossiliferous, light gray, several stylolites, with MnOx staining.

101.2'- 104.0'. LIMESTONE, very slightly weathered as above, with approx. 50% blue-gray chert. Large water take from the packer test.

--Run 13 from 104.0'-114.0' NO RECOVERY, TOTAL LOSS

114.0' - 119.0'. LIMESTONE, very slightly weathered to fresh, silty, hard to very hard, fine to coarsly crystalline, med light gray (coarse zones) to light olive gray (fine zones). Occasional chert is white to bluish white and very hard and brittle, very fossiliferous, stylolitic with dark gray clay on stylolites, medium bedded, widely fractured.

Total depth 119.0', 5-17-04. Hole reamed to 10" diameter to 80.0' and a 6" casing was installed and grouted. Hole then reamed to 6" from 80.0' to 105.0' and a 2" monitoring well was constructed.

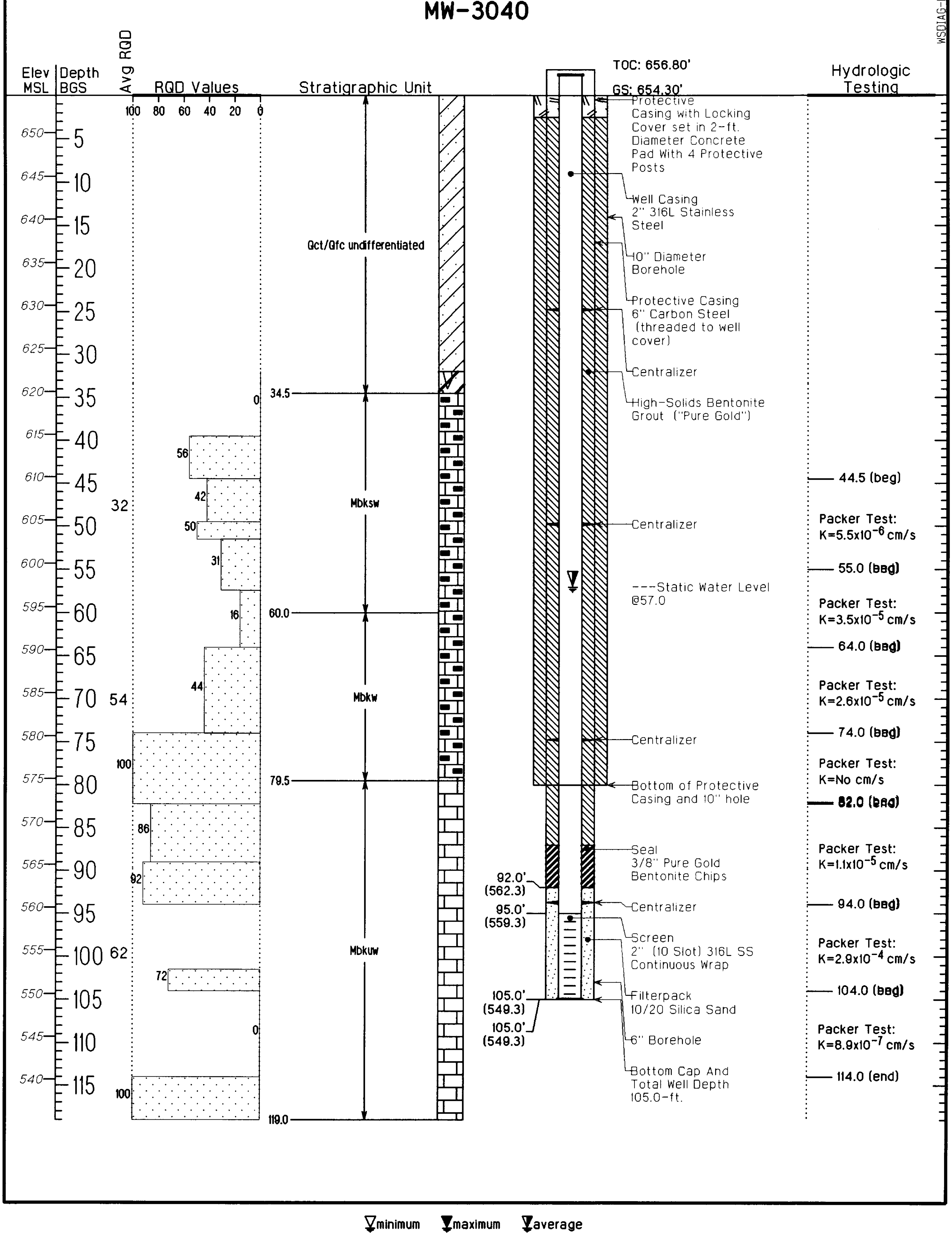
CONSTANT HEAD SINGLE PACKER TEST RESULTS

44.5 - 55.0-FT. K = 6.2E-6 cm/sec
55.0 - 64.0-FT. K = 3.5E-5 cm/sec
64.0 - 74.0-FT. K = 2.6E-5 cm/sec
74.0 - 82.2-FT. K = <1.0E-7 cm/sec
82.0 - 94.0-FT. K = 1.1E-5 cm/sec
94.0 - 104.0-FT. K = 2.9E-4 cm/sec
104.0 - 114.0-FT. K = 8.9E-7 cm/sec

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

BOREHOLE DIAGRAM

MW-3040



WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER MW-4040

SHEET 1 **OF** 2

NORTH (Y): 1042990.8

EAST (X): 753001.3

TOC ELEVATION 633.9

GROUND ELEVATION 631.7

STICKUP -2.2

HYDR CONDUCTIVITY (cm/sec) K= <1.0x10^{-7} (Packer Test)

WELL STATUS/COMMENTS ACTIVE

LOCATION ARMY PROPERTY EAST OF SITE

DRILLING CONTRACTOR ROBERTS ENVIRONMENTAL Inc.

DRILL RIG MAKE & MODEL CME-750 HSA/NQWL; I-R TH-60 AIR ROTARY

HOLE SIZE & METHOD 7-1/4" HSA-28.5' NQ-65' 6" AIR-65

ANGLE FROM HORIZONTAL & BEARING Vertical

DEPTH (FT.) FROM GROUND ELEV. TO:

BOTTOM OF HOLE (TD) 65.0

BEDROCK 28.5

WATER LEVELS & DATES ▽ ▼

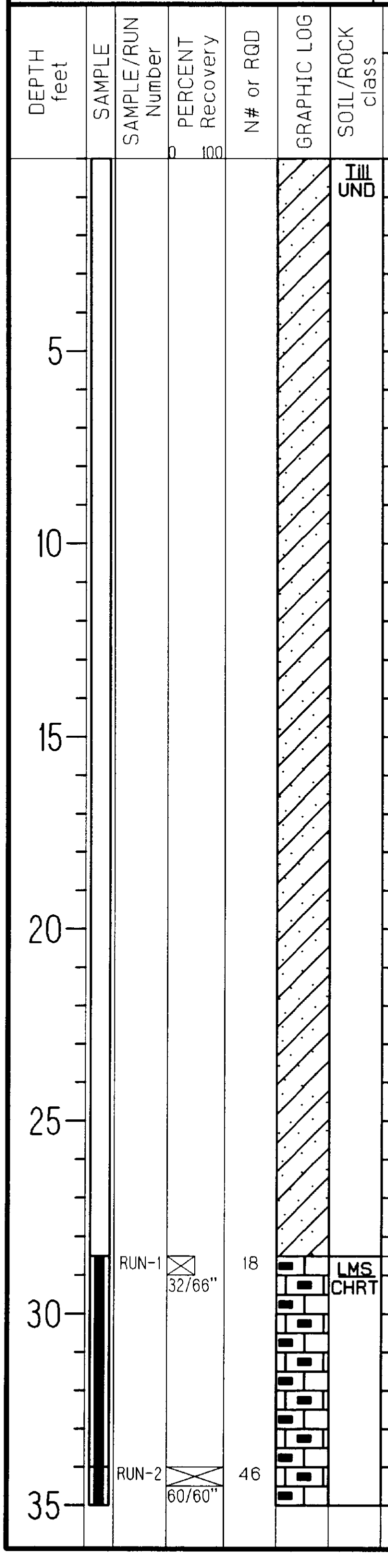
DRILL FLUIDS & ADDITIVES Water core; Air ream

CASING TYPE, DEPTH, SIZE 2" 316 SS Mon. Well

DATE START 05-17-04

DATE FINISH 05-20-04, Mon. Well

LITHOLOGY BY PAUL PATCHIN



DESCRIPTION AND REMARKS

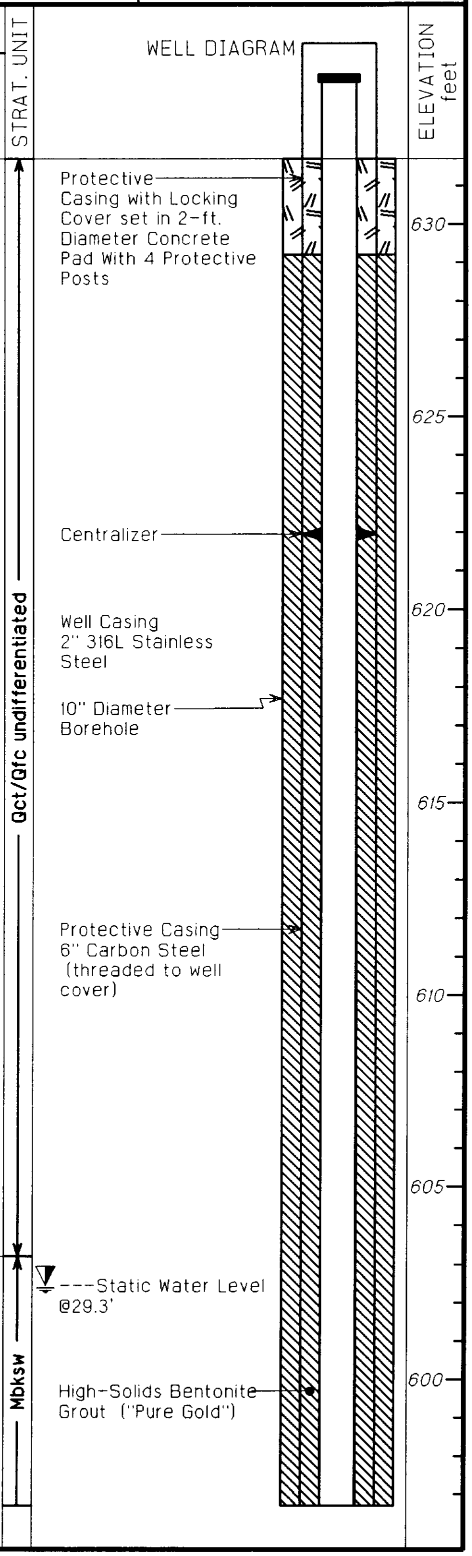
Soil not sampled or logged from the surface to 28.5-ft. Pound split spoon at 28.5' with 50 blows for 2". All limestone rock. Start coring at 28.5

Top of Rock @ 28.5. Switch to NQWL coring. Full circulation throughout coring.

28.5 - 30.2' core loss and LIMESTONE and CHERT rubble. Chert is sightly weathered, light gray (2.5Y7/1) very hard and fossiliferous, STRONGLY WEATHERED BURLINGTON-KEOKUK LIMESTONE UNIT

30.2 - 36.0'. ARGILLACEOUS LIMESTONE and CHERT (65%-35%) brecciated together. Limestone is FeOx-stained yellow (10YR7/6) moderately to highly weathered with conspicuous MnOx specs, slightly less weathered and harder with depth; very finely crystalline, very thinly bedded, very closely to closely fractured.

--Soft from 33 - 34'.



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

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER **MW-4040**

SHEET 2 OF 2

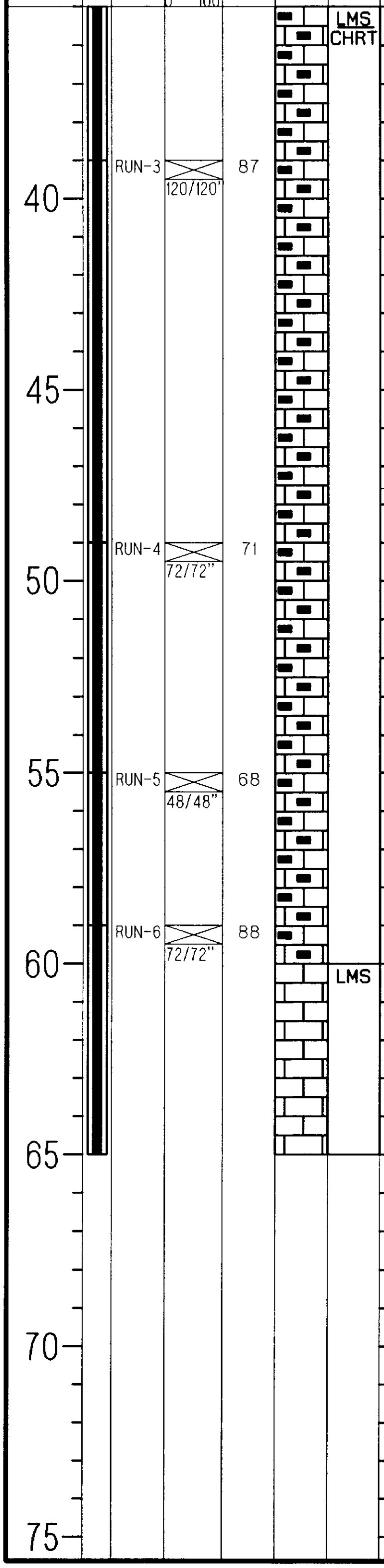
NORTH (Y): 1042990.8

EAST (X): 753001.3

WELL STATUS/COMMENTS ACTIVE

LOCATION ARMY PROPERTY EAST OF SITE

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery 0 100	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	WELL DIAGRAM	ELEVATION feet



36.0 - 41.0'. ARGILLACEOUS LIMESTONE with CHERT, limestone is silty, light gray (5Y7/1), with bluish gray chert, delayed HCL reaction, less weathered than above (slightly to moderately), less porosity, very fossiliferous, some stylolites with black clay coating, some FeOx, occasional vugginess, overall, moderately weathered. WEATHERED BURLINGTON-KEOKUK LIMESTONE

41.0 - 44.2'. ARGILLACEOUS LIMESTONE AND CHERT (65/35). Limestone is yellow (10YR7/6), but slightly grayer than the zone from 30.2 -36.0' very solutioned and vuggy (pinpoint to 1/2" size), some "bone marrow" texture, NO MnOx specks, highly weathered, soft.

44.2 - 44.5'. Chert bed, white, moderately weathered.

44.5 - 47.6'. SILTY ARGILLACEOUS LIMESTONE AND CHERT, (as in 36-41') with less weathering with depth, light brownish-gray (2.5Y6/2), very finely crystalline to micritic, slightly vuggy, mod. weathered, stylolitic, fossils in bluish gray chert which is finely divided into limestone, delayed HCL reaction.

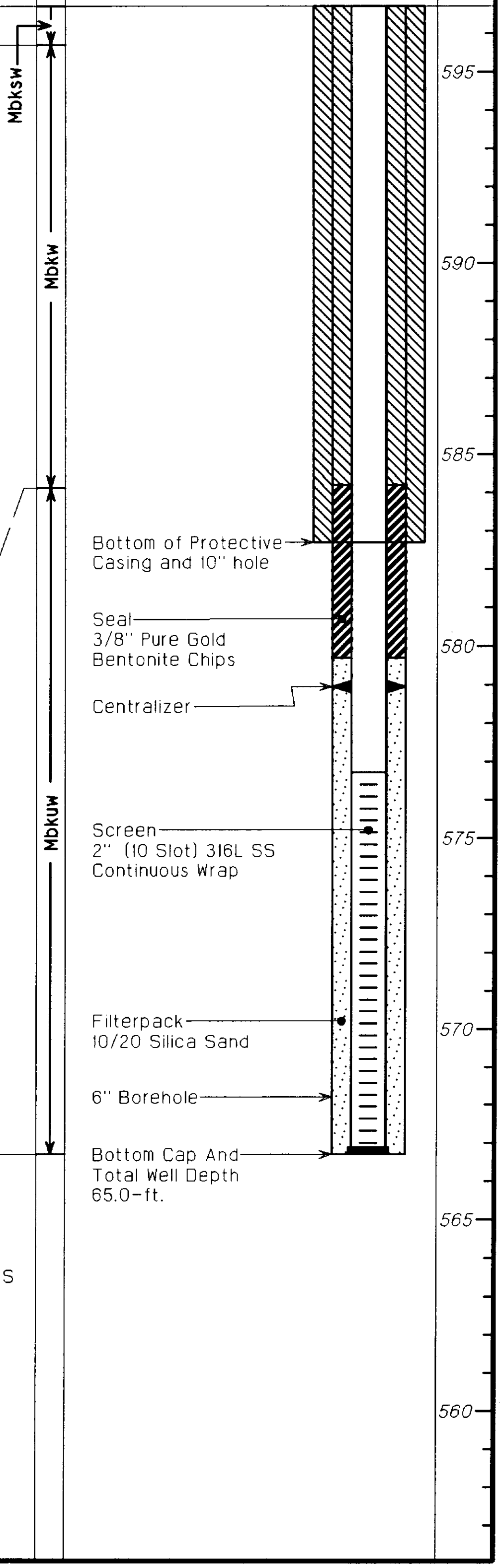
47.6 - 65.0'. LIMESTONE (60%) and CHERT (40%), interbedded. Limestone is medium to coarsly crystalline, pale yellow (2.5Y8/2), very slightly weathered to fresh, good HCL reaction, hard to very hard, very fossiliferous, (crinoids and bryazoan corals evident), thin bedded (2-8"), medium fractured, stylolitic (w/clay coatings), CHERT is bluish gray, very hard, in nodules and beds up to 9", globular patterns with "birds eye" look, fresh, chert bed from 54.0-56.2', fractures occur primarily at chert-limestone contacts. UNWEATHERED BURLINGTON-KEOKUK LIMESTONE UNIT

@55.2' Blocked off, change out drill bit.

Decreasing chert with depth. Limestone grain size primarily medium to finely crystalline with occasional zones of coarse.

Total depth 65.0', 5-19-04. Hole reamed to 10" diameter to 49.0' and a 6" casing was installed and grouted. Hole then reamed to 6" from 49.0' to 65.0' and a 2" monitoring well was constructed.

CONSTANT HEAD SINGLE PACKER TEST RESULTS
33.0 - 39.0-FT. K = <1.0E-7 cm/sec
38.0 - 49.0-FT. K = 1.6E-6 cm/sec
50.0 - 65.0-FT. K = 6.4E-7 cm/sec

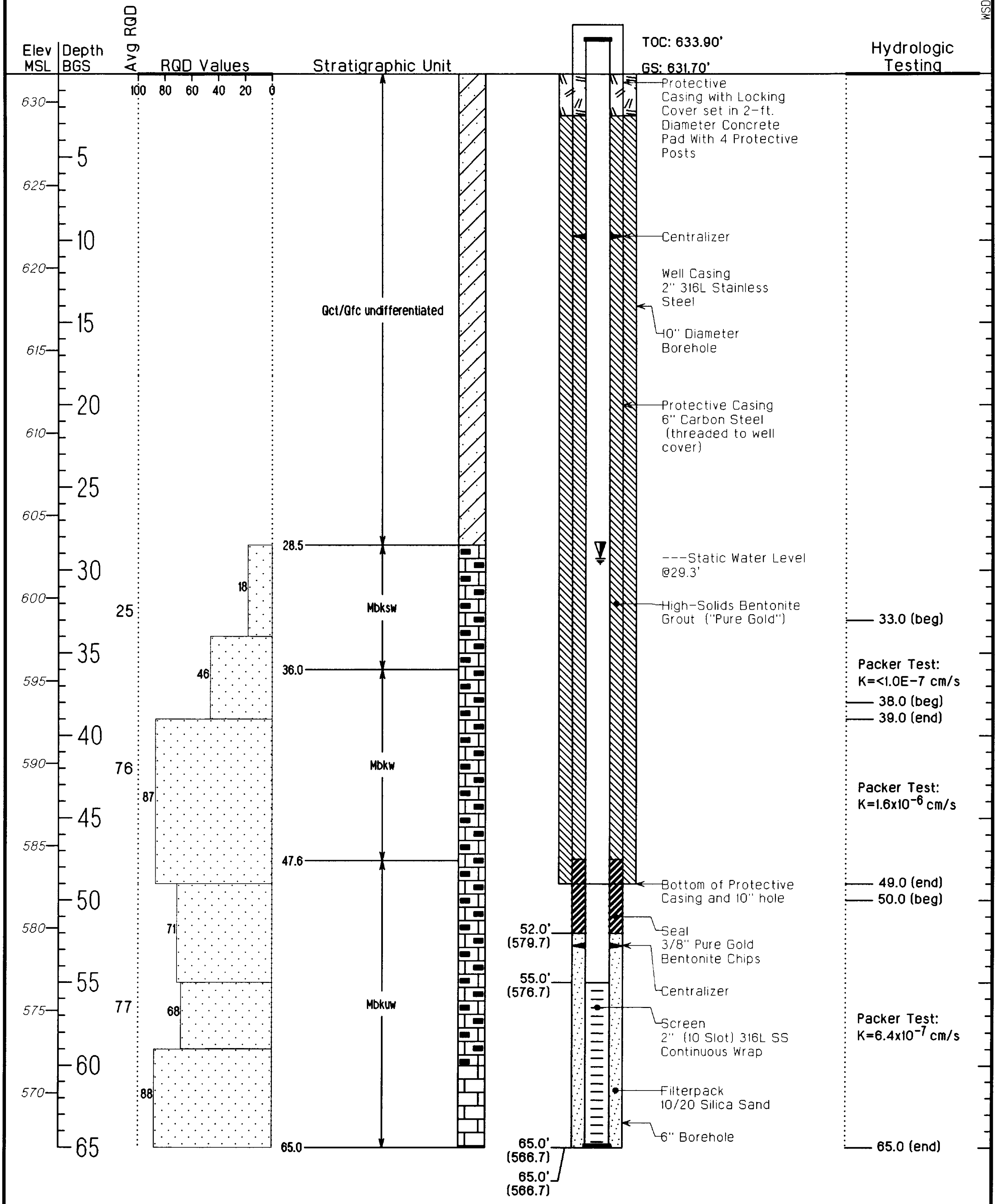


▮ Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

BOREHOLE DIAGRAM

Page 1 of 1

MW-4040



▽minimum ▼maximum ▼average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

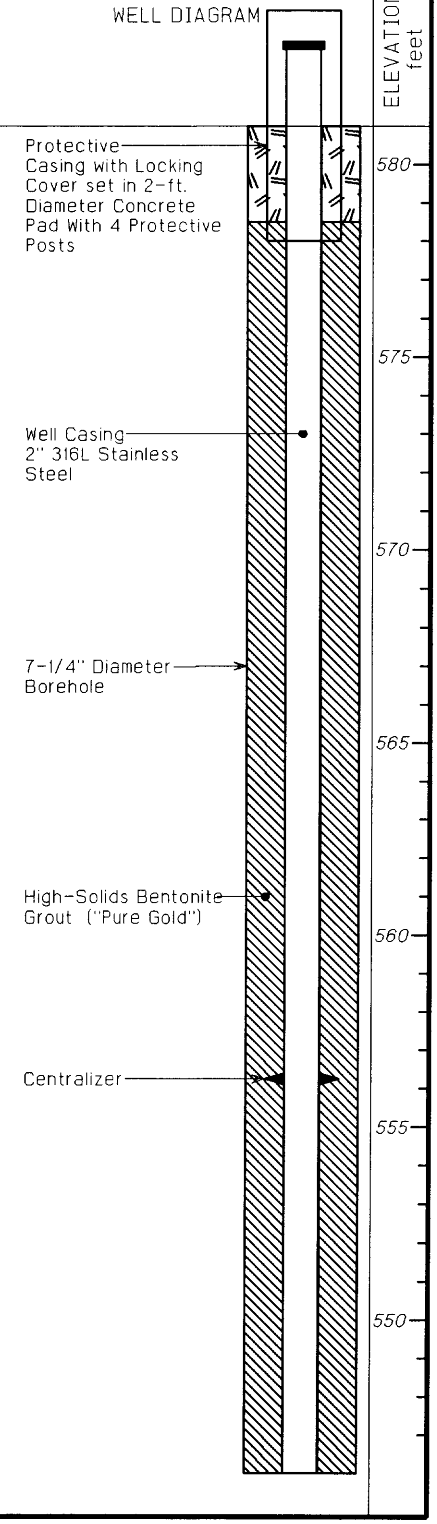
WSWLOG-C

HOLE NUMBER MW-4041			
SHEET 1 OF 2			
NORTH (Y): 1048463.8			
WELL STATUS/COMMENTS ACTIVE	**LOCATION** BUSCH WILDLIFE AREA		**EAST (X):** 753070.9
DRILLING CONTRACTOR ROBERTS ENVIRONMENTAL Inc.	**DRILL RIG MAKE & MODEL** CME-750 HSA/NQWL; I-R TH-60 AIR ROTARY		**TOC ELEVATION** 583.1
HOLE SIZE & METHOD 7-1/4" HSA-52.0' NQ-67' 6" AIR-58	**ANGLE FROM HORIZONTAL & BEARING** Vertical	**BOTTOM OF HOLE (TD)** 67.0	**GROUND ELEVATION** 581.0
DRILL FLUIDS & ADDITIVES Water core; Air ream	**CASING TYPE, DEPTH, SIZE** 2" 316 SS Mon. Well	**BEDROCK** 52.0	**STICKUP** -2.1
DATE START 05-06-04	**DATE FINISH** 05-17-04, Mon. Well	**WATER LEVELS & DATES** ∇ ▼	**HYDR CONDUCTIVITY (cm/sec)** K= $7.2x10^{-6}$ (Packer Test)

DEPTH (FT.) FROM GROUND ELEV. TO:

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery 0 100	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	LITHOLOGY BY ALLEN BENFER DESCRIPTION AND REMARKS	STRAT. UNIT
0–35					▨	Till UND	Soil not sampled or logged from the surface to 52.0-ft. Start NQ coring at 52.0 ft. at top of bedrock.	Qct/Qfc undifferentiated

Depth scale: 5, 10, 15, 20, 25, 30, 35



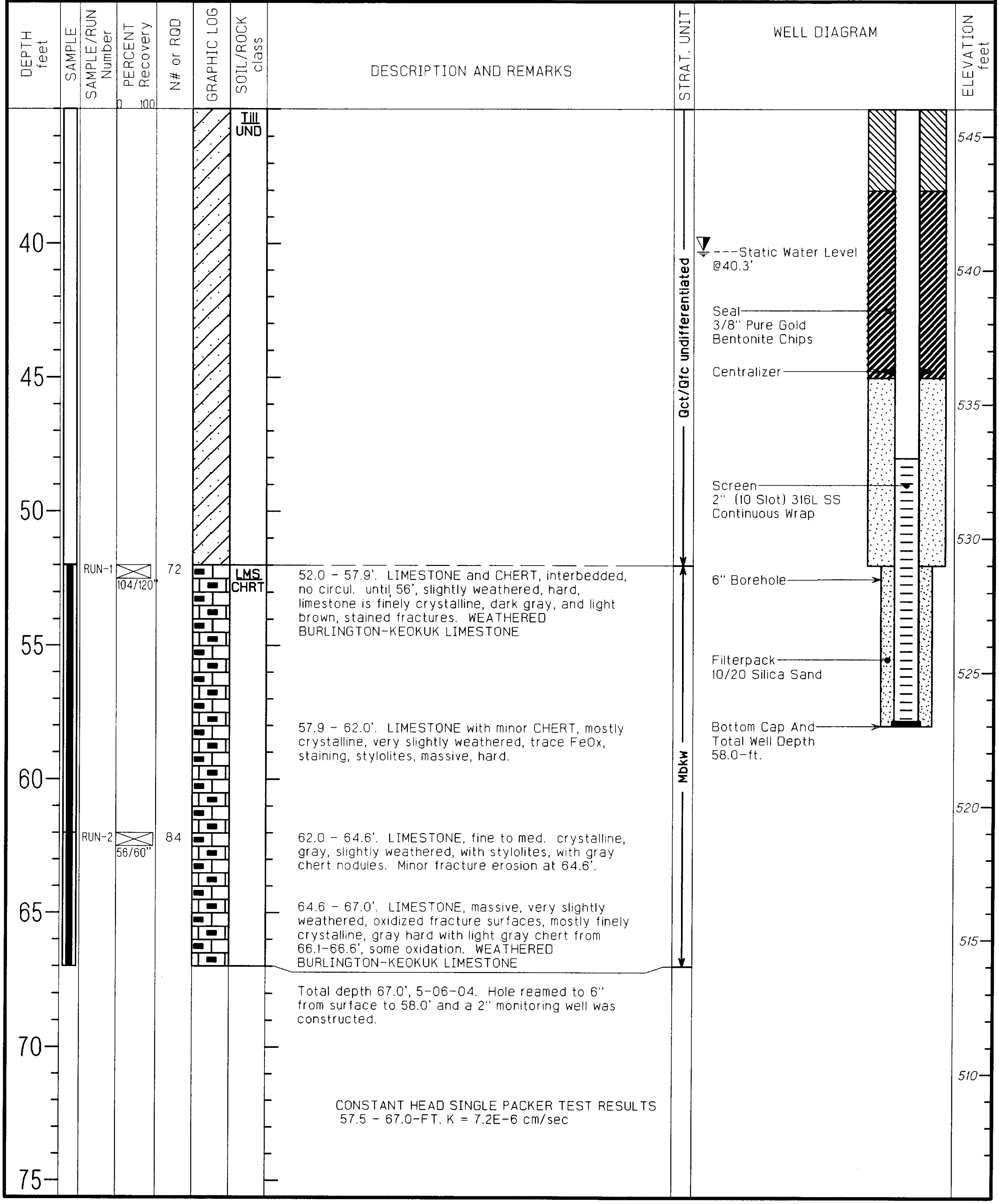
■ Sample Interval ☐ No Sample Taken ∇ minimum ▼ maximum ▼ average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER	MW-4041
SHEET 2 OF 2	
NORTH (Y):	1048463.8
EAST (X):	753070.9
WELL STATUS/COMMENTS	ACTIVE
LOCATION	BUSCH WILDLIFE AREA



52.0 - 57.9'. LIMESTONE and CHERT, interbedded, no circul. until 56', slightly weathered, hard, limestone is finely crystalline, dark gray, and light brown, stained fractures. WEATHERED BURLINGTON-KEOKUK LIMESTONE

57.9 - 62.0'. LIMESTONE with minor CHERT, mostly crystalline, very slightly weathered, trace FeOx, staining, stylolites, massive, hard.

62.0 - 64.6'. LIMESTONE, fine to med. crystalline, gray, slightly weathered, with stylolites, with gray chert nodules. Minor fracture erosion at 64.6'.

64.6 - 67.0'. LIMESTONE, massive, very slightly weathered, oxidized fracture surfaces, mostly finely crystalline, gray hard with light gray chert from 66.1-66.6', some oxidation. WEATHERED BURLINGTON-KEOKUK LIMESTONE

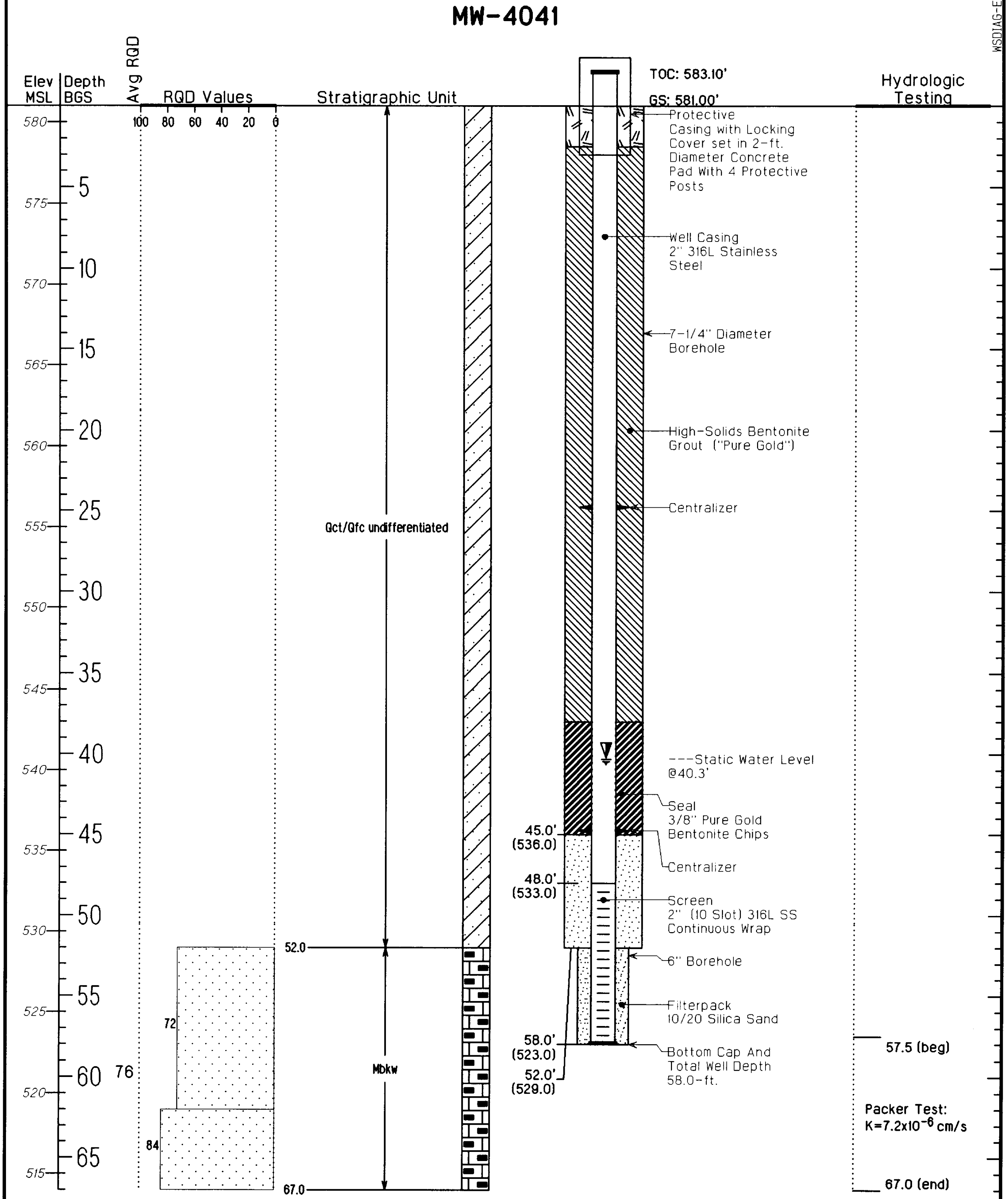
Total depth 67.0', 5-06-04. Hole reamed to 6" from surface to 58.0' and a 2" monitoring well was constructed.

CONSTANT HEAD SINGLE PACKER TEST RESULTS
57.5 - 67.0-FT. K = 7.2E-6 cm/sec

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

BOREHOLE DIAGRAM

MW-4041



∇minimum ▼maximum ▼average

FIELD PACKER TESTING FORMS

2/2

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP	Job Number:	Test Section: 38 to 48	Bore Hole: A
Test Equipment Identification Flow Meter - Master Meter Pressure Meter - Winters 1953	BORE HOLE Orientation: vertical Size: 2.98		Test By: A. Benfer Date: 5-4-04
Packers On Casing [✓ Single] Double Hydraulic [✓ Inflatable]	Groundwater Depth: 37.7' Ft.	Gauge Height Above Ground: 5.0 Ft.	Gravity Head: Ft.

AVE K = 4x10-4 cm/s

Begin 0950
End Test 1045
made water Trip

TEST 1

Inflow pressure (Hp) 10 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	950.0	955.1	960.1	965.1	970.2	975.2						5.0 GPM CFM
Take Per Min.		5.1	5.0	5.0	5.1	5.0						CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

FT. = FT. + FT. – FT.

$$K = \frac{Q\text{ (gpm)}}{H_T\text{ (ft)} \times L\text{ (ft)}} \times .011 \ln. \frac{L\text{ (ft)}}{r\text{ (ft)}} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 3 x 10-4

TEST 2

Inflow pressure (Hp) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	014.0	023.0	032.1	041.5	050.7	060.9	069.4	~~[illegible]~~				9.2 GPM CFM
Take Per Min.		9.0	9.1		9.2		9.4					

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 4.7x10-4

TEST 3

Inflow pressure (Hp) 30 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	092.0	103.1	114.2	125.4	136.6							11.2 GPM CFM
Take Per Min.		11.1	11.1	11.2	11.2							

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 4.6x10-4

1/1

PRESSURE TEST RESULTS (FIELD)

Project: GWOU-WSSRAP	Job Number:	Test Section: 49 to 59	Bore Hole: A

Test Equipment Identification	BORE HOLE Orientation: vertical	Size: 2.98	Test By: A. Benfer Date: 5-4-04
Packers On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable]	Groundwater Depth: 37.7' Ft.	Gauge Height Above Ground: 4.2 Ft.	Gravity Head: 41.9' Ft.

Begin Test 1250

End Test 1310

TEST 1

Inflow pressure (Hp) 20 psi × 2.31 = 46.2 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	2788	279.1	279.3	279.6	279.8	280.0						0.2 GPM CFM
Take Per Min.		0.3	0.2	0.3	0.2	0.2						CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

88.1 FT. = 41.9 FT. + 46.2 FT. – FT.

$$K = \frac{Q\text{ (gpm)}}{H_T\text{ (ft)} \times L\text{ (ft)}} \times .011 \ln. \frac{L\text{ (ft)}}{r\text{ (ft)}} = \frac{0.2}{88.1 \times 10} \times .011 \ln \frac{10}{.125} = $$

.00023 .04820

K, CM/SEC 1.1×10^{-5} ✓

TEST 2

Inflow pressure (Hp) 30 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	280.7	281.1	281.1	281.1								<0.13 GPM CFM
Take Per Min.		0.4	0									

H_T FT. = H_G FT. + H_P FT. – H_L FT.

No Take

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC ~~$<5.0 \times 10^{-6}$~~ $<1.0 \times 10^{-7}$

TEST 3

Inflow pressure (Hp) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC ~~$<1 \times 10^{-6}$~~

$<1 \times 10^{-7}$

Tests 4 + 5 No Take at 2nd 20 + 30 psi Both ⤵ $<1.0 \times 10^{-7}$

1/2

PRESSURE TEST RESULTS (FIELD)

Project: Gwoa - WSSRAP	Job Number:	Test Section: 59 to 69	Bore Hole: A
Test Equipment Identification: Flow Meter - Master Meter Press. gauge - Winters 1953	BORE HOLE Orientation: Vertical Size: 2.98		Test By: A. Benfer Date: 5-4-04
Packers On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable]	Groundwater Depth: 37.7' Ft.	Gauge Height Above Ground: 2.1 Ft.	Gravity Head: Ft.

Ave 2X10-5 cm/s

Begin Test 1420

End Test 1510

TEST 1

Inflow pressure (Hp) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	287.0	287.2	287.3	287.43	287.52	287.60	287.67	287.74				0.1 GPM CFM
Take Per Min.		0.2	0.1	0.13	.09	.08	0.07	0.07				CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

______ FT. = ______ FT. + ______ FT. − ______ FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ ln. \frac{L\ (ft)}{r\ (ft)} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 5.2x10-6

TEST 2

Inflow pressure (Hp) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	292.2	293.4	294.7	295.7	296.7	297.8	298.9					1.1 GPM CFM
Take Per Min.		1.2	1.3	1.0	1.0	1.1	1.1					

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. − H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 3.4x10-5

TEST 3

Inflow pressure (Hp) 60 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	301.8	303.5	305.2	306.6	308.1	309.6	311.1					1.6 GPM CFM
Take Per Min.			1.7	1.4	1.5	1.5	1.5					

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. − H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 3.6 X10-5

PRESSURE TEST RESULTS (FIELD)

Project:

Job Number:

Test Section: 59 to 69

Bore Hole: A

Test Equipment Identification: Flow Meter - Master Meter
Press. Meter - Winters 1953

BORE HOLE
Orientation: Vertical
Size: 2.98

Test By: A. Benfer
Date: 5-4-04

Packers
On Casing
[✓ Single] Double
Hydraulic [✓ Inflatable]

Groundwater Depth: 37.7 Ft.

Gauge Height Above Ground: 2.1 Ft.

Gravity Head: Ft.

TEST ~~1~~ 4 Inflow pressure (H_P) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	312.6	313.3	314.2	314.9	315.7	316.25	316.9	317.6				0.7 GPM CFM
Take Per Min.			0.9	0.7	0.8	0.		0.7				CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

FT. = FT. + FT. – FT.

$$K = \frac{Q\,(gpm)}{H_T\,(ft) \times L\,(ft)} \times .011\ \ln. \frac{L\,(ft)}{r\,(ft)} = \frac{\quad}{\times} \times \quad =$$

K, CM/SEC
2.2x10^{-5}

TEST 2 Inflow pressure (H_P) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\times} \times \quad =$$

K, CM/SEC

TEST ~~3~~ 5 Inflow pressure (H_P) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	318.9	319.1	319.3	319.5	319.7	319.85						0.2 GPM CFM
Take Per Min.		0.2	0.2	0.2	0.2	0.15						

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\times} \times \quad =$$

K, CM/SEC
1.0x10^{-5}

1/2

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP	Job Number:	Test Section: 32.0 to 38.0	Bore Hole: Boring B
Test Equipment Identification: Flow Meter - Master Meter press. meter - Wiaters 1953	BORE HOLE Orientation: vertical Size: 2.98"		Test By: A. Benfer Date: 4-29-04
Packers On Casing [✓ Single] Double Hydraulic [✓ Inflatable]	Groundwater Depth: ? Ft.	Gauge Height Above Ground: 2.0 Ft.	Gravity Head: 38 Ft.

38.5
2.5

380
8.5
29.5
3.5
3.0

Begin 15:15

15:40 end test

TEST 1

Inflow pressure (Hp) 10 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	899.0	899.2	899.38	899.50	899.69	899.77	899.89					0.15 GPM CFM
Take Per Min.	0.20	0.18	0.12	0.19	0.08	0.12						CFM × 7.48 = GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

61.1 FT. = 38 FT. + 23.1 FT. − FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ \ln. \frac{L\ (ft)}{r\ (ft)} = \frac{.15}{61.1 \times 6} \times \frac{6}{.125} = $$

K, CM/SEC 1.8×10^{-5}

.00041 .04258

TEST 2

Inflow pressure (Hp) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	901.0	901.40	901.70	902.0	902.2	902.31	902.45	902.54				0.2 GPM CFM
Take Per Min.	0.40	0.30	0.30	0.20	0.11	0.14	0.09					

H_T FT. = H_G FT. + H_P FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC 2×10^{-5}

TEST 3

No Take

Inflow pressure (Hp) 30 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	903.0	903.0	903.0									0 GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC $<10^{\cancel{-5}\ -7}$

2/2

PRESSURE TEST RESULTS (FIELD)

Project: Gwoa · WSSRAP	Job Number:	Test Section: 32.0 to 38.0	Bore Hole: Boring B
Test Equipment Identification Flow Meter - Master Meter Press. Meter - Winters 1983	BORE HOLE Orientation: Vertical	Size: 2.98"	Test By: A. Beafer Date:
Packers On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable]	Groundwater Depth: ? Ft.	Gauge Height Above Ground: 2.0' Ft.	Gravity Head: Ft.

No Take

TEST ~~1~~ 4 Inflow pressure (H_P) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	903.0	903.0										0 GPM CFM
Take Per Min.												

CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

____ FT. = ____ FT. + ____ FT. – ____ FT.

$$K = \frac{Q\ (\text{gpm})}{H_T\ (\text{ft}) \times L\ (\text{ft})} \times .011\ \ln. \frac{L\ (\text{ft})}{r\ (\text{ft})} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC: <10 ~~-5~~ -7

No Take

TEST ~~2~~ 5 Inflow pressure (H_P) 10 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	903.0											0 GPM CFM
Take Per Min.												

H_T ____ FT. = H_G ____ FT. + H_P ____ FT. – H_L ____ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC: <10 ~~-5~~ -7

TEST 3 Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T ____ FT. = H_G ____ FT. + H_P ____ FT. – H_L ____ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC:

1/2

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP -	Job Number:	Test Section: 38.0 to 48.0	Bore Hole: B
Test Equipment Identification Flow Meter - Master Meter Press. Meter - Winters 1953	BORE HOLE Orientation: Vertical	Size: 2.98	Test By: A. Benfer Date: 4-30-04
Packers On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable]	Groundwater Depth: ~36 Ft.	Gauge Height Above Ground: Ft.	Gravity Head: Ft.

Begin Test 09:00
End Test 0940

TEST 1

Inflow pressure (Hp) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	913.0	914.5	915.3	915.7	915.9	915.95	No Take					0.23 GPM CFM
Take Per Min.		~~1.5~~	0.8	0.4	0.2	0.05						CFM × 7.48 = GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

FT. = FT. +- FT. − FT.

$$K = \frac{Q\ (\text{gpm})}{H_T\ (\text{ft}) \times L\ (\text{ft})} \times .011\ \text{ln.}\ \frac{L\ (\text{ft})}{r\ (\text{ft})} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC 1×10⁻⁵

TEST 2

Inflow pressure (Hp) 30 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	916.40	916.52	916.66	916.79	916.84	916.87	.91					0.10 GPM CFM
Take Per Min.		.12	.14	.13	.15	.03						

H_T FT. = H_G FT. + H_P FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \text{ln.}\ \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC 4×10⁻⁴

TEST 3

Inflow pressure (Hp) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	918.35	918.70	918.82	918.86	918.91	918.97	[illegible]					0.12 GPM CFM
Take Per Min.		0.35	0.12	0.04	0.05	0.06						

H_T FT. = H_G FT. + H_P FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \text{ln.}\ \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC 4.2×10⁻⁶

.03

2/2

PRESSURE TEST RESULTS (FIELD)

Project:	Job Number:	Test Section: 38.0 to 48.0	Bore Hole: B
Test Equipment Identification	BORE HOLE Orientation: Size:	Test By: Date:	
Packers On Casing Single/Double Hydraulic/Inflatable	Groundwater Depth: ~ ~36' Ft.	Gauge Height Above Ground: 2.0 Ft.	Gravity Head: Ft.

TEST ~~1~~ 4 Inflow pressure (H_P) 30 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	921.0	921.12	921.39	921.49	921.65	921.85	922.04	922.24	922.45			0.19 GPM CFM
Take Per Min.		0.12	0.27	0.10	0.16	0.20	0.19	0.20	0.21			CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

FT. = FT. + FT. – FT.

$$K = \frac{Q\,(gpm)}{H_T\,(ft) \times L\,(ft)} \times .011 \ln. \frac{L\,(ft)}{r\,(ft)} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC 7.8×10-6

1.22
.65
.49
.16

No Take

TEST ~~2~~ 5 Inflow pressure (H_P) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC <10-~~8~~7

TEST 3 Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC

PRESSURE TEST RESULTS (FIELD)

Project: GWOU WSSRAP	Job Number:	Test Section: 48.0 to 58.0	Bore Hole: B

Test Equipment Identification	BORE HOLE Orientation: vert	BORE HOLE Size: 2.98	Test By: A. Benfer Date: 4-30-04

Packers On Casing Single/Double Hydraulic/Inflatable	Groundwater Depth: ~37 Ft.	Gauge Height Above Ground: 2.0 Ft.	Gravity Head: Ft.

0 Take
+ 30, 40,
0 PSI
↑
4th
Test

TEST 1 Inflow pressure (H_P) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM CFM
Take Per Min.												CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

______ FT. = ______ FT. + ______ FT. − ______ FT.

$$K = \frac{Q\ (\text{gpm})}{H_T\ (\text{ft}) \times L\ (\text{ft})} \times .011\ \ln.\frac{L\ (\text{ft})}{r\ (\text{ft})} = \frac{\quad}{\quad \times \quad} \times \boxed{\quad} =$$

K, CM/SEC <10-~~4~~7

TEST 2 Inflow pressure (H_P) 30 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM CFM
Take Per Min.												

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. − H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln.\frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \boxed{\quad} =$$

K, CM/SEC <10-7

TEST 3 Inflow pressure (H_P) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM CFM
Take Per Min.												

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. − H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln.\frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \boxed{\quad} =$$

K, CM/SEC <10-7

PRESSURE TEST RESULTS (FIELD)

Project:	Job Number:	Test Section: 58 to 64	Bore Hole: B

Test Equipment Identification	BORE HOLE Orientation: Vertical	BORE HOLE Size: 2.98	Test By: Date:

Packers On Casing Single/Double Hydraulic/Inflatable	Groundwater Depth: ~37' Ft.	Gauge Height Above Ground: 2.0' Ft.	Gravity Head: Ft.

Begin Test 13:25
End Test 13:35
No Take at 30, 40, 50 psI

TEST 1 Inflow pressure (H_P) 30 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM CFM
Take Per Min.												

CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

______ FT. = ______ FT. + ______ FT. – ______ FT.

$$K = \frac{Q\,(gpm)}{H_T\,(ft) \times L\,(ft)} \times .011 \ln. \frac{L\,(ft)}{r\,(ft)} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC $<10^{-7}$

TEST 2 Inflow pressure (H_P) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM CFM
Take Per Min.												

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. – H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC $<10^{-7}$

TEST 3 Inflow pressure (H_P) 50 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM CFM
Take Per Min.												

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. – H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC $<10^{-7}$

1/2

PRESSURE TEST RESULTS (FIELD)

Project:	Job Number:	Test Section: 68.7 to 77.0	Bore Hole: Boring C

Test Equipment Identification Flow gauge Master Meter Pressure gauge - Winters #1953	BORE HOLE Orientation: Vert.	Size: 2.98"	Test By: A. Benfer Date: 4-28-04

Packers On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable]	Groundwater Depth: 58' Ft.	Gauge Height Above Ground: 2.0 Ft.	Gravity Head: Ft.

Begin 12:11
End test 12:49

TEST 1 Inflow pressure (Hp) 20 psi × 2.31 = 46.2 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	780.5 ~~780.5~~	781.5	783.1	784.5	785.7	787.0	788.2	789.4				1.3 GPM CFM
Take Per Min.		1.0	1.6	1.4	1.2	1.3	1.2	1.2				CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

121.05 FT. = 74.85 FT. + 46.2 FT. – — FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ ln.\ \frac{L\ (ft)}{r\ (ft)} = \frac{1.3}{121.05 \times 8.3} \times .011 \ln \frac{8.3}{0.125} =$$

K, CM/SEC 5.8×10^{-5}

TEST 2 Inflow pressure (Hp) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	794.0	795.9	797.7	799.6	801.5	803.5	805.4					1.9 GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ ln.\ \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 6.3×10^{-5}

bouncing

TEST 3 Inflow pressure (Hp) 60 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	807.7	809.1	810.6	812.1	813.6	815.1	816.5					1.5 GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ ln.\ \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 3.8×10^{-5}

2/2

PRESSURE TEST RESULTS (FIELD)

Project: GWOU	Job Number:	Test Section: 68.7 to 77.0	Bore Hole: Boring C
Test Equipment Identification flowmeter - Master Meter press. meter - Winters 1953	BORE HOLE Orientation: vert.	Size: 2.98"	Test By: A. Benfer Date: 4-28-04
Packers wireline On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable]	Groundwater Depth: 58.0 Ft.	Gauge Height Above Ground: 2.0 Ft.	Gravity Head: Ft.

Steady

TEST ~~1~~ 4 Inflow pressure (H_P) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	820.5	822.5	824.6	826.6	828.6	830.7						2.0 GPM CFM
Take Per Min.		2.0	2.1	2.0	2.0	2.1						CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

______ FT. = ______ FT. + ______ FT. – ______ FT.

$$K = \frac{Q\,(gpm)}{H_T\,(ft) \times L\,(ft)} \times .011\ \ln. \frac{L\,(ft)}{r\,(ft)} = \frac{\quad}{\times} \times \quad = \boxed{K,\ CM/SEC\ \ 6.8 \times 10^{-5}}$$

Steady

TEST ~~2~~ 5 Inflow pressure (H_P) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	831.5	833.2	835.0	836.5	838.3	839.9	841.7					1.7 GPM CFM
Take Per Min.		1.7	1.8	1.5	1.8	1.6						

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. – H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\times} \times \quad = \boxed{K,\ CM/SEC\ \ 1 \times 10^{-4}}$$

TEST 3 Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. – H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\times} \times \quad = \boxed{K,\ CM/SEC\ \ }$$

1/2

PRESSURE TEST RESULTS (FIELD)

egin 15:00
nd 15: 42

Project:	Job Number:	Test Section: 78.7 to 87.0	Bore Hole: C

Test Equipment Identification: waterflow meter - Master Meter
PressureMeter - Winters

BORE HOLE

Orientation: vertical

Size: 2.98

Test By: A. Baufer

Date: 4-28-04

Packers
On Casing
Single/Double
Hydraulic/Inflatable

Groundwater Depth: 58' Ft.

Gauge Height Above Ground: 2.0' Ft.

Gravity Head: Ft.

TEST 1

Inflow pressure (H_P) 20 psi × 2.31 = ______ feet

Steady pressure

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	842.3	843.7	845.2	846.5	847.8	849.1						1.4 GPM CFM
Take Per Min.		1.4	1.5	1.3	1.3	1.3						CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

______ FT. = ______ FT. + ______ FT. − ______ FT.

$$K = \frac{Q\ (\text{gpm})}{H_T\ (\text{ft}) \times L\ (\text{ft})} \times .011\ \ln. \frac{L\ (\text{ft})}{r\ (\text{ft})} = \frac{\qquad}{\qquad \times \qquad} \times \qquad =$$

K, CM/SEC 5.8 x 10^{-5}

TEST 2

Inflow pressure (H_P) 40 psi × 2.31 = ______ feet

Bouncing ± 2 PSI

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	853.8	855.3	856.6	858.1	859.7	861.2	862.9	864.3	865.7			1.5 GPM CFM
Take Per Min.		1.3	1.5	1.6	1.5	1.7	1.4	1.4				

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. − H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\qquad}{\qquad \times \qquad} \times \qquad =$$

K, CM/SEC 4.7 x 10^{-5}

TEST 3

Inflow pressure (H_P) 60 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	868.8	870.5	872.1	873.6	875.3	876.9	878.3	879.9				1.6 GPM CFM
Take Per Min.		1.7	1.5		1.7	1.6	1.4	1.6				

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. − H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\qquad}{\qquad \times \qquad} \times \qquad =$$

K, CM/SEC 4.0 x 10^{-5}

2/2

PRESSURE TEST RESULTS (FIELD)

Project: GWOU	Job Number:	Test Section: 78.7 to 87.0	Bore Hole: C
Test Equipment Identification Flow meter - Master Meter Pressure Meter - Winters 1953	BORE HOLE Orientation: Vertical	Size: 2.98	Test By: A. Benfer Date: 4-28-04
Packers On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable]	Groundwater Depth: 58' Ft.	Gauge Height Above Ground: 2.0' Ft.	Gravity Head: Ft.

TEST ~~1~~ 4 Inflow pressure (H_P) 40 psi × 2.31 = ______ feet

Steady

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	881.5	882.3	883.2	884.0	884.7	885.5						0.8 GPM CFM
Take Per Min.	0.8	0.9	0.8	0.7	0.8							CFM × 7.48 = GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

FT. = FT. + FT. − FT.

$$K = \frac{Q\text{ (gpm)}}{H_T\text{ (ft)} \times L\text{ (ft)}} \times .011 \ln. \frac{L\text{ (ft)}}{r\text{ (ft)}} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 2.5×10^{-5}

TEST ~~2~~ 5 Inflow pressure (H_P) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	886.2	887.2	888.3	889.5	890.7	891.9	893.1					1.2 GPM CFM
Take Per Min.	1.0	1.1	1.2	1.2	1.2	1.2						

H_T FT. = H_G FT. + H_P FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 6.9×10^{-5}

TEST 3 Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC

1/1

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP Busch

Job Number:

Test Section: 69 to 79

Bore Hole: A

Test Equipment Identification: Flow meter - Master Meter
Press. Meter - winters 1953

BORE HOLE

Orientation: Vert.

Size: 2.98

Test By: A. Benfer

Date: 5-5-04

Packers
On Casing
[✓ Single] Double
Hydraulic [✓ Inflatable]

Groundwater Depth: 348 Ft.

Gauge Height Above Ground: 2.0 Ft.

Gravity Head: Ft.

NO Take at ← <10⁻⁷
20 PSI

Begin Test 0855

End Test 0925

TEST 1 Inflow pressure (H_P) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	329.0	330.1	330.7	330.8	330.9	330.95	331.0	331.0				0.2 GPM CFM
Take Per Min.		1.1	0.6	0.1	0.1	.05	.05	0				CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

FT. = FT. + FT. -- FT.

$$K = \frac{Q\text{ (gpm)}}{H_T\text{ (ft)} \times L\text{ (ft)}} \times .011 \ln. \frac{L\text{ (ft)}}{r\text{ (ft)}} = \frac{\qquad}{\times} \times \qquad =$$

K, CM/SEC 5×10⁻⁴

TEST 2 Inflow pressure (H_P) 60 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	331.5	331.75	332.0	332.1	332.2	332.45	332.9	333.5	334.0	334.55	335.55	0.5 GPM CFM
Take Per Min.		~~0.25~~	~~0.25~~	~~0.1~~	~~0.1~~	~~0.25~~	~~0.45~~	0.60	0.5	0.55	1.0	

11 335.6 12 336.1

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\qquad}{\times} \times \qquad =$$

K, CM/SEC 1.2×10⁻⁵

TEST 3 Inflow pressure (H_P) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												Ø GPM CFM
Take Per Min.												

No Take at repeat 40 and 20 PSI <10⁻⁷

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\qquad}{\times} \times \qquad =$$

K, CM/SEC ~~<10⁻⁴~~

<10⁻⁷

112

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP Busch	Job Number:	Test Section: 79 to 89	Bore Hole: A
Test Equipment Identification Flow meter: Master Meter Press. Meter - Winter 1953	**BORE HOLE** Orientation: Veit.	Size:	Test By: A. Benfer Date: 5-5-04
Packers On Casing Single/Double Hydraulic/Inflatable	Groundwater Depth: 34.8 Ft.	Gauge Height Above Ground: 2.4 Ft.	Gravity Head: Ft.

Begin Test at 1250
End Test 1330

TEST 1

Inflow pressure (H_P) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	342.2	342.5	343.0	343.4	343.8	344.2	344.5					0.4 GPM CFM
Take Per Min.		0.3	0.5	0.4	0.4	0.4	.03					CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

FT. = FT. + FT. – FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ \ln. \frac{L\ (ft)}{r\ (ft)} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 1.4 X 10-5

TEST 2

Inflow pressure (H_P) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	345.3	345.4	345.4	345.5	345.5	345.9	346.0	346.0				0.1 GPM CFM
Take Per Min.		0.1	0	0.1	0	0.4	0.1	0				

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 2.7 X 10-6

TEST 3

Inflow pressure (H_P) 60 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	347.0	347.6	348.2	348.8	349.5	350.2	350.8	351.4				0.6 GPM CFM
Take Per Min.		0.6	0.6	0.6	0.7	0.7	0.6	0.6				

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC 1.4 X 10-5

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PRESSURE TEST RESULTS (FIELD)

Project: GWOU-WSSRAP Busch	Job Number:	Test Section: 79 to 89	Bore Hole: A

Test Equipment Identification Flow Meter - Master Meter Press. Gauge - Winter 1953	BORE HOLE Orientation: Vertical	Size: 2.98	Test By: A. Benfer Date: 5-5-04
Packers On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable]	Groundwater Depth: 34.8 Ft.	Gauge Height Above Ground: 2.4 Ft.	Gravity Head: Ft.

TEST ~~1~~ 4 Inflow pressure (H_P) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	351.9	352.4	352.8	353.3	353.9	354.3	354.8	355.2				6.5 GPM CFM
Take Per Min.		0.5	0.4	0.5	0.6	0.4	0.5	0.4				CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

______ FT. = ______ FT. + ______ FT. − ______ FT.

$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ \ln. \frac{L\ (ft)}{r\ (ft)} = \frac{\quad}{\times} \times \underline{\quad} =$ K, CM/SEC 1.3x10⁻⁵

No Take at 20 psi repeat

TEST ~~2~~ 5 Inflow pressure (H_P) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM CFM
Take Per Min.												

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. − H_L ______ FT.

$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\times} \times \underline{\quad} =$ K, CM/SEC ~~<10⁻⁴~~

<10⁻⁷

TEST 3 Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. − H_L ______ FT.

$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\times} \times \underline{\quad} =$ K, CM/SEC

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP	Job Number:	Test Section: 19.0 to 29.7	Bore Hole: MW 2056

Test Equipment Identification Flow Meter - Master Meter Press. Meter - Winters 1953	BORE HOLE Orientation: vertical	Size: 2.98	Test By: A. Benfer Date: 5-10-04

Packers On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable]	Groundwater Depth: ~~7~~ 31.2' Ft.	Gauge Height Above Ground: 0.8' Ft.	Gravity Head: mid-point of tested zone ~~32.0~~ @ 24.3 Ft.

Begin Test 10:55

End Test 11:35

TEST 1

Inflow pressure (H_P) 5 psi × 2.31 = 11.6 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	386.0	388.3	392.0	395.2	398.2	401.3	404.5	407.2				3.2 GPM CFM
Take Per Min.	2.3	3.7	3.2	3.0	3.1	3.2	3.2					CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

35.9 FT. = 24.3 FT. + 11.6 FT. – negligible FT.

$$K = \frac{Q\,(gpm)}{H_T\,(ft) \times L\,(ft)} \times .011\ \ln. \frac{L\,(ft)}{r\,(ft)} = \frac{3.23}{35.9 \times 10.7} \times .011 \ln \frac{10.7}{.125} =$$

.00841

.04895

K, CM/SEC ~~4.0 X 10^-4~~

4.1 X 10-4

TEST 2

Inflow pressure (H_P) 10 psi × 2.31 = 23.1 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	412.0	416.4	420.8	425.3	429.8	434.5	439.0					4.5 GPM CFM
Take Per Min.	4.4	4.4	4.5	4.5	4.7	4.5						

H_T 47.4 FT. = H_G 24.3 FT. + H_P 23.1 FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{4.5}{47.4 \times 10.7} \times .011 \ln \frac{10.7}{.125} =$$

.00887

.04895

K, CM/SEC 4.3 x 10-4 ✓

TEST 3

Inflow pressure (H_P) 15 psi × 2.31 = 34.7 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	447.0	453.7	460.4	467.2	474.3	481.2	488.2	495.3				6.9 GPM CFM
Take Per Min.	6.7	6.7	6.8	7.1	6.9	7.0	7.1					

H_T 59.0 FT. = H_G 24.3 FT. + H_P 34.7 FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{6.9}{59 \times 10.7} \times .04895 =$$

.01093

K. CM/SEC ~~5.3 X 10^-4~~

5.4 X 10-4

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP Site	Job Number:	Test Section: 19.0 to 29.7	Bore Hole: MW 2056
Test Equipment Identification Flow Meter - Master Meter press-Meter - Winters 1953	BORE HOLE Orientation: Vertical	Size: 2.98	Test By: A. Benfer Date: 5-10-04
Packers On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable]	Groundwater Depth: 7.16 Ft.	Gauge Height Above Ground: 0.8' Ft.	Gravity Head: Mid-point of tested zone @ 24.3' Ft.

TEST ~~1~~ 4 Inflow pressure (H_P) 10 psi × 2.31 = 23.1 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	507.0	512.6	518.2	524.0	529.6	535.5	541.3	547.1				5.7 GPM CFM
Take Per Min.	5.6	5.6	5.8	5.6	5.9	5.8	5.8					CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

47.4 FT. = 24.3 FT. + 23.1 FT. – neg. FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ \ln. \frac{L\ (ft)}{r\ (ft)} = \frac{5.7}{47.4 \times 10.7} \times .04895 =$$

.01124

K, CM/SEC ~~5.4 x10-4~~ 5.5 x10-4

TEST ~~2~~ 5 Inflow pressure (H_P) 5 psi × 2.31 = 11.6 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	554.0	558.2	562.6	567.0	571.3	575.9	580.2					4.4 GPM CFM
Take Per Min.	4.2	4.4	4.4	4.3	4.6	4.3						

H_T 35.9 FT. = H_G 24.3 FT. + H_P 11.6 FT. – H_L negligible FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{4.4}{35.9 \times 10.7} \times .04895 =$$

.01145

K, CM/SEC ~~8.6x10-4~~ 5.6 x10-4

TEST 3 Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. – H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP

Job Number:

Test Section: 24.0 to 34.7

Bore Hole: MW 2056

Test Equipment Identification: Flow Meter - Master Meter; Press. Meter - Winters 1953

BORE HOLE

Orientation: vertical

Size: 2.98

Test By: A. Benfer

Date: 5-10-04

Packers
On Casing
[✓ Single] Double
Hydraulic [✓ Inflatable]

Groundwater Depth: ? 31.2 Ft.

Gauge Height Above Ground: 2.0 Ft.

Gravity Head: mid-point of tested zone ~~33.2~~ @ 29.4 Ft.

Begin test 1225

End Test 1305

TEST 1

Inflow pressure (Hp) 5 psi × 2.31 = 11.6 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	587.0	588.9	590.9	592.7	594.8	596.8	598.7					1.95 GPM CFM
Take Per Min.		1.9	2.0	1.8	2.1	2.0	1.9					CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

41.0 FT. = 29.4 FT. + 11.6 FT. – negligible FT.

$$K = \frac{Q\text{ (gpm)}}{H_T\text{ (ft)} \times L\text{ (ft)}} \times .011 \ln. \frac{L\text{ (ft)}}{r\text{ (ft)}} = \frac{1.95}{41.0 \times 10.7} \times .011 \ln \frac{10.7}{.125} =$$

.00444 .04895

K, CM/SEC ~~2.1 x 10^-4~~

2.2 x 10-4

TEST 2

Inflow pressure (Hp) 15 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	605.0	610.4	615.9	621.4	626.9	632.5						5.5 GPM CFM
Take Per Min.		5.4	5.5	5.5	5.5	5.6						

H_T 64.1 FT. = H_G 29.4 FT. + H_P 34.7 FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{5.5}{64.1 \times 10.7} \times .04895 =$$

.00802

K, CM/SEC ~~3.8 x 10-4~~

3.9 x 10-4

TEST 3

Inflow pressure (Hp) 25 psi × 2.31 = 57.8 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	642.5	651.5	660.4	669.4	678.4	687.6	697.9		715.7	725.1	734.7	9.3 GPM CFM
Take Per Min.		9.0	8.9	9.0	9.0	9.2	9.3			9.4	9.6	

H_T 87.2 FT. = H_G 29.4 FT. + H_P 57.8 FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{9.3}{87.2 \times 10.7} \times .04895 =$$

.00997

K, CM/SEC ~~4.8 x 10-4~~

4.9 x 10-4

PRESSURE TEST RESULTS (FIELD)

Project: Gwod - WSSRAP

Job Number:

Test Section: 24.0 to 34.7

Bore Hole: MW 2052

Test Equipment Identification: Flow Meter - Master Meter; Press. Meter - Winters 1953

BORE HOLE

Orientation: Vert.

Size: 2.98

Test By: A. Benfer

Date: 5-20-04

Packers: On Casing; [✓ Single]/Double; Hydraulic/[✓ Inflatable]

Groundwater Depth: ? 31.2 Ft.

Gauge Height Above Ground: 2.0 Ft.

Gravity Head: Mid-point of tested zone @ 29.4' Ft.

TEST ~~1~~ 4

Inflow pressure (H_P) 15 psi × 2.31 = 34.7 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	747.5	754.5	761.5	768.3	775.9	783.0	790.1					7.1 GPM CFM
Take Per Min.		7.0	7.0		7.6	7.9	7.1					CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

64.1 FT. = 29.4 FT. + 34.7 FT. − FT.

$$K = \frac{Q\,(\text{gpm})}{H_T\,(\text{ft}) \times L\,(\text{ft})} \times .011 \ln.\frac{L\,(\text{ft})}{r\,(\text{ft})} = \frac{7.1}{64.1 \times 10.7} \times .04895 =$$

.61035

K, CM/SEC: ~~4.9×10^{-4}~~ 5.1×10^{-4}

TEST ~~2~~ 5

Inflow pressure (H_P) 5 psi × 2.31 = 11.6 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	794.5	797.6	800.8	804.1	807.5	810.9	814.3	817.6				3.3 GPM CFM
Take Per Min.		3.1	3.2	3.3	3.4	3.4	3.4	3.3				

H_T 41.0 FT. = H_G 29.4 FT. + H_P 11.6 FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln.\frac{L}{r} = \frac{3.3}{41.0 \times 10.7} \times .04895 =$$

.60752

K, CM/SEC: ~~6.5×10^{-4}~~ 3.7×10^{-4}

TEST 3

Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln.\frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP	Job Number:	Test Section: 35 to 44.7	Bore Hole: MW 2056

Test Equipment Identification: Flow meter - Master Meter
Press. Meter - Winters 1953

BORE HOLE — Orientation: vert. — Size: 2.98

Test By: A. Benfer

Date: 5-10-04

Packers
On Casing
[✓ Single]/Double
Hydraulic/[✓ Inflatable]

Groundwater Depth: ? ~~32.1~~ 31.2 Ft.

Gauge Height Above Ground: 0.8 Ft.

Gravity Head: ~~32.9'~~ 32.0 Ft.

Begin Test 1505

End Test 1525

TEST 1

Inflow pressure (H_P) 10 psi × 2.31 = 23.1 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	822.50	822.55	822.75	822.75	822.75							~~<0.1~~ GPM .08 CFM
Take Per Min.	0.05	0.25	0	0								CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

55.1 FT. = 32.9 FT. + 23.1 FT. – negligible FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ ln.\ \frac{L\ (ft)}{r\ (ft)} = \frac{.08}{55.1 \times 9.7} \times .011\ln \frac{9.7}{.125} =$$

.00015

K, CM/SEC ~~<5×10-6~~

7.2 × 10-6

TEST 2

Inflow pressure (H_P) 20 psi × 2.31 = ____ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	823.40	823.4										No TAke GPM CFM
Take Per Min.	0											

H_T ____ FT. = H_G ____ FT. + H_P ____ FT. – H_L ____ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ ln.\ \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC <1.0 × 10-7

TEST 3

Inflow pressure (H_P) 30 psi × 2.31 = 69.3 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	824.7	824.75	824.80	824.85	824.90	824.95						0.05 GPM CFM
Take Per Min.	0.05	0.05	0.05	0.05	0.05							

H_T 101.3 FT. = H_G 32.0 FT. + H_P 69.3 FT. – H_L negligible FT.

$$K = \frac{Q}{H_T \times L} \times .011\ ln.\ \frac{L}{r} = \frac{.05}{101.3 \times 9.7} \times .04787 =$$

.00005

K, CM/SEC ~~2.2×10-6~~

2.4 × 10-6

Tests 4 & 5 No Take at 0 & 20 psi repeat

2 × <1.0 × 10-7

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSS RAP	Job Number:	Test Section: 45 to 54.7	Bore Hole: MW 2056
Test Equipment Identification Flow Meter · Master Meter press. Meter - winters 1953	BORE HOLE Orientation: Vert	Size: 2-98	Test By: A. Beufer Date: 5-11-04
Packers On Casing [✓ Single] Double Hydraulic [✓ Inflatable]	Groundwater Depth: ~~16.0~~ 31.2 Ft.	Gauge Height Above Ground: 0.8' Ft.	Gravity Head: 32.0 Ft.

Begin Test 0905

Test 1 No Take at 10 PSI L(<1.0x10-7)

End Test 0930

TEST ~~1~~ 2 Inflow pressure (H_P) 30 psi × 2.31 = 69.3 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	829.0	829.2	829.35	829.48	829.50	829.50						0.1 GPM CFM
Take Per Min.		0.2	0.15	0.13	0.02	0						CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

101.3 FT. = 32.0 FT. + 69.3 FT. − negligible FT.

$$K = \frac{Q\,(\text{gpm})}{H_T\,(\text{ft}) \times L\,(\text{ft})} \times .011 \ln. \frac{L\,(\text{ft})}{r\,(\text{ft})} = \frac{0.1}{101.3 \times 9.7} \times .011 \ln \frac{9.7}{.125} =$$

K, CM/SEC ~~4 x 10-6~~

.00010 (.04787) 4.9 X 10-6

TEST ~~2~~ 3 Inflow pressure (H_P) 50 psi × 2.31 = 115.5 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	833.3	834.0	834.4	835.3	836.1	836.7	837.4	838.0				0.7 GPM CFM
Take Per Min.		0.7	0.6	0.7	0.8	0.6	0.7	0.6				

H_T 147.5 FT. = H_G 32.0 FT. + H_P 115.5 FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{0.7}{147.5 \times 9.7} \times .04787 =$$

K, CM/SEC ~~2 x 10-5~~

2.3 X 10-5

.00049

Test 5 No Take at 30 PSI repeat (<1.0 x 10-7)

TEST ~~3~~ 4 Inflow pressure (H_P) 30 psi × 2.31 = ____ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM <1.0x10-7 CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC

PRESSURE TEST RESULTS (FIELD)

Project: GWOU-WSSRAP	Job Number:	Test Section: 55 to 64.7	Bore Hole: MW 2056
Test Equipment Identification Flow Meter - Master Meter press. Meter - winters 1953	BORE HOLE Orientation: Vert.	Size: 2.98	Test By: A. Benfer Date: 5-11-04
Packers On Casing [✓ Single] Double Hydraulic [✓ Inflatable]	Groundwater Depth: ~~16'~~ 31.2 Ft.	Gauge Height Above Ground: 1.1 Ft.	Gravity Head: 32.3 Ft.

Begin Test 1145

End Test 1230

TEST 1

Inflow pressure (Hp) 15 psi × 2.31 = 34.7 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	841.1	841.4	841.7	841.9	842.1	842.4	842.6					0.25 GPM CFM
Take Per Min.		0.3	0.3	0.2	0.2	0.3	0.2					CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

67.0 FT. = 32.3 FT. + 34.7 FT. – negligible FT.

$$K = \frac{Q\text{ (gpm)}}{H_T\text{ (ft)} \times L\text{ (ft)}} \times .011 \ln. \frac{L\text{ (ft)}}{r\text{ (ft)}} = \frac{.25}{67.0 \times 9.7} \times .011 \ln \frac{9.7}{.125} =$$

K, CM/SEC ~~1.3 x10^-5~~

(.04787) 1.8×10^{-5}

15

35

55

TEST 2

Inflow pressure (Hp) 35 psi × 2.31 = 80.9 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	844.5	845.5	846.4	847.7	848.9	850.1	851.6	852.4				1.1 GPM CFM
Take Per Min.		1.0	0.9	1.3	1.2	1.2	1.5	0.8				

H_T 113.2 FT. = H_G 32.3 FT. + H_P 80.9 FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{1.1}{113.2 \times 9.7} \times .04787 =$$

.00100

K, CM/SEC ~~3.9X10^-5~~

4.8×10^{-5}

TEST 3

Inflow pressure (Hp) 55 psi × 2.31 = 127.1 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	865.0	866.3	867.6	869.0	870.5	871.9	873.3					1.4 GPM CFM
Take Per Min.		1.3	1.3	1.4	1.5	1.4	1.4					

H_T 159.4 FT. = H_G 32.3 FT. + H_P 127.1 FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{1.4}{159.4 \times 9.7} \times .04787 =$$

.00091

K, CM/SEC 3.6×10^{-5}

4.4×10^{-5}

PRESSURE TEST RESULTS (FIELD)

Project: Gwoa - WSSRAP -	Job Number:	Test Section: 55 to 64.7	Bore Hole: MW 2056

Test Equipment Identification
Flow Meter - Master Meter
Press. Meter - Winters 1953

BORE HOLE
Orientation: Vert.
Size: 2.98

Test By: A. Benfer
Date: 5-11-04

Packers
On Casing
[✓ Single] Double
Hydraulic [✓ Inflatable]

Groundwater Depth: ~~Zero~~ 31.2 Ft.

Gauge Height Above Ground: 1.1 Ft.

Gravity Head: 32.3 Ft.

TEST ~~1~~ 4 Inflow pressure (H_P) 35 psi × 2.31 = 80.9 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	865.7	867.4	869.1	871.0	872.2	874.4	876.9	877.4	879.0	880.4	881.9	1.6 GPM CFM
Take Per Min.		1.7	1.5	1.9	1.2	2.2	2.5	0.5	1.6	1.4	1.5	CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

113.2 FT. = 32.3 FT. + 80.9 FT. – FT.

$$K = \frac{Q\,(gpm)}{H_T\,(ft) \times L\,(ft)} \times .011\ ln. \frac{L\,(ft)}{r\,(ft)} = \frac{1.6}{113.2 \times 9.7} \times .04787 =$$

.00146

K, CM/SEC ~~5.6 x 10^-5~~

6.9 X 10^-5

No Take at 15 PSI repeat

TEST ~~2~~ 5 Inflow pressure (H_P) 15 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC $<1.0 \times 10^{-7}$

TEST 3 Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC

PRESSURE TEST RESULTS (FIELD)

Project: GWOU-WSSRAP	Job Number:	Test Section: 65 to 74.9	Bore Hole: MW 2056

Test Equipment Identification Flow Meter-Master Meter Press. Meter-Winters 1953	BORE HOLE Orientation: vertical	BORE HOLE Size: 2.98	Test By: A. Benfer Date: 5-11-04

Packers On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable]	Groundwater Depth: 16.0 Ft.	Gauge Height Above Ground: 1.0 Ft.	Gravity Head: Ft.

20
40
60

Begin
est.
355

No Take
at 20 PSI
or 40 PSI
or 60 PSI

End Test
410

TEST 1 Inflow pressure (H_P) 20 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM <1.0×10^{-7} CFM
Take Per Min.												CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

FT. = FT. + FT. – FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ \ln. \frac{L\ (ft)}{r\ (ft)} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC

TEST 2 Inflow pressure (H_P) 40 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM <1.0×10^{-7} CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC

TEST 3 Inflow pressure (H_P) 60 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM <1.0×10^{-7} CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad = $$

K, CM/SEC

PRESSURE TEST RESULTS (FIELD)

Project: Gwoa - WSSRAP Chem. Plant

Job Number:

Test Section: 44.5 to 55

Bore Hole: Mw 3040

Test Equipment Identification: Flow Meter - Master Meter press. Meter - Winters 1953

BORE HOLE

Orientation: Vert.

Size: 2.98"

Test By: A. Benfer

Date: 5-12-04

Packers
On Casing
[✓ Single]/Double
Hydraulic/[✓ Inflatable]

Groundwater Depth: ~~44~~ 49.8 Ft.

Gauge Height Above Ground: 2.3' Ft.

Gravity Head: 52.1 Ft.

Begin Test 1510

Test 1 No Take at 15 PSI

Test 2 No Take at 30 PSI (<10^-7)

Tests 4 & 5 No Take at 15 & 30 psi repeat (<10^-7)

End Test 1530

TEST ~~1~~ 3 Inflow pressure (H_P) 45 psi × 2.31 = 103.9 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	897.3	898.2	899.1	899.9	900.8	901.6	902.5					0.9 GPM CFM
Take Per Min.		0.9	0.9	0.8	0.9	0.8	0.9					CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

156 FT. = 52.1 FT. + 103.9 FT. − FT.

$$K = \frac{Q\,(\text{gpm})}{H_T\,(\text{ft}) \times L\,(\text{ft})} \times .011\ \ln.\frac{L\,(\text{ft})}{r\,(\text{ft})} = \frac{.9}{156 \times 10.5} \times .011 \ln \frac{10.5}{.125} =$$

.00055

.04874

K, CM/SEC ~~2.6×10^-5~~ 2.7×10^-5

TEST 2 Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln.\frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC

TEST 3 Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln.\frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP - Chem - Plant	Job Number:	Test Section: 55 to 64	Bore Hole: MW 3040
Test Equipment Identification Flow Meter - Master Meter Press. Meter - Winters 1953	BORE HOLE Orientation: Vertical Size: 2.98"		Test By: A. Benfer Date: 5-13-04
Packers On Casing [✓ Single] Double Hydraulic [✓ Inflatable]	Groundwater Depth: ~~44.9~~ 57.0 Ft.	Gauge Height Above Ground: 2.3 Ft.	Gravity Head: 59.3 Ft.

0850 Begin Test

End Test 0940

TEST 1 Inflow pressure (Hp) 10 psi × 2.31 = 23.1 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	908.4	908.7	909.1	909.4	909.7	910.1	910.5					0.34 GPM CFM
Take Per Min.		0.3	0.4	0.3	0.3	0.4	0.4					CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

82.4 FT. = 59.3 FT. + 23.1 FT. – negligible FT.

$$K = \frac{Q\,(gpm)}{H_T\,(ft) \times L\,(ft)} \times .011 \ln. \frac{L\,(ft)}{r\,(ft)} = \frac{.34}{82.4 \times 9} \times .011 \ln \frac{9}{.125} = 2.1 \times 10^{-5}$$ ✓

.00046

.04704

pressure fluctuating ± 2 psi

TEST 2 Inflow pressure (Hp) 30 psi × 2.31 = 69.3 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	915.5	916.4	917.4	918.5	919.4	920.5	921.4	922.3				0.97 GPM CFM
Take Per Min.		0.9	1.0	1.1	0.9	1.1	0.9	0.9				

H_T 128.6 FT. = H_G 59.3 FT. + H_P 69.3 FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{0.97}{128.6 \times 9} \times .04704 = 3.5 \times 10^{-5}$$ ✓

.00084

TEST 3 Inflow pressure (Hp) 50 psi × 2.31 = 115.5 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	928.5	930.4	932.2	934.2	936.0	937.6	939.2	940.9	942.9	944.9	946.9	1.8 GPM CFM
Take Per Min.		1.9	1.8	2.0	1.8	1.6	1.6	1.7	2.0	2.0	2.0	

H_T 174.8 FT. = H_G 59.3 FT. + H_P 115.5 FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{1.8}{174.8 \times 9} \times .04704 = ~~5.4 \times 10^{-5}~~$$

.00109

5.1×10^{-5} ✓

average 3.5×10^{-5} cm/sec

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP Chem Plant	Job Number:	Test Section: 55 to 64	Bore Hole: MW. 3040
Test Equipment Identification Flow Meter - Master Meter Press. Meter - Winters 1953	BORE HOLE Orientation: Vertical	Size: 2.98"	Test By: A. Benfer Date: 5-13-04
Packers On Casing [✓ Single] Double Hydraulic [✓ Inflatable]	Groundwater Depth: ~~44.9'~~ 57.0' bgs Ft.	Gauge Height Above Ground: 2.3 Ft.	Gravity Head: 59.3 Ft.

TEST ~~1~~ 4

Inflow pressure (H_P) 30 psi × 2.31 = 69.3 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	948.5	949.3	950.2	951.1	951.9	952.8						0.9 GPM CFM
Take Per Min.		0.8	0.9	0.9	0.8	0.9						CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

128.6 FT. = 59.3 FT. + 69.3 FT. − FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ \ln.\frac{L\ (ft)}{r\ (ft)} = \boxed{\frac{.9}{128.6 \times 9}} \times \boxed{.04704} = $$

.00078

K, CM/SEC ~~3.4×10^{-5}~~ 3.7×10^{-5} ✓

TEST ~~2~~ 5

Inflow pressure (H_P) 10 psi × 2.31 = 23.1 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	953.5	953.9	954.3	954.8	955.2	955.6						0.4 GPM CFM
Take Per Min.		0.4	0.4	0.5	0.4	0.4						

H_T 82.4 FT. = H_G 59.3 FT. + H_P 23.1 FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln.\frac{L}{r} = \boxed{\frac{0.4}{82.4 \times 9}} \times \boxed{.04704} = $$

.00054

K, CM/SEC ~~4.8×10^{-5}~~

2.5×10^{-5} ✓

TEST 3

Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln.\frac{L}{r} = \boxed{\frac{\quad}{\quad \times \quad}} \times \boxed{\quad} = $$

K, CM/SEC

PRESSURE TEST RESULTS (FIELD)

Project:	Job Number:	Test Section:	Bore Hole:
GWOU - WSSRAP Chem Plant		64 to 74	MW 3040

Test Equipment Identification	BORE HOLE Orientation:	BORE HOLE Size:	Test By: / Date:
Flow Meter · Master Meter Press. Meter · Winters 1953	vertical	2.98"	A. Benfer Date: 5-13-04

Packers	Groundwater Depth:	Gauge Height Above Ground:	Gravity Head:
On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable] NQ wL	~~44.9~~ 57.0' Ft.	2.5 Ft.	59.5' Ft.

Begin Test
1050

End Test
1125

TEST 1

Inflow pressure (H_P) 20 psi × 2.31 = 46.2 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	962.0	962.7	963.4	964.0	964.7	965.3	966.0					0.7 GPM CFM
Take Per Min.		0.7	0.7	0.6	0.7	0.6	0.7					CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

105.7 FT. = 59.5 FT. + 46.2 FT. – FT.

$K = \frac{Q \text{ (gpm)}}{H_T \text{ (ft)} \times L \text{ (ft)}} \times .011 \ln. \frac{L \text{ (ft)}}{r \text{ (ft)}} = \frac{.7}{105.7 \times 10} \times .0111n \frac{10}{.125} =$ K, CM/SEC ~~2.7×10-5~~

.00066

.04820 3.2×10-5

TEST 2

Inflow pressure (H_P) 40 psi × 2.31 = 92.4 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	968.0	968.8	969.6	970.4	971.1	971.9						0.8 GPM CFM
Take Per Min.		0.8	0.8	0.8	0.7	0.8						

H_T 151.9 FT. = H_G 59.5 FT. + H_P 92.4 FT. – H_L FT.

$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{.8}{151.9 \times 10} \times .04820 =$ K, CM/SEC ~~2.3×10-5~~

.00053

2.5×10-5 ✓

TEST 3

Inflow pressure (H_P) 60 psi × 2.31 = 138.6 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	975.0	976.2	977.4	978.6	979.9	981.3	982.5					1.25 GPM CFM
Take Per Min.		1.2	1.2	1.2	1.3	1.4	1.2					

H_T 198.1 FT. = H_G 59.5 FT. + H_P 138.6 FT. – H_L FT.

$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{1.25}{198.1 \times 10} \times .04820 =$ K, CM/SEC ~~2.9×10-5~~

.00063

3.0×10-5 ✓

PRESSURE TEST RESULTS (FIELD)

Project: GW02a - WSSRAP - Chem Plant	Job Number:	Test Section: 64 to 74	Bore Hole: MW 3040
Test Equipment Identification Flow Meter - Master Meter Press. Meter - Winters 1953	BORE HOLE Orientation: Vertical	Size: 2.98"	Test By: A. Benfer Date: 5-13-04
Packers On Casing [✓ Single]/Double Hydraulic/[✓ Inflatable] NQWL	Groundwater Depth: ~~44.9~~ 57.0' Ft.	Gauge Height Above Ground: 2.5' Ft.	Gravity Head: 59.5 Ft.

TEST ~~1~~ 4 Inflow pressure (H_P) 40 psi × 2.31 = 92.4 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	986.3	987.1	987.9	988.7	989.5	990.3						0.8 GPM CFM
Take Per Min.		0.8	0.8	0.8	0.8	0.8						CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

151.9 FT. = 59.5 FT. + 92.4 FT. – FT.

$$K = \frac{Q\text{ (gpm)}}{H_T\text{ (ft)} \times L\text{ (ft)}} \times .011 \ln.\frac{L\text{ (ft)}}{r\text{ (ft)}} = \frac{.8}{151.9 \times 10} \times .04820 =$$

.00053

K, CM/SEC ~~2.3x10^-5~~ 2.5x10^-5 ✓

TEST ~~2~~ 5 Inflow pressure (H_P) 20 psi × 2.31 = 46.2 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	991.0	991.4	991.8	992.2								0.4 GPM CFM
Take Per Min.		0.4	0.4	0.4								

H_T 105.7 FT. = H_G 59.5 FT. + H_P 46.2 FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln.\frac{L}{r} = \frac{0.4}{105.7 \times 10} \times .04820 =$$

.00038

K, CM/SEC ~~2.1x10^-5~~ 1.8x10^-5 ✓

TEST 3 Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln.\frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP Chem Plant

Job Number:

Test Section: 74 to 82.2

Bore Hole: MW 3040

Test Equipment Identification: FLOW METER - MASTER METER
PRESS METER - WINTERS 1953

BORE HOLE

Orientation: Vertical

Size: 2.98"

Test By: A. Benter

Date: 5-13-04

Packers
On Casing
[✓ Single]/Double
Hydraulic/[✓ Inflatable]

5
50
75

Groundwater Depth: ~~44.9~~ 57.0 Ft.

Gauge Height Above Ground: 2.5 Ft.

Gravity Head: 59.5 Ft.

Begin Test 1310

No Take at 30 PSI
No Take at 50 PSI
No Take at 70 PSI

End Test 1325

TEST 1

Inflow pressure (H_P) 30 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM CFM
Take Per Min.												

CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

FT. = FT. + FT. – FT.

$$K = \frac{Q\text{ (gpm)}}{H_T\text{ (ft)} \times L\text{ (ft)}} \times .011 \ln. \frac{L\text{ (ft)}}{r\text{ (ft)}} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC $<1 \times 10^{-7}$

TEST 2

Inflow pressure (H_P) 50 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC $<1 \times 10^{-7}$

TEST 3

Inflow pressure (H_P) 70 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												0 GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC $<1 \times 10^{-7}$

PRESSURE TEST RESULTS (FIELD)

Project: GWOU-WSSRAP Chem Plant

Job Number:

Test Section: 82 to 94

Bore Hole: MW 3040

Test Equipment Identification: Flow Meter Press-Meter.

BORE HOLE

Orientation: Vert.

Size: 2.98

Test By: A. Beafer

Date: 5-14-04

Packers: On Casing, [✓ Single]/Double, Hydraulic/[✓ Inflatable]

Groundwater Depth: ~~44.0~~ 57.0 Ft.

Gauge Height Above Ground: 3.6' Ft.

Gravity Head: 60.6 Ft.

Test 1 No Take at 25 PSI $(<10^{-7})$

Begin Test 11:40

End Test 12:20

TEST ~~1~~ 2 Inflow pressure (H_P) 50 psi × 2.31 = 115.5 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	009.2	009.5	009.9	010.2	010.6	010.9	011.2	[illegible]				0.3 GPM CFM
Take Per Min.		0.3	0.4	0.3	0.4	0.3	0.3					CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

176.1 FT. = 60.6 FT. + 115.5 FT. – FT.

$K = \frac{Q \text{ (gpm)}}{H_T \text{ (ft)} \times L \text{ (ft)}} \times .011 \ln. \frac{L \text{ (ft)}}{r \text{ (ft)}} = \frac{0.3}{176.1 \times 8} \times .04575 =$ K, CM/SEC ~~6.9x10-6~~ 9.7×10^{-6}

.00021

TEST ~~2~~ 3 Inflow pressure (H_P) 75 psi × 2.31 = 173.3 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	012.6	014.4	015.8	017.3	018.9	020.7	022.4	024.0	025.5	0		1.6 GPM CFM
Take Per Min.		1.8	1.4	1.5	1.6	2.2	1.7	1.6	1.5			

H_T 233.9 FT. = H_G 60.6 FT. + H_P 173.3 FT. – H_L FT.

$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{1.6}{233.9 \times 8} \times .04575 =$ K, CM/SEC ~~2.5x10-5~~ 3.9×10^{-5} ✓

.00086

TEST ~~3~~ 4 Inflow pressure (H_P) 50 psi × 2.31 = 115.5 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	026.0	026.17	026.35	026.50	026.64	026.77						0.15 GPM CFM
Take Per Min.		0.17	0.18	0.15	0.14	0.13						

H_T 176.1 FT. = H_G 60.6 FT. + H_P 115.5 FT. – H_L FT.

$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{0.15}{176.1 \times 8} \times .04575 =$ K, CM/SEC ~~3.1x10-6~~ 4.9×10^{-6} ✓

.00011

Test 5 No Take at 25 PSI $(<10^{-7})$

PRESSURE TEST RESULTS (FIELD)

packer press. 230 psi

Project: GWOU - WSSRAP Chem. Plant

Job Number:

Test Section: 94 to 104

Bore Hole: MW 3040

Test Equipment Identification: Flow Meter - Master Meter; press. Meter - Winters 1953

BORE HOLE

Orientation: Vert.

Size: 2.98"

Test By: A. Benfer

Date: 5-14-04

Packers: On Casing; [✓ Single]/Double; Hydraulic/[✓ Inflatable]

Groundwater Depth: ~~44.8~~ 57.0 Ft.

Gauge Height Above Ground: 2.4 Ft.

Gravity Head: 59.4 Ft.

Begin test 1420

'510 End Test

TEST 1

Inflow pressure (H_P) 30 psi × 2.31 = 69.3 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	039.0	046.7	054.5	062.3	070.2	078.0						7.8 GPM CFM
Take Per Min.		7.7	7.8	7.8	7.9	7.8						CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

128.7 FT. = 59.4 FT. + 69.3 FT. − FT.

$$K = \frac{Q\,(gpm)}{H_T\,(ft) \times L\,(ft)} \times .011 \ln.\frac{L\,(ft)}{r\,(ft)} = \frac{7.8}{128.7 \times 10} \times .04820 =$$

.00606

K, CM/SEC ~~2.2 x10-4~~ 2.9 x10-4 ✓

TEST 2

Inflow pressure (H_P) 60 psi × 2.31 = 138.6 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	098.5	109.5	120.5	131.6	142.7							11 GPM CFM
Take Per Min.		11.0	11.0	11.1	11.1							

H_T 198.0 FT. = H_G 59.4 FT. + H_P 138.6 FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln.\frac{L}{r} = \frac{11}{198.0 \times 10} \times .04820 =$$

.00556

K, CM/SEC ~~2.2x10-4~~ 2.7 x10-4 ✓

TEST 3

Inflow pressure (H_P) 90 psi × 2.31 = 207.9 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	0167.0	180.1	194.8	208.3	222.6	236.7	250.7					14 GPM CFM
Take Per Min.		13.7	14.1	13.	14.3	14.1	14.0					

H_T 267.3 FT. = H_G 59.4 FT. + H_P 207.9 FT. − H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln.\frac{L}{r} = \frac{14}{267.3 \times 10} \times .04820 =$$

.00524

K, CM/SEC ~~2.2 x10-4~~ 2.5 x10-4 ✓

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP - Chem Plant

Job Number:

Test Section: 94 to 104

Bore Hole: MW 3040

Test Equipment Identification: Flow Meter - Master Meter; Press. Meter - Winter 1953

BORE HOLE

Orientation: Vert

Size: 2.98"

Test By: A. Benfer

Date: 5-14-04

Packers
On Casing
[✓ Single]/Double
Hydraulic/[✓ Inflatable]

Groundwater Depth: ~~44.8~~ 57.0 Ft.

Gauge Height Above Ground: 2.4 Ft.

Gravity Head: 59.4 Ft.

TEST 14

Inflow pressure (H_P) 60 psi × 2.31 = 138.6 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	262.0	273.8	285.9	298.0	310.2	322.4						12 GPM CFM
Take Per Min.		11.8	12.1	12.1	12.2	12.2						

CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

198.0 FT. = 59.4 FT. + 138.6 FT. – FT.

$$K = \frac{Q\,(gpm)}{H_T\,(ft) \times L\,(ft)} \times .011 \ln \frac{L\,(ft)}{r\,(ft)} = \frac{12}{198.0 \times 10} \times .04820 =$$

.00606

K, CM/SEC: ~~2.4 x10-4~~

2.9 x 10-4 ✓

TEST 15

Inflow pressure (H_P) 30 psi × 2.31 = 69.3 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	332.0	340.7	349.5	358.3	367.1							8.8 GPM CFM
Take Per Min.		8.7	8.8	8.8	8.8							

H_T 128.7 FT. = H_G 59.4 FT. + H_P 69.3 FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln \frac{L}{r} = \frac{8.8}{128.7 \times 10} \times .04820 =$$

.00684

K, CM/SEC: ~~3.0x10-4~~

3.3 x10-4 ✓

TEST 3

Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC:

Page 1 of 2

PRESSURE TEST RESULTS (FIELD)

Project: GWOU - WSSRAP Chem Plant

Job Number:

Test Section: 104 to 114

Bore Hole: MW 3040

Test Equipment Identification: Single Packer Master Meter flow meter Winters 1953 pressure guage

BORE HOLE

Orientation: Vert

Size: 2.98"

Test By: P. Patchin

Date: 5/17/04

Packers
On Casing
[✓ Single]/Double
Hydraulic/Inflatable

Groundwater Depth: 57.0 ~~45.0~~ Ft.

Gauge Height Above Ground: 2.8 Ft.

Gravity Head: 59.8 Ft.

Packer pressure 240

TEST 1

Inflow pressure (Hp) 45 psi × 2.31 = 104 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	438 .970	438 .000	8 .015	.050	.075	.105	.137	.170	.200			0.03 GPM CFM
Take Per Min.		.13	.015	.035	.025	.030	.032	.033	.030			CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

163.8 FT. = 59.8 FT. + 104 0 FT. – negligible FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011 \ln. \frac{L\ (ft)}{r\ (ft)} = \frac{.03}{163.8 \times 10} \times .011 \ln \frac{10}{.125}\ (.04820) = $$

.00002

K, CM/SEC ~~6×10-7~~ 8.8×10-7

TEST 2

Inflow pressure (Hp) 70 psi × 2.31 = 161.7 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	438 .350	.380	.410	.433	.465	.498	.523	.555				0.03 GPM CFM
Take Per Min.		.030	.030	.023	.032	.033	.025	.032				

H_T 221.5 FT. = H_G 59.8 FT. + H_P 161.7 FT. – H_L neg FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{.03}{221.5 \times 10} \times .04820 = $$

.00001

K, CM/SEC ~~5×10-7~~ 6.5×10-7

TEST 3

Inflow pressure (Hp) 95 psi × 2.31 = 219.5 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	8 .750	.835	.922	9 .005	.095	.178	.253					0.08 GPM CFM
Take Per Min.		.085	.087	.083	.090	.083	.086					

H_T 279.3 FT. = H_G 59.8 FT. + H_P 219.5 FT. – H_L negl FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{.08}{279.3 \times 10} \times .04820 = $$

.00003

K, CM/SEC ~~1×10-6~~ 1.4×10-6

Page 2 of 2

PRESSURE TEST RESULTS (FIELD)

Project: W SSRAP	Job Number:	Test Section: 104 to 114	Bore Hole: MW 3040
Test Equipment Identification	BORE HOLE Orientation: Vertical Size: 2.98"		Test By: P. Patchin Date: 5/17/04
Packers On Casing [✓ Single]/Double Hydraulic/Inflatable	Groundwater Depth: 57' ~~45'~~ Ft.	Gauge Height Above Ground: 2.8' Ft.	Gravity Head: 59.8' Ft.

TEST ~~1~~ 4 Inflow pressure (Hp) 70 psi × 2.31 = 161.7 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	9. .380	.411	.439	.467	.497	.523	.548	.				0.03 GPM CFM
Take Per Min.		.031	.028	.026	.030	.026	.025					CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

221.5 FT. = 59.8 FT. + 161.7 FT. – FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ ln. \frac{L\ (ft)}{r\ (ft)} = \frac{.03}{221.5 \times 10} \times .04820 =$$

.00001

K, CM/SEC ~~5x10^-7~~ 6.5x10^-7

TEST ~~2~~ 5 Inflow pressure (Hp) 45 psi × 2.31 = 104 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	9 .630	.654	.684	.711	.741	.768	.795					0:03 GPM CFM
Take Per Min.		.024	.030	.027	.030	.027	.027					

H_T 163.8 FT. = H_G 59.8 FT. + H_P 104 FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ ln. \frac{L}{r} = \frac{.03}{163.8 \times 10} \times .04820 =$$

.00002

K, CM/SEC ~~6x10^-7~~ 8.8x10^-7

TEST 3 Inflow pressure (Hp) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC

Page 1 of 2

PRESSURE TEST RESULTS (FIELD)

Project: WSSRAP

Job Number:

Test Section: 33.0 to 39.0

Bore Hole: MW-4040

Test Equipment Identification

BORE HOLE

Orientation: VERTICAL

Size: 2.98

Test By: P. Pakhin

Date: 5/18/04

Packers
On Casing
[✓ Single]/Double
Hydraulic/Inflatable

Groundwater Depth: 33.7, ~~15.8~~ Ft.

Gauge Height Above Ground: 7 2.8 Ft.

Gravity Head: 36.5 Ft.

TEST 1

Inflow pressure (H_P) 15 psi × 2.31 = 23.1 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	39.→ .790	.792	.792	.792	.792	.792	.792					No take GPM CFM
Take Per Min.		.02	.00	.00	.00	.00	.00					CFM × 7.48 – GPM

Total Head (H_T)	=	Gravity Head (H_G)	+	Pressure Head (H_P)	–	Head Losses (H_L)
59.6 FT.	=	36.5 FT.	+	23.1 FT.	–	negligible FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ \ln. \frac{L\ (ft)}{r\ (ft)} = \frac{}{59.6 \times 6} \times \boxed{} =$$

K, CM/SEC ~~10-8~~ <1 x 10-7

TEST 2

Inflow pressure (H_P) 15 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	9 .810	.810	.810	.812	.812	.812	.812					No take GPM CFM
Take Per Min.		.00	.00	.02	.00	.00	.00					

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. – H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{}{\times} \times \boxed{} =$$

K, CM/SEC ~~10-8~~ <1X10-7

TEST 3

Inflow pressure (H_P) 25 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	9 .830	.830	.831	.831	.831	.831						NO TAKE GPM CFM
Take Per Min.		.00	.01	.00	.00	.00						

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. – H_L No FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{}{\times} \times \boxed{} =$$

K, CM/SEC ~~10-8~~

<1X10-7

Page 2 of 2

PRESSURE TEST RESULTS (FIELD)

Project: WSSRAP	Job Number:	Test Section: 33.0 to 39.0'	Bore Hole: MW-4040

Test Equipment Identification

BORE HOLE
Orientation: Vert
Size:

Test By: P. Patchin
Date: 5/18/04

Packers
On Casing
[✓ Single]/Double
Hydraulic/Inflatable

Groundwater Depth: 33.7 ~~15.8~~ Ft.

Gauge Height Above Ground: 2.8 Ft.

Gravity Head: 36.5 Ft.

TEST ~~1~~4

Inflow pressure (H_P) 10 psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	.831	.831	.831	.831	.831	.831						NO TAKE GPM CFM
Take Per Min.		.00	.00	.00	.00	.00						CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

______ FT. = ______ FT. + ______ FT. – ______ FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ \ln. \frac{L\ (ft)}{r\ (ft)} = \frac{\quad}{\times} \times \quad =$$

K, CM/SEC ~~10^{-8}~~

1×10^{-7}

TEST 2

Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. – H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\times} \times \quad =$$

K, CM/SEC

TEST 3

Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. – H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\times} \times \quad =$$

K, CM/SEC

Page 1 of 2

PRESSURE TEST RESULTS (FIELD)

Project: WSSRAP	Job Number:	Test Section: 38.0 to 49.0'	Bore Hole: MW-4040

Test Equipment Identification: Packer Pressure 240 psi

BORE HOLE — Orientation: | Size: 2.98"

Test By: P. Patchin

Date: 5/18/04

Packers
On Casing
[✓ Single]/Double
Hydraulic/Inflatable

Groundwater Depth: ~~15.8'~~ 33.7' Ft.

Gauge Height Above Ground: 2.0' Ft.

Gravity Head: 35.7 Ft.

TEST 1

Inflow pressure (H_P) 10 psi × 2.31 = 23.1 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	39 .950	.960	.973	.983	40 .998	40 .005	.017	.025	.037	.050	.055	0.01 GPM CFM
Take Per Min.		.010	.013	.010	.015	.007	.012	.008	.012	.013	.005	CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

58.8 FT. = 35.7 FT. + 23.1 FT. – negligible FT.

$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ \ln \frac{L\ (ft)}{r\ (ft)} = \frac{.01}{58.8 \times 9} \times .011\ \ln \frac{9}{.125}$ (.04704) =

.00002

K, CM/SEC ~~7x10-7~~ 8.9×10^{-7}

TEST 2

Inflow pressure (H_P) 20 psi × 2.31 = 46.2 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	40 .150	.182	.212	.242	.272	.302						0.03 GPM CFM
Take Per Min.		.03	.03	.03	.03	.03						

H_T 81.9 FT. = H_G 35.7 FT. + H_P 46.2 FT. – H_L negligible FT.

$K = \frac{Q}{H_T \times L} \times .011\ \ln \frac{L}{r} = \frac{.03}{81.9 \times 9} \times .04704 =$

.00004

K, CM/SEC ~~2×10^{-6}~~ 1.9×10^{-6}

TEST 3

Inflow pressure (H_P) 30 psi × 2.31 = 69.3 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	40 .500	.548	.601	.648	.693	.741	.791					0.05 GPM CFM
Take Per Min.		.048	.053	.047	.045	.048	.050					

H_T 105.0 FT. = H_G 35.7 FT. + H_P 69.3 FT. – H_L negligible FT.

$K = \frac{Q}{H_T \times L} \times .011\ \ln \frac{L}{r} = \frac{.05}{105.0 \times 9} \times .04704 =$

.00005

K, CM/SEC 2×10^{-6} 2.5×10^{-6}

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PRESSURE TEST RESULTS (FIELD)

Page 2 of 2

Project: WSSRAP	Job Number:	Test Section: 38.0 to 49.0	Bore Hole: MW-4040
Test Equipment Identification	BORE HOLE Orientation: Vertical Size: 2.98"		Test By: P. Patchen Date: 5/18/04
Packers On Casing Single/Double Hydraulic/Inflatable	Groundwater Depth: 33.7' ~~15.8'~~ Ft.	Gauge Height Above Ground: 2.0' Ft.	Gravity Head: 35.7 Ft.

TEST ~~1~~ 4 Inflow pressure (H_P) 20 psi × 2.31 = 46.2 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	40 .850	.877	.906	.936	.964	.993						0.03 GPM CFM
Take Per Min.		.027	.029	.030	.027	.029						CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

81.9 FT. = 35.7 FT. + 46.2 FT. – FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ \ln. \frac{L\ (ft)}{r\ (ft)} = \frac{.03}{81.9 \times 9} \times .04704 =$$

.00004

K, CM/SEC ~~1x10^-6~~

1.9 x10^-6

TEST ~~2~~ 5 Inflow pressure (H_P) 10 psi × 2.31 = 23.1 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	41, .000	.005	.007	.008	.011	.013	.015					<0.01 GPM CFM
Take Per Min.		.005	.002	.001	.003	.002	.002					

H_T 58.8 FT. = H_G 35.7 FT. + H_P 23.1 FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{<.01}{58.8 \times 9} \times .04704 =$$

.00002

K, CM/SEC ~~10^-8~~ <8.9x10^-7

TEST 3 Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T FT. = H_G FT. + H_P FT. – H_L FT.

$$K = \frac{Q}{H_T \times L} \times .011\ \ln. \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC

PRESSURE TEST RESULTS (FIELD)

Page 1 of 2

Project: WSSRAP

Job Number:

Test Section: 50.0 to 65.0

Bore Hole: MW-4040

Test Equipment Identification

BORE HOLE

Orientation: Vert

Size: 2.98"

Test By: P. Patchin

Date: 5/19

Packers
On Casing
[✓ Single]/Double
Hydraulic/Inflatable

Packer Press 240 psI

Groundwater Depth: 33.7' ~~15.8'~~ Ft.

Gauge Height Above Ground: 2.2 Ft.

Gravity Head: 35.9 ~~18.0~~ Ft.

TEST 1

Inflow pressure (H_P) 20 psi × 2.31 = 46.2 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	41 .100	.104	.115	.121	.127	.138	.144	.155	.167	.177	.195	0.01 GPM CFM
Take Per Min.		.004	.011	.006	.006	.011	.006	.010	.012	.010	.018	CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

82.1 FT. = 35.9 FT. + 46.2 FT. – negligible FT.

$$K = \frac{Q\,(\text{gpm})}{H_T\,(\text{ft}) \times L\,(\text{ft})} \times .011 \ln. \frac{L\,(\text{ft})}{r\,(\text{ft})} = \frac{.01}{82.1 \times 15} \times .011 \text{ LN } \frac{15}{.125} \; (.05266) = $$

.00000

K, CM/SEC ~~3×10-7~~

4.3×10-7

TEST 2

Inflow pressure (H_P) 30 psi × 2.31 = 69.3 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	1 .300	.333	.363	.400	.429	.458	.488	.521	.553			0.03 GPM CFM
Take Per Min.		.033	.030	.037	.029	.029	.030	.33	.32			

H_T 105.2 FT. = H_G 35.9 FT. + H_P 69.3 FT. – H_L negligible FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{.03}{105.2 \times 15} \times .05266 = $$

.00002

K, CM/SEC ~~9×10-7~~

1.0×10-6

TEST 3

Inflow pressure (H_P) 45. psi × 2.31 = 104 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	1 .650	.693	.732	.769	.812	.851	.897	.937	.971			0.04 GPM CFM
Take Per Min.		.043	.039	.037	.043	.039	.046	.040				

H_T 139.9 FT. = H_G 35.9 FT. + H_P 104 FT. – H_L neglib FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln. \frac{L}{r} = \frac{.04}{139.9 \times 15} \times .05266 = $$

.00002

K. CM/SEC ~~9×10-7~~

1.0×10-6

PRESSURE TEST RESULTS (FIELD)

Page 2 of 2

Project: WSSRAP	Job Number:	Test Section: 50.0 to 65.0	Bore Hole: MW -4040

Test Equipment Identification	**BORE HOLE**		Test By: P. Patchin
	Orientation: VERTICAL	Size: 2.98"	Date: 5/
Packers On Casing [✓ Single]/Double Hydraulic/Inflatable	Groundwater Depth: ~~15.8'~~ 33.7' Ft.	Gauge Height Above Ground: 2.2 Ft.	Gravity Head: ~~18.0~~ 35.9 Ft.

TEST ~~1~~ 4 Inflow pressure (H_P) 30 psi × 2.31 = 69.3 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	42 .000	.003	.011	.013	.020	.022	.027	.032				<0.01 GPM CFM
Take Per Min.		.003	.008	.003	.007	.002	.005	.005				CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) – Head Losses (H_L)

105.2 FT. = 35.9 FT. + 69.3 FT. – negl. FT.

$$K = \frac{Q\,(gpm)}{H_T\,(ft) \times L\,(ft)} \times .011 \ln \frac{L\,(ft)}{r\,(ft)} = \frac{<.01}{105.2 \times 15} \times .05266 =$$

.00000

K, CM/SEC ~~10-7~~

3.3 X 10-7

TEST ~~2~~ 5 Inflow pressure (H_P) 20 psi × 2.31 = 46.2 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	2 .040	.043	.049	.053	.057	.062	.066					<0.01 GPM CFM
Take Per Min.		.003	.006	.004	.004	.005	.004					

H_T 82.1 FT. = H_G 35.9 FT. + H_P 46.2 FT. – H_L negl. FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln \frac{L}{r} = \frac{<.01}{82.1 \times 15} \times .05266 =$$

.00000

K, CM/SEC ~~10-8~~

4.3 X 10-7

TEST 3 Inflow pressure (H_P) ______ psi × 2.31 = ______ feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.												GPM CFM
Take Per Min.												

H_T ______ FT. = H_G ______ FT. + H_P ______ FT. – H_L ______ FT.

$$K = \frac{Q}{H_T \times L} \times .011 \ln \frac{L}{r} = \frac{\quad}{\quad \times \quad} \times \quad =$$

K, CM/SEC

PRESSURE TEST RESULTS (FIELD)

Project: GWOU-WSSRAP Busch

Job Number:

Test Section: 57.5 to 67.0

Bore Hole: MW-4041

Test Equipment Identification: Flow Meter - Master Meter press. Meter - Winters 1953

BORE HOLE

Orientation: vertical

Size: 2.98

Test By: A. Benfer

Date: 5-6-04

Packers
On Casing
[✓ Single]/Double
Hydraulic/[✓ Inflatable]

Groundwater Depth: ~~40~~ 40.3 Ft.

Gauge Height Above Ground: 1.6 Ft.

Gravity Head: 41.9 Ft.

Test 1
No Take
at 20 PSI
<1.0 x 10^-7

Begin
Test
1540

End Test
1425

TEST ~~1~~ 2 Inflow pressure (H_P) 40 psi × 2.31 = 92.4 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	360.7	360.8	360.9	361.0	361.1	361.2						0.1 GPM CFM
Take Per Min.		0.1	0.1	0.1	0.1	0.1						CFM × 7.48 – GPM

Total Head (H_T) = Gravity Head (H_G) + Pressure Head (H_P) − Head Losses (H_L)

134.3 FT. = 41.9 FT. + 92.4 FT. − negligible FT.

$$K = \frac{Q\ (gpm)}{H_T\ (ft) \times L\ (ft)} \times .011\ ln. \frac{L\ (ft)}{r\ (ft)} = \frac{0.1}{134.3 \times 9.5} \times .011\ LN \frac{9.5}{.125}\ (.04764) =$$

.00007

K, CM/SEC 3.7 x 10^-6

TEST ~~2~~ 3 Inflow pressure (H_P) 60 psi × 2.31 = 138.6 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	362.4	362.75	363.25	363.70	364.4	365.35	366.35	367.25	368.15	369.15	370.2	0.98 GPM CFM
Take Per Min.		0.35	0.50	0.45	0.70	0.95 ✓	1.0 ✓	0.90 ✓	0.90 ✓	1.0 ✓	1.05 ✓	

H_T 180.5 FT. = H_G 41.9 FT. + H_P 138.6 FT. − H_L negligible FT.

$$K = \frac{Q}{H_T \times L} \times .011\ ln. \frac{L}{r} = \frac{.98}{180.5 \times 9.5} \times .04764 =$$

.00057

K, CM/SEC 2.7 x 10^-5

TEST ~~3~~ 4 Inflow pressure (H_P) 40 psi × 2.31 = 92.4 feet

TIME, MIN.	0	1	2	3	4	5	6	7	8	9	10	Q AVERAGE FLOW
Meter Reading Gallons or Cu. Ft.	372.0	372.1	372.2	372.4	372.6	372.7	372.85	372.95				.14 GPM CFM
Take Per Min.		0.1	0.1	0.2	0.2	0.1	0.15	1.0				

TEST 5
No Take
at repeat
20 PSI
<1.0 x 10^-7

H_T 134.3 FT. = H_G 41.9 FT. + H_P 92.4 FT. − H_L negligible FT.

$$K = \frac{Q}{H_T \times L} \times .011\ ln. \frac{L}{r} = \frac{0.14}{134.3 \times 9.5} \times .04764 =$$

.00011

K, CM/SEC 5.2 x 10^-6

WELL DEVELOPMENT FORMS

WELDON SPRING SITE REMEDIAL ACTION PROJECT

MONITORING WELL DEVELOPMENT FORM

ES&H 4.4.8.2, Rev. 1, 7/96

ROJECT NAME WSSRAP WORK PACKAGE NO.

SHEET 1 OF 2

EVELOPED BY Roberts Environmental Drilling

1. Well Number.: MW-2056 Well Location: Frog Pond Area

2. Date of Installation: 5/14/04

3. Date of Development: 5/24/04 - 5/26/04

4. Static Water Level: Before Development 31.2 bgsuc ft.; At least 24 hrs. after 31.5 bgs ft.

5. Organic Vapor: Before development None ppm; After development none ppm.

5. Quantity of water loss during drilling, if used: ? gal.

7. Quantity of standing water in well and annulus before development: 14.0 gal.

. Depth from top of well casing to bottom of well: 85.9 ft. (from Well Installation Diagram)

. Well diameter: 2 in.

.0. Screen length: 10 ft.

.1. Minimum quantity of water to be removed: 42 gal.

.2. Depth to top of sediment: Before development — ft.; After development — ft.

3. Physical character of water (before/after development): ~~Cl~~ very Cloudy / very Clear

4. Type and size of well development equipment:

5. Description of surge technique: Surge screen with 2" grundfos pump two episodes Overpump and low flow pump

6. Height of well casing above ground surface: 2.8' ft. (from Well Installation Diagram).

7. Quantity of water removed: 45 gal. Time for removal: 3 hrs cumulative hr./min.

WELDON SPRING SITE REMEDIAL ACTION PROJECT

MONITORING WELL DEVELOPMENT FORM

ES&H 4.4.8.2, Rev. 1, 7/96

PROJECT NAME WSSRAP WORK PACKAGE NO. ______

SHEET 2 OF 2

DEVELOPED BY Roberts Environmental Drilling

Well Number: MW-2056 Well Locations: Frog Pond Area, NE of Cell

Date/ Time	Hrs. Dev./ Cum. Hrs. Dev.	Gals. Purged/ Cum. Gals. Purged	pH	Temp.	Cond.	Turb	Remarks
5/24/04	2 hrs	19 gAl 1st pump 7 gAl 2nd pump	No	parameters			Surge well w/ pump. Surge well w/ pump
5/25 9:35	10 / 2:10	3/19	6.85	16.2	.423	31.8	Slightly cldy
9:45	10m / 2:20	7/26	7.28	16.8	.514	26.2	V. slightly cldy water @75.2' Dry @ 12ga
13:20		1/27	7.72	16.9	.456	263	
13:25		1/28	7.72	16.8	.444	56.1	
13:30		1/29	7.52	17.0	.427	43.4	
13:35		1/30	7.40	17.7	.442	59.7	
13:38		1/31	7.38	17.0	.425	112	Dry
5/26 10:42		1/32	7.34	15.9	.451	148	
10:45		1/33	7.44	15.6	.423	33.2	
10:49		1/34	7.36	16.1	.416	15.7	
10:52		1/35	7.39	16.2	.412	8.2	clear
10:55		1/36	7.43	16.0	.413	6.4	clear
10:58		1/37	7.38	16.4	.414	5.7	
11:02		1/38	7.39	16.6	.416	5.8	
11:06		1/39	7.43	17.1	.421	6.9	water @69.6'
11:10		1/40	7.42	17.7	.434	11.1	
11:13		1/42	7.45	17.4	.458	17.5	
11:17		1/43	7.47	17.6	.518	33.9	
11:20		2/45 NO Sample			45 gal		

TOTAL

WELDON SPRING SITE REMEDIAL ACTION PROJECT

MONITORING WELL DEVELOPMENT FORM

ES&H 4.4.8.2, Rev. 1, 7/96

ROJECT NAME WSSRAP WORK PACKAGE NO.

SHEET 1 OF 2

EVELOPED BY Roberts Envioronmental

Well Number.: MW-3040 Well Location: N. Side of Cell

Date of Installation: 5/19/04

Date of Development: 5/24/04 - 25/26/04

Static Water Level: Before Development 60.04 BTOC ft.; At least 24 hrs. after 56.7 bgs ft.
(57.0 bgs.

Organic Vapor: Before development 0 ppm; After development 0 ppm.

Quantity of water loss during drilling, if used: ? gal.

Quantity of standing water in well and annulus before development: 12.4 gal.

Depth from top of well casing to bottom of well: 107.5' ft. (from Well Installation Diagram)

Well diameter: 2 IN in.

11

13 gal 1st pumping
5 gAl 2nd pumping
5.45 m
1/2 gal 3rd pumpm

10. Screen length: 10 ft.

11. Minimum quantity of water to be removed: 37 gal.

12. Depth to top of sediment: Before development N/A ft.; After development N/A ft.

3. Physical character of water (before/after development): very Cloudy / very Clear

4. Type and size of well development equipment:

5. Description of surge technique: Surge screen with 2" pump. (two episodes, overpump and low flow pump

6. Height of well casing above ground surface: 2.5' ft. (from Well Installation Diagram).

7. Quantity of water removed: 42 gal. Time for removal: ~4hr hr./min.

WELDON SPRING SITE REMEDIAL ACTION PROJECT

MONITORING WELL DEVELOPMENT FORM

ES&H 4.4.8.2, Rev. 1, 7/96

PROJECT NAME WSSRAP WORK PACKAGE NO. ____________

SHEET 2 OF 2

DEVELOPED BY Roberts Environmental

Well Number: MW-3040 Well Locations: N. side of cell

Date/ Time	Hrs. Dev./ Cum. Hrs. Dev.	Gals. Purged/ Cum. Gals. Purged	pH	Temp.	Cond.	Remarks	
5/24/04 12:30	pump 13 gal let recharge	19 / 19	No	parameters		Surged w/ pump then pumped 13 gal Surged again then 6 gal.	
5/25/04 10:21		5 / 24	7.56	16.7	1.54	Turb 63.5	
10:30		5 / 29 + 1	7.29	18.2	1.41	118	30 gal total
5/26/04 9:20		1 / 31	6.25	14.7	1.72	62.1	
9:28		1 / 32	6.85	14.6	1.555	18.7	Clear! 1/2 gal/m
9:35		1 / 33	7.09	14.8	1.48	8.7	
9:43		1 / 34	7.12	15.5	1.51	11.0	
9:50		1 / 35	7.17	16.0	1.50	?	
9:55		2 / 37	7.22	17.1	1.48	12.90	
10:00		1 / 38	7.30	16.8	1.51	9.73	Water @ 89.0'
10:08		2 / 40	7.22	18.4	1.53	21.7	
10:15		2 / 42	7.24	17.5	1.50	68.8*	→ turbidity due to near pump stirring
		↑ Development complete					

1

91.5
2.5
89.0

WELDON SPRING SITE REMEDIAL ACTION PROJECT

MONITORING WELL DEVELOPMENT FORM

ES&H 4.4.8.2, Rev. 1, 7/96

PROJECT NAME WSSRAP WORK PACKAGE NO.

SHEET 1 OF 2

DEVELOPED BY Roberts Environmental Drilling Inc.

1. Well Number.: MW-4040 Well Location: Army Property

2. Date of Installation: 5/20/04

3. Date of Development: 5/24/04 - 5/26/04

4. Static Water Level: Before Development 31.5 BTOC 29.3' Bgs ft.; At least 24 hrs. after 31.6 bgs ft.

5. Organic Vapor: Before development 5 ppm; After development 5 ppm.

6. Quantity of water loss during drilling, if used: ? gal.

7. Quantity of standing water in well and annulus before development: 10.5 gal.

8. Depth from top of well casing to bottom of well: 67.2' ft. (from Well Installation Diagram)

9. Well diameter: 2 in.

10. Screen length: 10 ft.

1st pump 7 gal
2nd pump 2 gal

11. Minimum quantity of water to be removed: 28 gal. ← parameters stable low turbidity

12. Depth to top of sediment: Before development N/A ft.; After development N/A ft.

13. Physical character of water (before/after development): very cloudy /

14. Type and size of well development equipment:

5. Description of surge technique: surge with 2" grundfos pump throughout length of screen then over pump

6. Height of well casing above ground surface: 2.2 ft. (from Well Installation Diagram).

7. Quantity of water removed: 28 gal. Time for removal: 2½ hr hr./min.

WELDON SPRING SITE REMEDIAL ACTION PROJECT

MONITORING WELL DEVELOPMENT FORM

ES&H 4.4.8.2, Rev. 1, 7/96

PROJECT NAME WSSRAP WORK PACKAGE NO.

SHEET 2 OF 2

DEVELOPED BY Roberts Environmental Drilling Inc

Well Number: MW-4040 Well Locations: Army Property near fence

Date/ Time	Hrs. Dev./ Cum. Hrs. Dev.	Gals. Purged/ Cum. Gals. Purged	pH	Temp.	Cond.	Turb	Remarks
5/24/04		9 gallons	no	parameters			Surging Well w/ pump (two episodes)
5/25/04 11:30	7.58	3/12	7.58	16.9	.955	136	Cloudy
5/25 11:42		3/15+3	7.55	17.8	.930	79	slightly Cloudy out of water @ 9gall
12:19		4/19	7.94	17.7	1.16	522	Cloudy out of water @ 19gal
5/26/04 12:42		1/20	7.31	15.1	1.26	Error	very tur
12:48		1/22	7.51	15.1	1.25	218	
12:52		1/23	7.45	15.1	1.21	31.1	
12:57		1/24	7.48	15.7	.967	15.7	
13:04		1/25	7.51	16.0	.948	10.9	
13:10		1/26	7.50	16.2	.930	34.9	
13:12		1/27	7.53	16.6	.920	23.0	
13:18		1/28	7.64	16.5	.939	44.7	water @ 6'

WELDON SPRING SITE REMEDIAL ACTION PROJECT

MONITORING WELL DEVELOPMENT FORM

ES&H 4.4.8.2, Rev. 1, 7/96

PROJECT NAME WSSRAP WORK PACKAGE NO.

SHEET 1 OF 2

DEVELOPED BY Roberts Environmental Drilling Inc

1. Well Number.: MW-4041 Well Location: Busch Wildlife Area.

2. Date of Installation: 5/17/04

3. Date of Development: 5/26/04

4. Static Water Level: Before Development 40.3 bgs ft.; At least 24 hrs. after 40.5 bgs. ft.

5. Organic Vapor: Before development None ppm; After development none ppm.

5. Quantity of water loss during drilling, if used: 7 gal.

7. Quantity of standing water in well and annulus before development: 10.6 gal.

. Depth from top of well casing to bottom of well: 60 ft. (from Well Installation Diagram)

. Well diameter: 2 in.

0. Screen length: 10 ft.

1. Minimum quantity of water to be removed: 32 gal.

2. Depth to top of sediment: Before development N/A ft.; After development N/A ft.

3. Physical character of water (before/after development): Extremely turbid / slightly cloudy

4. Type and size of well development equipment:

5. Description of surge technique: Surge with 2" Grudfos pump throughout screen length, over pump (high flow), low flow pump.

5. Height of well casing above ground surface: 2.0' ft. (from Well Installation Diagram).

7. Quantity of water removed: 174 gal. Time for removal: 2½ hr./min.

WELDON SPRING SITE REMEDIAL ACTION PROJECT

MONITORING WELL DEVELOPMENT FORM

ES&H 4.4.8.2, Rev. 1, 7/96

PROJECT NAME WSSRAP WORK PACKAGE NO.

SHEET 2 OF 2

DEVELOPED BY: Roberts Environmental Drilling

Well Number: MW-4041 Well Locations: Busch Wildlife

Date/ Time	Hrs. Dev./ Cum. Hrs. Dev.	Gals. Purged/ Cum. Gals. Purged	pH	Temp.	Cond.	Remarks
5/26 14:20						Surging well
14:30		5.10.15.20 25.30.35	.40.45	48 gal		New barrel @ 20 2½ gal/min to Dry
	OVER pumping.		50.55	.60	.65.70	.75.80.85.90.95
			100	.105	.110 (1½	gal/m.) 115.120
16:16		121/121	7.27	14.8	.454	>1000
16:19		4/125	7.24	14.6	.461	808
16:23		5/130	7.28	14.6	.462	471
16:27		5/135	7.25	14.6	.463	272
16:31		5/140	7.26	14.7	.463	173
16:36		5/145	7.31	14.6	.463	198 water staying @ 48.6 bgs slightly cldy
16:40		5/150	7.34	14.6	.464	138
16:44		5/155	7.27	14.6	.463	107
16:49		5/160	7.35	14.7	.463	93.7
16:53		5/165	7.35	14.6	.463	94.0
~~16~~17:00		5/170	7.38	14.9	.463	49.5
17:01		1/171	7.36	14.9	.463	58.4 SLIGHTLY CLOUDY
17:04	11	1/172	7.32	15.1	.463	59.9
17:06		1/173	7.38	15.3	.463	64.4
17:08		1/174	7.28	15.3	.463	41.0

^ TOTAL pumped.

Appendix C

Chronology of Events

The following is a chronology of the Groundwater Operable Unit of the Weldon Spring Site Remedial Action Project.

Table C−1. Groundwater Operable Unit Chronology of Events

Event	Date
DOE designates the Weldon Spring Site Remedial Action Project as a major project	01-Jan-85
The Project Management Contractor (PMC) is selected	01-Feb-86
DOE and PMC establish a Site Office	01-Jul-86
PMC assumes site control	01-Oct-86
Weldon Spring Quarry placed on the NPL	22-Jul-87
WSSRAP designated as a Major Systems Acquisition	01-May-88
Remedial Investigation for the GWOU issued	01-Jul-97
Baseline Risk Assessment for the GWOU issued	01-Jul-97
Feasibility Study for Remedial Action for the GWOU issued	10-Mar-99
Pilot-Scale Pump and Treat Study	Jul-98
Proposed Plan for Remedial Action at the GWOU issued	21-May-99
Interim ROD for the GWOU finalized	29-Sep-00
Additional Groundwater Field Studies began	09-Mar-01
Additional Groundwater Field Studies completed	13-Nov-010
Pilot-Scale ICO Treatment began	26-Mar-02
Pilot-Scale ICO Treatment completed	08-Jul-02
Support Evaluation for the Proposed Plan for Final GWOU Remedial Action issued	01-Aug-03
Proposed Plan for Final Remedial Action at the GWOU issued	01-Aug-03
Record of Decision for Final Remedial Action at the GWOU finalized	24-Feb-04
Installation of GWOU MNA monitoring wells began	26-Apr-04
Installation of GWOU MNA monitoring wells completed	20-May-04
GWOU Pre-final Inspection	20-Jul-04
Remedial Design/Remedial Action Work Plan for the GWOU issued	29-Jul-04

End of current text

Appendix D

Quality Control

D.1 Construction Quality Assurance/Quality Control

All construction activities were performed under an established quality program. For activities performed prior to 2004, the project management contractor (PMC) established the *Project Management Contractor Quality Assurance Program Plan* (QAP) (MKF and JEG 1992). The QAP was reviewed annually and revised as necessary to comply with the current DOE orders and contract requirements. The *Quality Assurance Program* satisfied the requirements of DOE Order 414.1A – *Quality Assurance*, which superseded DOE Order 5700.6A, Title 10 *Code of Federal Regulations* Part 830.120 – *Quality Assurance,* and associated reference documents identified in the QAP.

For construction activities performed after 2004, the technical assistance contractor (TAC), as obligated by DOE Order 414.1A, has developed a quality assurance program as documented in the *Quality Assurance Manual* (STO 1). This manual includes requirements for organization, personnel training, quality improvement, documents and records, work processes, design, procurement, inspection and acceptance testing, and a routine assessment program.

D.1.1 Environmental Quality Assurance/Control

D.1.1.1 Characterization and Environmental Monitoring Activities

For sampling activities performed prior to October 2003, environmental compliance issues were addressed in the *Environmental Quality Assurance Project Plan* (EQAPjP) (MKF and JEG 2000), which was developed by the PMC. The EQAPjP focused on the EPA requirements under CERCLA and met the applicable requirements of EPA QA/R-5, *EPA Requirements for Quality Assurance Project Plans for Environmental Operations*. The document primarily specified the quality assurance requirements for WSSRAP environmental data operations and supports the PMC Quality Assurance Program. The environmental data operations referred to activities involving the acquisition, analysis, and evaluation of environmental data that included all work performed to obtain, use, or report information pertaining to environmental processes and conditions. The *Sample Management Guide* (MKF and JEG 1997), PMC standard operating procedures (SOPs), departmental instructions, the WSSRAP health and safety program, and work plans written for specific environmental tasks, supported the EQAPjP.

Subcontracted off-site laboratories that performed analysis used Contract Laboratory Program (CLP) methodologies when applicable. Each of the subcontracted off-site laboratories was required to submit a site-specific Quality Assurance Project Plan (QAPjP) and controlled copies of their standard operating procedures (SOPs). The QAPjPs and SOPs were reviewed and approved by the PMC before any samples were shipped to the laboratory. Changes to the standard analytical protocols or methodology are documented in the controlled SOPs. Quality assurance assessments were performed routinely to inspect the laboratory facilities and operations to ensure that the laboratories were performing analyses as specified in their contracts, and to check that WSSRAP data documentation and records were being properly maintained.

Data verification was performed on all analytical data received from laboratories performing analysis on environmental, waste management, health physics, and geochemical samples in accordance with WSSRAP procedure. Data verification included non-analytical processing and review of analytical laboratory data and associated documentation to ensure that samples were collected, shipped, maintained, and analyzed in accordance with established data quality requirements and standard operating procedures.

Data validation was performed on analytical data received from laboratories performing analysis for the site as required under DOE Order 5400.1 in accordance with WSSRAP procedure. At a minimum, the WSSRAP Data Validation Group determined the analytical accuracy, precision, and completeness of 10 percent of the environmental data collected. The data validation review was performed by using analysis-specific checklists, which followed EPA Functional Guidelines for Inorganics and Organics, and SAIC Guidelines for Radionuclides.

D.1.1.2 Long-Term Monitoring Activities

Beginning in October 2003, monitoring activities were managed by S.M. Stoller Inc. (Stoller). Sampling, analysis, and data management are performed in accordance with the *Sampling and Analysis Plan for GJO Projects* (DOE 2002). This plan incorporates DOE-GJO SOPs into groundwater and surface-water sampling activities. This document provides detailed procedures to ensure samples are collected in a consistent and technically sound manner.

DOE Grand Junction SOPs are contained in the *Environmental Procedures Catalog*, (STO 6) (DOE continually updated), which incorporates DOE and EPA guidance. The procedures in the *Environmental Procedures Catalog* are intended as general guidance and require additional detail from project planning documents in order to be complete. Sampling for the GWOU is performed as outlined in the LTS&M Plan for the WSSRAP.

All samples are analyzed by approved sub-contracted laboratories. Quality control is performed in accordance with the *Analytical Chemistry Laboratory Administrative Plan and Quality Control Procedures*. This manual defines the non-technical policies and procedures necessary to ensure the laboratory will provide high quality analytical data and maintain customer confidentiality. It provides a framework for performing, controlling, documenting, and reporting analyses and related laboratory activities. Analytical methods used for groundwater and surface water analyses are detailed in *Analytical Chemistry Laboratory Handbook of Analytical and Sample-Preparation Procedures*. This manual contains detailed procedures used for each analytical method and includes specific requirements for reagents and standards, detection limits, quality control, calculations, and data reporting. In addition, interferences associated with each analytical method are listed in each section.

Environmental data management activities performed for the Weldon Spring Site are detailed in the *Sampling and Analysis Plan for GJO Projects*. This plan directs data management activities, and data validation requirements. This plan and the associated data validation requirements have been adopted for the monitoring program at the Weldon Spring Site. The primary activities associated with data management and data quality are field documentation, sample management, data validation, data review, and database maintenance. These programs ensure that analytical data generated by laboratories for samples collected at the Weldon Spring Site are reviewed and qualified prior to release for general usage.

Data validation is the process of reviewing the sampling documentation and analytical data to ensure that adequate documentation was maintained and that results are qualified in compliance with established reporting requirements. Data generated during sampling activities and by analytical laboratories for the Weldon Spring Site monitoring programs are validated.

The validation process consists of reviewing data for transcription errors, reviewing sampling documentation and chain-of-custody documentation, and comparing actual holding times to the method specified holding times. During validation, personnel determine whether the laboratory records document the established quality control criteria for the analytical methodology utilized at the laboratory. This is to ensure the analytical procedures were followed, quality control samples are within their respective acceptance limits, and that adequate documentation is available to support the validity of the data.

Also, during the validation process, the data are reviewed and qualified by the data reviewer for comparability with historical results and for statistical and compliance evaluations.

Upon completion of data validation, data are flagged with appropriate final data qualifiers and are then available for general use. All databases containing final validated data are backed up regularly. To maintain the integrity of the computer files, access to edit the database is extensively restricted.

D.1.3 References

MK-Ferguson Company and Jacobs Engineering Group (MKF and JEG), 1992. *Project Management Contractor Quality Assurance Program Plan*, Rev. 0, DOE/OR/21548-333, prepared for the U.S. Department of Energy, Oak Ridge Operations Office, St. Charles, Missouri, September.

———, 1997. *Sample Management Guide*, Rev. 1, DOE/OR/21548-499, prepared for the U.S. Department of Energy, Oak Ridge Operations Office, St. Charles, Missouri, August.

———, 2000. *Environmental Quality Assurance Project Plan*, Rev. 5, DOE/OR/21548-352, prepared for the U.S. Department of Energy, Oak Ridge Operations Office, St. Charles, Missouri, November.

STO 1. *Quality Assurance Manual*, prepared by S.M. Stoller Corp, Grand Junction, Colorado, for the U.S. Department of Energy, Office of Legacy Management, Grand Junction, Colorado, continually updated.

STO 6. *Environmental Procedures Catalog*, prepared by S.M. Stoller Corp, Grand Junction, Colorado, for the U.S. Department of Energy, Office of Legacy Management, Grand Junction, Colorado, continually updated.

U.S. Department of Energy, 2002. *Sampling and Analysis Plan for GJO Projects*, GJO-20030402-TAC, prepared by U.S. Department of Energy, Grand Junction Office, Grand Junction, Colorado, December.

U.S. Environmental Protection Agency, *Requirements for Quality Assurance Project Plans for Environmental Operations*, EPA QA/R-5, Washington, D.C.

End of current text

Appendix E

Health and Safety

E.1 Health and Safety

Health and safety requirements and procedures for all field activities were consistent with DOE orders, regulations, codes, and standards. Environmental Management activities were specified in the *Weldon Spring Site Remedial Action Project Health and Safety Plan* (MKF and JEG 2001) and LTS&M program activities are conducted in accordance with the *Weldon Spring Site Project Safety Plan* (DOE 2003). These documents were an integral component of the contract documents for every subcontract package at the Weldon Spring Site Remedial Action Project (WSSRAP). These documents included information and requirements on the following topics:

- Contaminant and hazard description
- Work practices and engineering controls
- Personal protective equipment
- Monitoring for radiological and industrial hygiene related hazards
- Construction and industrial safety
- Medical surveillance
- Training and qualifications
- Site access control and security
- Decontamination
- Emergency response

Overall adherence to health and safety requirements at the WSSRAP was excellent. The WSSRAP employed an extensive staff of field-oriented health and safety professionals to help identify hazards and prescribe appropriate controls for all field activities. This staff routinely monitored all daily work activities to ensure compliance. However, one of the most effective means of ensuring health and safety requirements implementation was the Time Out for Safety Program. This program allowed and encouraged anyone to stop any work activity that they felt was not being performed in a safe manner. Once a Time Out was taken, employees from all appropriate entities got together to evaluate the situation and make any necessary changes to ensure the work would be performed safely. Workers were recognized in a positive manner and rewarded for taking Time Outs. This resulted in extensive worker buy-in to the health and safety program.

The WSSRAP was formally recognized in outstanding safety and health performance by becoming the first DOE hazardous waste remediation site to receive DOE Voluntary Protection Program (DOE-VPP) Gold Star. The DOE-VPP provides public recognition to sites whose health and safety programs go beyond DOE and OSHA standards to protect workers more effectively. The Gold Star is the highest available award in the DOE-VPP.

E.1.1 References

MK-Ferguson Company and Jacobs Engineering Group, 2001. *Weldon Spring Site Remedial Action Project Health and Safety Plan,* Rev. 7, DOE/OR/21548-511, prepared for the U.S. Department of Energy, Oak Ridge Operations Office, St. Charles, Missouri.

U.S. Department of Energy, 2003. *Weldon Spring Site Project Safety Plan*, GJO-2003-442-TAC, prepared by S.M. Stoller Corp, Grand Junction, Colorado, for the U.S. Department of Energy, Office of Legacy Management, Grand Junction, Colorado, April.

Appendix F

Operable Unit Contact Information

F.1 Operable Unit Contact Information

Agency or Organization	Contact Information
Department of Energy	U.S. Department of Energy Weldon Spring Site Remedial Action Project Thomas Pauling, Weldon Spring Site Manager 2597 B ¾ Road Grand Junction, CO 81503 Phone Number: (970) 248-6048
Technical Assistance Contractor (TAC) Legacy Management – Post-January 2003 Contract number is DE-AC01-02GJ79491	S.M. Stoller, Inc. Sam Marutzky, Weldon Spring Project Manager 2597 B ¾ Road Grand Junction, CO 81503 Phone Number: (970) 248-6059 S.M. Stoller, Inc – Weldon Spring Site Office Yvonne Deyo, Site Manager 7295 Highway 94 South St. Charles, MO 63304 Phone Number: (636) 300-0012
Project Management Contractor (PMC) Environmental Restoration – Pre-January 2003 contract number was DE-AC05-86OR21548	Washington Group International Robert Cooney 720 Park Blvd. Boise, ID 83712 Phone Number: (208) 386-5000 Jacobs Engineering Group Jim Meier, Jacobs Weldon Spring Site Representative 1111 South Arroyo Parkway Pasadena, CA 91105 Phone Number: (626) 578-3500
Technical Support Contractor	Argonne National Laboratory Mary Picel, Project Manager 9700 South Cass Avenue Argonne, IL 60439 Phone Number: (630) 252-7669
Environmental Protection Agency, Region VII	Daniel Wall, Remedial Project Manager U.S. EPA, Region VII 726 Minnesota Avenue Kansas City, KS 66101 Phone Number: (913) 551-7710
Missouri Department of Natural Resources Federal Facilities Program	Larry Erickson Hazardous Waste Management Program P.O. Box 176 Jefferson City, MO 65102 Phone Number: (573) 751-3907

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