LOST CREEK HYDROLOGIC TESTING – MINE UNIT 1 NORTH AND SOUTH TESTS

10758 West Centennial Road, Suite 200
Littleton, Colorado 80127 USA

LOST CREEK PROJECT, SWEETWATER COUNTY, WY

OCTOBER 2009

(Revised November 2010)

Prepared By:
Petrotek Engineering Corporation
10288 West Chatfield Ave., Suite 201
Littleton, Colorado 80127
Phone: (303) 290-9414
Fax: (303) 290-9580

TABLE OF CONTENTS

Tables

Figures

Figures

Appendices

EXECUTIVE SUMMARY

- ☐ Lost Creek ISR, LLC (LC ISR) plans to develop and extract uranium from in-situ recovery (ISR) mine units within the HJ Horizon of the Battle Spring Formation located at the Lost Creek Project Area (LCPA). To support State and Federal permit applications necessary for the project, LC ISR has completed the Mine Unit 1 (MU1) pump tests from pumping wells located north and south of the Lost Creek Fault, within MU1. Both pump tests targeted the primary Production Zone (HJ Horizon) aquifer and supplement two previous smaller-scale pump tests conducted within the HJ Horizon.

- ☐ Pump testing performed in the HJ Horizon north of the fault has demonstrated hydraulic communication between the HJ Horizon pumping well and the surrounding HJ monitor wells; likewise, pump testing conducted in the HJ Horizon south of the fault has demonstrated hydraulic communication between the HJ Horizon and surrounding HJ monitor wells.

- ☐ Testing has confirmed that the Lost Creek Fault is a partial barrier to groundwater flow within the HJ Horizon. During both tests, responses observed in the HJ Horizon on the opposite side of the fault were an order of magnitude lower than those observed on the pumping well side.

- ☐ The observed response during the north test at well MU-108 (24.7 feet of drawdown, completed in the underlying UKM Sand) was due to damage to the casing and annular seal during well completion. This well was subsequently plugged and abandoned. LC ISR conducted additional hydrologic testing during June 2009 to confirm the successful abandonment and hydraulic isolation at this location between the HJ Horizon and the underlying UKM Sand by pumping from the UKM Sand and monitoring the aquifer response in the HJ at well MP-108 (located approximately 15 feet adjacent to MU-108), where water levels were not observed to vary in response to the pumping.

- ☐ Geologic data indicate that the overlying and underlying confining shale units are continuous throughout the permit area. Testing results indicate adequate vertical confinement of the HJ Horizon and successful abandonment of well MU-108.

- ☐ Responses in the overlying and underlying aquifers were minor and an order of magnitude lower than responses observed in the HJ Horizon. Additional evaluation as to the cause of the responses is being conducted. LC ISR is pursuing the proper plugging and abandonment of historic wells to mitigate the potential for communication through improperly abandoned wells.

- ☐ Based on testing results to date, it is anticipated that the minor communication between the HJ Horizon and the overlying and underlying sands can be managed through operational practices, detailed monitoring, and engineering operations.

- ☐ The pump test results provide sufficient aquifer characterization of the HJ Horizon such that mining can proceed after the appropriate Nuclear Regulatory Commission (NRC) license and Wyoming Land Quality Division (LQD) permit are issued, and demonstrate that the HJ Horizon has sufficient transmissivity for ISR operations.

1.0 INTRODUCTION

1.1 BACKGROUND

The Lost Creek Project Area (LCPA) is located in the northeastern portion of the Great Divide Basin of Wyoming, within Sweetwater County (Figure 1-1). LC ISR plans to develop and extract uranium from ISR mine units within the HJ Horizon of the Battle Spring Formation. This report provides a summary of the mine-unit scale hydrogeologic testing conducted in the HJ Horizon during November and December 2008 to support State and Federal permit applications necessary for the project. Pump tests were conducted at separate locations north and south of the Lost Creek Fault (referenced as “fault” within this report), identified within the proposed MU1. The pump test on the north side of the fault (“north test”) was conducted at pumping well PW-102, and the test on the south side of the fault (“south test”) was conducted at pumping well PW-101.

The LCPA is located in all or parts of Sections 13, 24, and 25 of T25N, R93W, and Sections 16 through 20, and 29 through 31 of T25N, R92W. Figure 1-1 shows the LCPA and its relationship to the Great Divide Basin. Figures 1-2 and 1-3 present the location of the pumping wells and monitor wells used for the north and south pump tests, respectively.

There are no active ISR operations within ten miles of the LCPA. Areva’s Christensen Ranch and Cameco Resources’ Smith Ranch-Highland uranium project are located approximately 150 miles to the northeast and east, respectively. The primary Production Zone at Lost Creek is the HJ Horizon that occurs between depths of 300 and 450 feet below ground surface, although the ore bearing sand is typically found in the middle portion of the HJ horizon.

In the LCPA, water is beneficially used for livestock watering as well as for purposes related to mining (monitoring, test wells, dewatering, industrial, stock, reservoir supply, and miscellaneous use). Currently, water is not used for domestic or irrigation purposes within two miles of the LCPA.

1.2 REGULATORY REQUIREMENTS

The objectives of mine-unit scale pumping tests, as stated in the Wyoming Department of Environmental Quality/Land Quality Division (WDEQ/LQD) Chapter 11 (and associated guidelines) and Nuclear Regulatory Commission (NRC) NUREG 1569 (Section 2.7; Hydrology), are to:

1. Determine the hydrologic characteristics of the Production Zone Aquifer;
2. Demonstrate hydrologic communication between the Production Zone pumping well and the surrounding Production Zone monitor wells;
3. Assess the presence of hydrologic boundaries, if any, within the Production Zone Aquifer over the area evaluated by the Pump Test; and,

4. Evaluate the degree of hydrologic communication, if any, between the Production Zone and the overlying and underlying aquifers in the vicinity of the pumping well.

The testing procedures and results are presented and discussed in this report. Two pump tests were conducted because of the presence of a fault (Lost Creek Fault) that bisects MU1 (Figures 1-2 and 1-3). Results from previous aquifer testing conducted on a smaller scale at the site within the HJ Horizon Production Zone Aquifer (Petrotek 2007a, Petrotek 2007b) indicated that the fault acts as a hydraulic barrier to groundwater flow in the production zone aquifer.

1.3 PURPOSE AND OBJECTIVES

The purpose of this report is to demonstrate that the recently completed hydrologic tests meet the requirements and objectives of WDEQ and NRC as previously stated. This report demonstrates that the HJ Horizon on both sides of the identified fault within MU1 has been sufficiently evaluated with respect to hydrogeologic conditions and is suitable for ISR mining.

The objective of this report is to present the information required by WDEQ/LQD and NRC NUREG 1569 (Section 2.7; Hydrology) for a Hydrologic Test Report. In accordance with these regulations the following information is included or referenced:

- A description and maps of the proposed permit area;
- Geological cross-sections, including data from monitor wells and test holes;
- Isopach maps of the Production Zone, Overlying Confining Unit, and Underlying Confining Unit;
- Well completion reports;
- A description of hydrologic testing;
- Discussion of the hydrologic test results including raw pump test data, type curve matches, potentiometric surface maps, water level graphs, drawdown maps, and other hydrologic data with interpretation and conclusions, as appropriate; and,
- Verification, based on the test data, that: (1) the monitor wells completed within the Production Zone are in communication with the pumping well; and (2) there is adequate confinement between the HJ Horizon Production Zone and the overlying (LFG Sand) and underlying (UKM Sand) aquifers, and (3) the Lost Creek Fault acts as a hydraulic barrier.

1.4 REPORT ORGANIZATION

The results of the MU1 pump tests conducted on both sides of the fault are included within this report. This report includes nine sections, summarized below:

1.0 Introduction
2.0 Site Characterization
3.0 Monitor Well Locations, Installation, and Completion
4.0 Pump Test Design and Procedures
5.0 Barometric Pressure Correlations and Corrections
6.0 Test Results
7.0 Analytical Methods and Results
8.0 Summary and Conclusions
9.0 References

Field activities for the Lost Creek Pump Test were jointly performed by LC ISR and Petrotek Engineering Corporation (Petrotek) personnel. Geologic interpretations were performed by LC ISR geologists. Aquifer test analyses were performed by Petrotek, and the summary report was written by Petrotek.

2.0 SITE CHARACTERIZATION

2.1 HYDROSTRATIGRAPHY

The LCPA is underlain by the upper portion of the Battle Spring Formation. The total thickness of the Battle Spring Formation is approximately 6,000 ft. The Battle Spring Formation unconformably overlies the Fort Union Formation. LC ISR utilizes the following nomenclature for the hydrostratigraphic units of interest within the Battle Spring Formation. The primary Production Zone is identified as the HJ Horizon. The HJ Horizon is subdivided into the Upper (UHJ), Middle (MHJ), and Lower (LHJ) Sands. The HJ Horizon is bounded above and below by areally extensive confining units identified as the Lost Creek Shale and the Sagebrush Shale, respectively. Overlying the Lost Creek Shale is the FG Horizon, the overlying aquifer to the HJ Production Zone (HJ Horizon). The FG Horizon consists of an upper and lower sand sequence that are hydrostratigraphically connected. The deepest sand in the FG Horizon is designated as the Lower FG (LFG) Sand and is the interval in which all overlying monitor wells are completed. Beneath the Sagebrush Shale is the KM Horizon, the underlying aquifer to the HJ Horizon. Similar to the HJ Horizon, the KM Horizon consists of upper, middle, and lower sand intervals that are hydrostratigraphically connected. The uppermost sand within the KM Horizon is designated the Upper KM (UKM) Sand and is the interval in which all of the underlying monitor wells were completed, with the exception of UKMU-103 (Middle KM [MKM] Sand completion). The shallowest occurrence of groundwater within the LCPA occurs within the DE Horizon, which is above the FG Horizon. Figure 2-1 depicts the hydrostratigraphic relationship of these units.

Thickness (isopach) maps of the overlying shale (Lost Creek Shale), the Production Zone Aquifer (HJ Horizon), and the underlying shale (Sagebrush Shale) were created utilizing geologic data provided by LC ISR, and are presented on Figures 2-2, 2-3, and 2-4, respectively. A structure map of the formation top of the HJ Horizon is presented on Figure 2-5.

Multiple cross-sections were also constructed from available geologic data. The cross-section locations are shown on Figure 2-6. North-south cross sections are presented in Figures 2-7 through 2-9, and west-east cross sections are presented in Figures 2-10 and 2-11.

2.2 OVERLYING UNITS: LFG SAND AND LOST CREEK SHALE

The overlying aquifer designated for the pump tests is the LFG Sand, the lowermost portion of the FG Horizon. The LFG Sand is continuous throughout the LCPA and ranges from 20 to 50 feet thick. The Lost Creek Shale is the confining layer that separates the overlying LFG Sand and Production Zone HJ Horizon. The Lost Creek Shale is continuous throughout MU1, and ranges from 4 to 40 feet thick, with typical thickness of 10 to 25 feet (Figure 2-2). Additional description of the LFG Sand can be found in Appendix D6 - Lost Creek Project – WDEQ Permit to Mine Application (LC ISR, 2007).

The DE Sand overlies the LFG sand, separated by an unnamed shale unit (Figure 2-1). Several observation wells were monitored during testing and the results are reported to supplement the majority of data recorded in wells screened to the immediately overlying sand (LFG).

2.3 PRODUCTION ZONE: HJ HORIZON

The Production Zone aquifer is designated as the HJ Horizon. The HJ Horizon is continuous throughout the proposed MU1 with a total thickness ranging from 100 to 151 feet, and averages approximately 120 feet (Figure 2-3). As mentioned above, the majority of mineralization within the HJ Horizon occurs in the middle portion (MHJ). For purposes of this report and because no laterally extensive confining units have been observed between the UHJ, MHJ and LHJ Sands, discussions and analyses presented herein will focus on the HJ Horizon as a single hydrostratigraphic unit. Additional description of the HJ Horizon can be found in Appendix D6 - Lost Creek Project - WDEQ Permit to Mine Application (LC ISR, 2007).

2.4 UNDERLYING UNITS: SAGEBRUSH SHALE AND UKM SAND

The underlying aquifer is designated as the UKM Sand, a member of the KM Horizon. The total thickness of the UKM Sand is typically 30 to 60 feet and is continuous throughout MU1. The Sagebrush Shale is the confining layer that separates the underlying UKM Sand and the Production Zone HJ Horizon. The Sagebrush Shale is continuous throughout MU1 and ranges from 5 to 38 feet thick, as seen in Figure 2-4. Additional description of the UKM Sand and Sagebrush Shale can be found in Appendix D6 - Lost Creek Project - WDEQ Permit to Mine Application (LC ISR, 2007).

2.5 STRUCTURE

In the LCPA, the Battle Spring Formation dips to the west at a rate of approximately three degrees. The Lost Creek Fault zone extends the length of the MU1 from the west-southwest to the east-northeast. The main fault bisects MU1 and is downthrown to the south. Displacement across the fault ranges from approximately 30 to 50 feet on the western end to approximately 80 feet on the eastern end (see Figures 2-5, 2-7, 2-8, and 2-9). There is also a fault splay to the south of the main Lost Creek Fault that intersects the main fault near the center of MU1. The fault splay generally trends to the east, subparallel to the main fault. The splay is upthrown to the south creating a downthrown fault block between the splay and the Lost creek Fault (Figure 2-5). Displacement associated with the splay is approximately 14 feet in the western portion of the splay (Figure 2-8) and increases to approximately 28 feet farther to the east (Figure 2-9).

In previous pump test reports, LC ISR postulated that the Lost Creek Fault was a “scissor fault”, with essentially no displacement near the center of MU1 at the hinge of the fault. Based on additional review of available geologic information of historic and newly installed borings, LC ISR personnel concluded that displacement increases from west to east.

The degree of hydraulic connection between hydrostratigraphic units across the fault is of interest with respect to ISR operations. As described above, the maximum observed displacement across the fault is approximately 80 feet. The thickness of the HJ Horizon averages about 120 feet thick throughout MU1. This indicates that the HJ Horizon should have sand to sand contact across the fault everywhere within MU1. However, water level elevation data and previous pump test results indicate that hydraulic communication across the fault is limited and that groundwater flow within the HJ Horizon is impeded (i.e., the fault acts as a low permeability barrier to flow).

2.6 PREVIOUS TESTING

Several historic pumping tests were conducted on the Lost Creek project in 1982 and 2006 to assess hydraulic characteristics of the Production Zone as well as overlying and underlying hydrostratigraphic units. Historic testing was performed by Hydro-Search Inc. (1982) and Hydro-Engineering, Inc. (2007). A pump test was conducted by LC ISR in the HJ Horizon north of the fault (pumping well LC19M) in June and July 2007 (Petrotek 2007a). A summary of these tests is presented in Appendix D6 of the Lost Creek WDEQ Permit to Mine (LC ISR, 2007). A second pump test was conducted by LC ISR in the HJ Horizon south of the fault (pumping well LC16M) in October and November 2007 (Petrotek 2007b).

The following discussion briefly summarizes the results of two previous regional pump tests conducted within MU1 at LCPA:

- **Regional Test #1 (June – July 2007)** – Pumping was conducted on the north side of the fault in the HJ Horizon (pumping well LC19M) for a period of 5.73 days, at an average rate of 42.9 gallons per minute (gpm). Calculated transmissivities ranged from 30 to 76 ft^2/day, with an average transmissivity of 61 ft^2/day. Calculated storativities ranged from 6.6×10^{-5} to 1.5×10^{-4}, with an average storativity of 1.1×10^{-4}.

- **Regional Test #2 (October – November 2007)** – Pumping was conducted on the south side of the fault in the HJ Horizon (pumping well LC16M) for a period of 5.5 days, at an average rate of 37.4 gpm. Calculated transmissivities ranged from 57 to 110 ft^2/day, with an average transmissivity value of 76 ft^2/day. Calculated storativities ranged from 3.5×10^{-5} to 9.1×10^{-4}, with an average storativity of 2.9×10^{-4}.

3.0 MONITOR WELL LOCATIONS, INSTALLATION, AND COMPLETION

3.1 WELL LOCATIONS

All of the pumping and observation wells monitored during pump testing are located in the proposed MU1 of the LCPA. The monitor wells included in the north and south pump tests are shown on Figures 1-2 and 1-3, respectively. Surveyed locations of all wells and test holes presented in this report are based on the NAD 83 Wyoming State Plane West Central Coordinate System.

3.2 WELL INSTALLATION AND COMPLETION

All of the wells used for this test are located in Sections 17, 18, 19 and 20, Township 25 North, Range 92 West (Figures 1-2 and 1-3), and were constructed with 4.5-inch nominal diameter casing. The wells were developed using standard water well construction techniques, including air lifting, pumping, swabbing, and/or surging. Completion information for each well is provided in Appendix A. Specific data related to well location, completion interval, and initial water levels are provided in Table 3-1.

3.2.1 NORTH TEST, PUMPING WELL PW-102

For the pump test conducted on the north side of the Fault, LC ISR monitored 99 wells (Figure 1-2), including 44 Production Zone (HJ Horizon) monitor wells, 25 Overlying (LFG Sand) monitor wells, 26 Underlying (UKM Sand and one well completed in the MKM) monitor wells, 3 monitor wells in the uppermost DE Horizon, and PW-102 (pumping well completed in the HJ Horizon).

3.2.2 SOUTH TEST, PUMPING WELL PW-101

For the pump test conducted on the south side of the Fault, LC ISR monitored 101 wells (Figure 1-3), including 48 Production Zone (HJ Horizon) monitor wells, 25 Overlying (LFG Sand) monitor wells, 25 Underlying (UKM Sand) monitor wells, 2 monitor wells in the uppermost DE Horizon, and PW-101 (pumping well completed in the HJ Horizon).

4.0 PUMP TEST DESIGN AND PROCEDURES

The following section details pump test design and procedures for the MU1 pump tests conducted at pumping wells PW-102 (north test) and PW-101 (south test). Pumping was conducted for the north test during November 18 – 20, 2008. Pumping was conducted for the south test during December 9 – 12, 2008. Details of pump testing at both locations are summarized separately below.

4.1 TEST DESIGN

The two MU1 tests are the first mine-unit scale hydrologic tests conducted in the LCPA. These tests were conducted in the HJ Horizon on both sides of the Lost Creek Fault and designed to:

1. Demonstrate hydrologic communication between the Production Zone pumping well and the surrounding Production Zone monitor wells;
2. Assess the hydrologic characteristics of the Production Zone aquifer within the test area;
3. Evaluate the presence or absence of hydrologic boundaries in the Production Zone within the LCPA; and
4. Demonstrate sufficient confinement between the Production Zone and the Overlying and Underlying aquifers for the purposes of ISR mining.

The general testing procedures were as follows:

1. Install In-Situ Level TROLL® data-logging transducers (vented) in wells to record changes in water levels during tests. Verify setting depths and head readings with manual water level measurements;
2. Measure and record background water levels and barometric pressure for a minimum of 96 hours prior to the test;
3. Run the pumping well at a constant rate (or as close as practical); and
4. Record water levels and barometric pressure throughout background, pumping, and recovery periods.

4.2 PUMP TEST EQUIPMENT

4.2.1 NORTH TEST, PUMPING WELL PW-102

Aquifer testing was performed utilizing a Grundfos 85S100-9, 10 hp, 460V, 3-phase electrical submersible pump powered by a portable diesel generator. At pumping well PW-102, the pump was set at a depth of 345 feet (approximately 122 feet off the bottom). The static depth to water in PW-102 was approximately 171 feet, providing for approximately 175 feet of head above the pump. Flow from the pump was controlled with a manual gate valve. Surface flow monitoring equipment included two 1.5” turbine meters (Turbines Incorporated FW Series, provided by LC ISR) that display total flow (in gallons) and instantaneous flow rates (in gallons per minute [gpm]). Per discussions with WDEQ/WQD, no Temporary Discharge Permit was required. Discharge water was land applied approximately 350 feet downgradient from PW-102 via a 3” HDPE line.

Water levels in 53 wells (including the pumping well, 28 HJ Horizon observation wells, and 24 wells in the overlying and underlying aquifers) were measured and recorded with In-Situ Level TROLL® pressure transducer dataloggers. The pressure rating for the transducers ranged from 15 to 100 psi, and they were programmed to record depth to water at 5 minute intervals at all pumping and observation wells (during background monitoring, and the pumping and recovery periods). A detailed summary of the monitoring equipment used is presented in Table 4-1.

In addition to the wells continuously monitored using the Level TROLLS®, numerous other wells were periodically measured for depth to water using a manual electronic water level meter. This allowed for a more extensive assessment of the potentiometric surface before, during, and after the pump test. A list of wells that were included in the hand measurement rounds is provided in Table 4-1.

The following is an interval-specific summary of water level monitoring locations recorded during testing at PW-102:

- HJ Horizon – 29 wells (including the pumping well) were monitored by dataloggers; 16 wells were periodically measured by e-line.
- Overlying LFG Sand – 12 wells were monitored by dataloggers; 13 wells were periodically measured by e-line.
- Underlying UKM Sand – 12 wells were monitored by dataloggers; 14 wells were periodically measured by e-line.
- Overlying DE Horizon – 3 wells were periodically measured by e-line.

Petrotek and LC ISR personnel installed the monitoring equipment prior to testing, verified the datalogger programming and equipment layout, and performed a short-term constant rate pump test at PW-102. Thereafter, Petrotek and LC ISR personnel collected the daily downloads and transferred the data to Petrotek for review/QA/QC for the duration of the long-term pumping test. Table 4-3 contains the drawdown response observed for each well at or near the end of pumping for the north test.

4.2.2 SOUTH TEST, PUMPING WELL PW-101

Aquifer testing was performed utilizing a Grundfos 75S100-16, 10 hp, 460V, 3-phase electrical submersible pump powered by a portable diesel generator. At pumping well PW-

101, the pump was set at a depth of 365 feet (approximately 130 feet off the bottom). The static depth to water in PW-101 was approximately 185 feet, providing for approximately 180 feet of head above the pump. Flow from the pump was controlled with a manual gate valve. Surface flow monitoring equipment included two 1.5” turbine meters (Turbines Incorporated FW Series, provided by LC ISR) that display total flow (in gallons) and instantaneous flow rates (in gallons per minute [gpm]). Per discussions with WDEQ/WQD, no Temporary Discharge Permit was required. Discharge water was land applied approximately 350 feet downgradient from PW-101 via a 1.5” HDPE line.

Water levels in 52 wells (including the pumping well, 31 HJ Horizon observation wells, and 20 wells in the overlying and underlying aquifers) were measured and recorded with In-Situ Level TROLLs®. The pressure rating for the Level TROLLS® ranged from 15 to 100 psi, and they were programmed to record depth to water at 5 minute intervals at all pumping and observation wells (during background monitoring, and the pumping and recovery periods). A detailed summary of the monitoring equipment used is presented in Table 4-2.

In addition to the wells continuously monitored using the Level TROLLS®, numerous other wells were periodically measured for depth to water using a hand lowered electronic water level meter. This allowed for a more extensive assessment of the potentiometric surface before, during, and after the pump test. A list of wells that were included in the hand measurement rounds is provided in Table 4-2.

The following is an interval-specific summary of water level monitoring locations recorded during testing at PW-101:

- HJ Horizon – 32 wells (including the pumping well) were monitored by dataloggers; 17 wells were periodically measured by e-line.
- Overlying LFG Sand – 10 wells were monitored by dataloggers; 15 wells were periodically measured by e-line.
- Underlying UKM Sand – 10 wells were monitored by dataloggers; 15 wells were periodically measured by e-line.
- Overlying DE Horizon – 2 wells were periodically measured by e-line.

Petrotek and LC ISR personnel installed the monitoring equipment prior to testing, verified the Level TROLL® programming and equipment layout, and performed a step-rate pump test at PW-101. Thereafter, Petrotek and LC ISR personnel collected the daily downloads and transferred the data to Petrotek for review/QA/QC for the duration of the long-term pumping test. Table 4-4 contains the drawdown response observed for each well at or near the end of pumping for the south test.

4.3 POTENTIOMETRIC SURFACES

Figure 4-1 presents potentiometric elevations within the Production Zone (HJ Horizon) within MU1 from water level measurements on December 8, 2008. The data are considered representative of static conditions within the HJ Horizon because the water levels were collected after an extended period in which there were no drilling activities or pumping tests conducted in the immediate vicinity (i.e., shut-in for the north side pump test at PW-102 occurred on November 20, 2008, allowing approximately 18 days of recovery). The data from December 8 are the most comprehensive set of water levels collected to date as all available monitor wells were included.

Based on potentiometric elevations, the direction of groundwater flow within MU1 in the HJ Horizon on both the north and south sides of the fault is predominantly to the west-southwest. Calculated hydraulic gradients were approximately 0.0052 ft/ft (27.4 ft/mile) on the north side and 0.0087 ft/ft (45.9 ft/mile) on the south side. The potentiometric elevation on the north side of the fault ranges from approximately 5 to 17 feet higher than the south side under static, non-pumping conditions. It is postulated that as the regional groundwater flow is in a southwesterly direction, groundwater mounding is observed on the north side as flow encounters the fault. The steep gradient observed in the potentiometric surface across the fault is likely a manifestation of a lower permeability transition area associated with the fault smear zone (Petrotek 2007a, 2007b). The observed potentiometric surface configuration is consistent with groundwater flow systems impacted by lower permeability zones as studied and modeled by Freeze (1969). Although limited groundwater leakage occurs across the fault, the majority of groundwater flow on both sides of the fault appears to be generally parallel to the fault, to the west-southwest. Water level data used for preparation of this map are presented in Table 3-1.

Figure 4-2 presents potentiometric elevations within the Overlying (LFG Sand) aquifer on December 8, 2008. The direction of groundwater flow within MU1 in the LFG Sand also trends to the west-southwest. The calculated hydraulic gradient on the north side of the fault is approximately 0.006 ft/ft (31.7 ft/mile) and approximately 0.0046 ft/ft (24.3 ft/mile) on the south side. Similar to the HJ Horizon, a steep gradient is also observed in the potentiometric surface from the north to the south side of the fault.

Figure 4-3 presents potentiometric elevations within the Underlying (UKM Sand) aquifer on December 8, 2008. The direction of groundwater flow within MU1 in the UKM Sand trends to the west-southwest, similar to the observed flow directions in the HJ and LFG Sands. The calculated hydraulic gradient on the north side of the fault is approximately 0.006 ft/ft (31.7 ft/mile) and approximately 0.0054 ft/ft (28.5 ft/mile) on the south side of the fault. Unlike the HJ Horizon and LFG Sand, the fault does not appear to impede groundwater flow within the UKM Sand as there is little or no displacement in the potentiometric surface across the fault

Water level data for the LFG Sand (overlying), HJ Horizon (production), and UKM Sand (underlying) were analyzed in several locations to evaluate vertical hydraulic gradients within MU1. Water level data were analyzed from MU1 well clusters at select locations north and south of the fault, and are presented in Table 4-5. At well cluster locations on the north side of the fault, the potentiometric surface of the HJ Horizon is approximately 10 to 12 feet lower than the potentiometric surface of the overlying LFG Sand. At well cluster locations south of the fault, the potentiometric elevation of the HJ Horizon ranges between

10 and 24 feet lower than the elevation within the LFG Sand. Similarly, the water level elevations in the underlying UKM Sand are lower than the water level elevations within the HJ Horizon (approximately 20 to 22 feet lower on the north side well clusters, and 2 to 19 feet lower within the south side well clusters [Table 4-5]). The downward hydraulic gradients observed in the three horizons are consistent with the regional hydraulic flow characteristics in this portion of the Great Divide Basin. There is at least one location in the southwest corner of the permit area (approximately 12,000 feet from MU1) where the potentiometric head in the HJ Horizon is slightly greater than the potentiometric head in the overlying LFG Sand, indicating an upward vertical gradient at that location. Near Lost Creek, groundwater flows to the southwest towards the center of the basin, from upland areas of regional and local recharge to discharge areas near the basin center.

The data presented in the potentiometric surface maps in Figures 4-1 to 4-3, and Table 4-5 suggest that the FG, HJ, and KM Horizons are not in direct hydraulic communication within MU1, under natural non-stressed conditions. The hydraulic gradients between horizons will influence potential leaks or excursions. The higher head in the overlying FG Horizon will serve to retard or minimize vertical migration of fluid from the underlying HJ Horizon. Similarly, fluid with higher head in the HJ Horizon could potentially drain to the underlying KM Horizon if an artificial pathway were present (e.g., improperly constructed well or improperly abandoned borehole).

4.4 BACKGROUND MONITORING, TEST PROCEDURES, AND DATA COLLECTION

4.4.1 NORTH TEST, PUMPING WELL PW-102

The majority of the testing equipment (e.g., pump, flow meters, Level TROLLS®) for the test conducted at PW-102 was installed and checked by Petrotek on November 5, 2008. A short-term constant rate test was conducted on November 11, 2008, to evaluate potential pumping rates for the long-term test. Initial test plans included a step-rate test, but due to an initial calibration error in the discharge line totalizers, a short-term constant rate test at 86.4 gpm was substituted. The short-term constant rate test was run for 5.8 hours.

Background-monitoring followed the short-term pump test and ran for a period of approximately seven days. Water levels were recorded every 5 minutes during background monitoring.

Level TROLLS® were programmed to record water levels every 5 minutes during the pumping and recovery periods. Pumping was conducted during November 18 – 20, 2008, and water level recovery data was collected through December 2, 2008. Pumping rate data for this test are shown on Table 4-6. A CD containing the water level data for the step test, background monitoring, pumping, and recovery periods is included in Appendix E-1. Manually collected e-line data are included in Appendix E-3.

4.4.2 SOUTH TEST, PUMPING WELL PW-101

The majority of the testing equipment (e.g., pump, flow meters, Level TROLLS®) for the test conducted at PW-101 was installed and checked by Petrotek on December 2 – 3, 2008. A step-rate test was conducted on November 12, 2008. Rates utilized during this step-test were 39.0, 54.4, 72.9, and 80.8 gpm. No losses in well efficiency were observed at the higher pumping rates

The background-monitoring for the south side pump test followed the completion of datalogger installations on December 3, 2008, for a period of approximately 6 days. Water levels were recorded every 5 minutes during background monitoring.

Level TROLLS® were programmed to record water levels every 5 minutes during the pumping and recovery periods. Pumping was conducted during December 9 – 12, 2008, and water level recovery data were collected through December 22, 2008. Pumping rate data for this test are shown on Table 4-7. A CD containing the water level data for the step test, background monitoring, pumping, and recovery periods is included in Appendix E-2. Manually collected e-line data are included in Appendix E-4.

5.0 BAROMETRIC PRESSURE CORRELATIONS AND CORRECTIONS

5.1 MONITORING EQUIPMENT

As previously discussed, all of the In-Situ Level TROLLS® used for both pump tests were vented (gauged). In-Situ has stated that if vented transducers are used, the vent eliminates the impact of barometric pressure on the sensor. However, a change in water levels due to barometric changes will occur whether a vented sensor is used or not. Hence, use of vented equipment eliminates the barometric impact on the sensor, but does not correct the water level measurements for barometric effects on the aquifer. In this regard, the vented Level TROLLS® are barometrically *compensated*, but not *corrected*. If significant variations in water levels are observed, the data may require correction for fluctuations in water levels associated with changes in barometric pressure.

5.2 BAROMETRIC CORRECTIONS

To demonstrate the effect of barometric pressure on water levels for the pump tests, two different corrections were evaluated. The first correction, referred to as the manual correction, involves evaluating the data based on total head (i.e., depth to water in the well plus barometric pressure as feet of water), and normalizing the values to the initial barometric pressure at the start of each pump test. The manual correction input parameters and calculation follows:

$$WL_c = (WL + BP) - BP_i$$

Where:

WL_c = Corrected water level elevation (ft)
WL = Water level elevation (ft)
BP = Barometric pressure (ft)
BP_i = Initial barometric pressure (ft)

The second method utilizes a software program entitled BETCO (barometric and earth tide correction) developed to analyze barometric and tidal effects on groundwater levels (Toll & Rasmussen, 2007). BETCO was developed to remove the effects of barometric pressure and earth tides from water level observations from a multiple regression analysis. The BETCO program is publicly available at http://www.hydrology.uga.edu/tools.html.

Water level observations from selected wells from the pump tests were evaluated by both correction methods to evaluate the potential impact of barometric pressure on water levels. Wells MP-106 (north test) and MP-109 (south test) were evaluated by the two methods and the graphical results are presented on Figures 5-1 and 5-2, respectively. From well MP-106, the largest magnitude of water level fluctuation by the manual correction was approximately 0.4 ft, and approximately 0.6 ft for the BETCO correction (Figure 5-1). Compared to the approximately 30 feet of observed drawdown in this well, the impact of the corrections is minimal. From well MP-109, the largest magnitude of water level fluctuation from the manual correction was approximately 0.6 ft, and approximately 0.2 ft for the BETCO correction (Figure 5-2). Observed drawdown in this well was approximately 18 feet.

An analysis of aquifer properties, including transmissivity (T), hydraulic conductivity (K), and storativity (S) were evaluated based on the two corrected water level elevation data sets and compared to the uncorrected data. A more complete discussion of the analytical methods is presented in Section 7. The following table presents a summary of the comparative analysis of aquifer properties evaluated by the Theis (1935) method.

Well	MP-106	MP-106	MP-106	MP-109	MP-109	MP-109
Barometric Pressure Correction	Uncorrected	Manual Correction	BETCO Software	Uncorrected	Manual Correction	BETCO Software
T (ft^2/day)	67.9	68.3	68.6	71.6	69.0	70.4
K (ft/day)	0.57	0.57	0.57	0.60	0.58	0.59
Storativity	1.38×10^{-4}	1.36×10^{-4}	1.35×10^{-4}	8.29×10^{-5}	8.30×10^{-5}	8.23×10^{-5}

Comparison of the two correction methods for the MU1 pump tests indicate that barometric pressure had minimal impact on water levels prior to, during, and after the pumping test in the HJ Horizon observation wells. Additionally, differences between the analytical results of aquifer properties between uncorrected and corrected data were minimal (on the order of 1% to 4% difference). Observed drawdown is approximately two orders of magnitude greater than the potential barometric pressure effects on water levels. These results are in agreement with those of previous pump tests conducted at the LCPA (Petrotek 2007a, 2007b) which showed the effects of barometric pressure were negligible. Due to the negligible impact on water levels and minimal impact on the analytical analysis, uncorrected water levels were utilized in the evaluation of observed drawdown, potentiometric surfaces, and in the analysis of aquifer properties (see Section 7).

6.0 TEST RESULTS

The following section discusses the results of pump testing and details background monitoring, response in the Production Zone aquifer, and responses in the overlying and underlying aquifers for the north and south-side tests conducted at pumping wells PW-102 and PW-101, respectively.

6.1 BACKGROUND TRENDS

6.1.1 NORTH TEST, PUMPING WELL PW-102

Water level stability data were collected prior to the start of the north side pump test. Plots of the background, pumping, and recovery data for wells completed in the HJ Horizon and monitored with transducers are shown in Figures 6-1 through 6-4. Wells completed in the HJ Horizon were grouped into four geographical categories: 1) west side of the pumping well and north of the fault (Figure 6-1), 2) central area near pumping well (approximately 1000 foot radius) and north of the fault (Figure 6-2), 3) east side of the pumping well and north of the fault (Figure 6-3), and all wells located south of the fault (Figure 6-4).

Water level data for the overlying (LFG Sand) and underlying (UKM Sand) wells monitored by transducers are presented in Figures 6-5 through 6-8. Water level graphs on these figures are grouped by location relative to the fault. Wells in the LFG Sand located north and south of the fault are presented on Figures 6-5 and 6-6, respectively. Wells completed in the UKM Sand located north and south of the fault are presented on Figures 6-7 and 6-8, respectively.

Water level versus barometric pressure plots for all wells monitored by transducers during the test are presented in Appendix B-1. Individual well water levels for wells equipped with transducers versus pumping well water levels are presented in Appendices C-1 to C-4.

Prior to conducting the short-term constant rate pump test at pumping well PW-102 on November 11, 2008, water levels were increasing slightly in the HJ Horizon. Subsequent to this short-term test and prior to the start of the long-term pump test, water levels were still equilibrating and had risen to within approximately 1 foot or less of the observed static water level prior to the short-term test. The recovery interval prior to initiation of the long-term pump test at PW-102 was approximately seven days.

It is noted that during background monitoring of HJ wells on the south side of the fault, water levels responded to the step-rate pump test conducted at pumping well PW-101 on November 12, 2008 (Figure 6-4). Water levels were allowed to recover for approximately six days prior to the initiation of pumping at PW-102.

In general, water levels in the LFG Sand and UKM Sand north and south of the fault were increasing slightly prior to the start of the short-term pump test, and generally decreasing or steady prior to the start of the long-term pump test at PW-102.

6.1.2 SOUTH TEST, PUMPING WELL PW-101

Water level stability data were collected prior to the start of the south side pump test. Plots of the background, pumping, and recovery data for wells completed in the HJ Horizon and monitored with transducers are shown in Figures 6-9 through 6-12. Wells completed in the HJ Horizon were grouped into four geographical categories: 1) west side of the pumping well and south of the fault (Figure 6-9), 2) central area near pumping well (approximately 1000 foot radius) and south of the fault (Figure 6-10), 3) east side of the pumping well and south of the fault (Figure 6-11), and all wells located north of the fault (Figure 6-12).

Water level data for the overlying (LFG Sand) and underlying (UKM Sand) wells monitored by transducers are presented in Figures 6-13 to 6-16. Water level depictions on these figures are grouped by location relative to the fault. Wells in the LFG Sand located south and north of the fault are presented on Figures 6-13 and 6-14, respectively. Wells completed in the UKM Sand located south and north of the fault are presented on Figures 6-15 and 6-16, respectively.

Water levels versus barometric pressure plots for all wells monitored by transducers during the test are presented in Appendix B-2. Individual well water levels for wells equipped with transducers versus pumping well water levels are presented in Appendices C-5 to C-8.

Level TROLLS® were installed on December 2 – 3, 2008, allowing approximately 6 to 7 days of background monitoring prior to the start of the mine-unit scale pump test on December 9, 2008. In general, water levels in the HJ Horizon on the south side of the fault zone were slightly increasing prior to the pump test. Water levels monitored on the north side of the fault rose approximately 0.5 to 2.0 ft during the course of background monitoring (see Figure 6-12), as these wells were likely equilibrating in response to the pump test previously conducted on the north side of the fault.

In general, water levels in the LFG Sand and UKM Sand north and south of the fault were increasing slightly prior to the start of the short-term pump test, and generally decreasing or steady prior to the start of the long-term pump test at PW-101.

It is also noted that the abrupt spike in water level observed on December 5, 2008 at well M-104 is due to placement of cement to plug and abandon an adjacent well (see Figure 6-11) that failed mechanical integrity testing (MIT). Prior to the start of the south side pump test, LC ISR personnel plugged this older well to ensure hydraulic isolation at well M-104.

6.2 PUMP DURATION AND RATE

6.2.1 NORTH TEST, PUMPING WELL PW-102

The north test was started at 10:30 on November 18, 2008 and was terminated at 10:30 on November 20, 2008. The total length of pumping was approximately 2,880 minutes (2.0 days). The average pumping rate during the PW-102 test was 70.9 gpm.

6.2.2 SOUTH TEST, PUMPING WELL PW-101

The south test was started at 14:00 on December 9, 2008 and was terminated at 11:45 on December 12, 2008. The total length of pumping was approximately 4,185 minutes (2.9 days) and the average pumping rate during the PW-101 test was 58.1 gpm. Due to ice in the 3-inch HDPE discharge line utilized for the step-rate test, the long-term pump test at PW-101 was conducted utilizing 1.5-inch discharge pipe. It is noted that there were several short false starts that occurred on December 9, 2008 at times 10:15, 10:50, and 11:15. These false starts were due to ice in the pump assembly and discharge line. As these false starts were short in duration and produced minimal groundwater volume, the pumping well recovered quickly prior to the initiation of the long-term pump test.

6.3 HJ HORIZON REPONSE

6.3.1 NORTH TEST, PUMPING WELL PW-102

Drawdown observed in the monitor wells completed in the HJ Horizon is presented on Figure 6-17. Drawdown values presented on this figure are a combination of water levels observed from Level TROLLS® and hand measured e-line data collected on November 20, 2008, just prior to shut-in at PW-102. A summary of these data are also included as Table 4-3. It is noted that residual drawdown after the end of pumping was observed in many wells located distant from the pumping well.

The drawdown contour map includes 45 HJ Horizon wells, of which 29 were monitored by Level TROLLS® and 16 measured by e-line. As shown in Figure 6-17, considerable drawdown (i.e. greater than 2 feet) was observed prior to shut-in at all wells located north of the fault. The maximum drawdown observed in the pumping well PW-102 was 111.1 feet. At the closest observation well (MP-107), observed drawdown was 48.6 feet. Observed drawdown in the perimeter “ring” observation wells located on the north side of the fault (M-114 to M-126) ranged from 2.8 to 36.5 feet.

As discussed in Section 4.3, the potentiometric level on the north side of the fault ranges from approximately 5 to 17 feet higher than the south side under static, non-pumping conditions. Observed drawdown responses in the 13 wells located south of the fault ranged from 0.0 to 2.7 feet, with the largest responses observed in those wells closest to the fault. The total head difference across the fault just prior to shut-in can be seen by comparing the drawdown responses between wells HJT-101 (34.2 feet, located north of the fault) and MP-109 (2.7 feet, south of the fault), which are located approximately 100 feet apart. Since the total head difference across the fault was on the order of 30 feet, a large hydraulic stress was applied to the aquifer across the fault. Based on the substantial drawdown observed in the HJ Horizon north of the fault in response to pumping at PW-102, and the minimal response observed in wells located south of the fault, the Lost Creek Fault is a partial barrier to groundwater flow within MU1. The drawdown observed in wells south of the fault, although minimal, suggests that some leakage across the fault does occur.

6.3.2 SOUTH TEST, PUMPING WELL PW-101

Drawdown observed in the monitor wells completed in the HJ Horizon is presented on Figure 6-18. Drawdown values presented on this figure are a combination of water levels observed from Level TROLLS® and hand measured e-line data collected on December 12, 2008, just prior to shut-in at PW-101. A summary of these data is included as Table 4-4. It is noted that residual drawdown after the end of pumping was observed in many wells located distant from the pumping well.

The drawdown contour map includes 50 HJ Horizon wells, of which 33 were monitored by transducers and 17 measured by e-line. As shown in Figure 6-18, considerable drawdown (i.e. greater than 2 feet) was observed prior to shut-in at all wells located south of the fault. The maximum drawdown observed in the pumping well PW-101 was 63.5 feet. At the closest observation wells (HJMP-109 and MP-104), observed drawdowns were 41.7 and 48.1 feet, respectively. Observed drawdown in the perimeter “ring” observation wells located on the south side of the fault (M-101 to M-113, and M-127 and M-128) ranged from 4.8 to 34.1 feet.

As discussed in Section 4.3, the potentiometric levels on the south side of the fault range from approximately 5 to 17 feet lower than the north side under static, non-pumping conditions. Observed drawdown responses in the 21 wells located north of the fault ranged from 0.1 to 2.0 feet, with the largest responses generally seen in those wells closest to the fault. The total head difference across the fault just prior to shut-in can be seen by comparing the drawdown responses between wells MP-104 (48.1 feet, located south of the fault) and HJT-104 (2.0 feet, north of the fault), which are located a distance of approximately 190 feet apart. It is also apparent from the relatively steep drawdown contours north and northeast of the pumping well across the fault splay that the splay influences the propagation of drawdown and acts as a minor barrier to flow across the fault (Figure 6-18). Observed drawdowns at the two wells (UKMO-101 and HJT-105) located within the downthrown fault block north of the splay and south of the main fault are 17.4 and 12.2 feet, respectively. Measured drawdowns at monitoring wells south of the pumping well and located a similar distance from the pumping well (e.g. wells M-106, M-107 and M-108) are approximately twice that observed north of the splay.

Similar to results of the north test, a large hydraulic stress was applied to the aquifer across the fault and minimal response was observed on the north side of the fault. Therefore, the fault acts as a partial barrier to groundwater flow, with the minimal responses observed across the fault indicating that some leakage across the fault does occur.

6.4 CONFINING UNITS RESPONSE

6.4.1 NORTH TEST, PUMPING WELL PW-102

During the pump test, small responses were observed in the overlying and underlying aquifer observation wells. The observed responses correlate with the beginning and ending of the PW-102 pump test. The responses ranged from 0.1 to 3.4 feet in the overlying LFG Sand aquifer, and 0.0 to 2.2 feet (excluding the response observed in MU-108, discussed below) in the underlying UKM Sand aquifer (Table 4-3). Graphical presentations of well response in these aquifers are included as Figures 6-5 to 6-8. Three wells in the uppermost DE Sand aquifer were monitored on the south side of the fault, and e-line measurements indicate no observed response (i.e., greater than 0.1 feet) from pumping in this aquifer (Table 4-3). Drawdown contour maps prior to test shut-in for the overlying LFG Sand and underlying UKM Sand are presented in Figures 6-19 and 6-20, respectively. The water level plots for all wells instrumented with transducers are included in Appendices C-3 and C-4.

The observed drawdown response in well MU-108 (not presented on Figures 6-7 and 6-20), completed in the underlying UKM Sand, was 24.7 feet and was due to damage to the casing and annular seal during well completion operations. Drilling records for this well indicated that the underreamer bit was not fully closed upon withdrawal into the casing. Due to the large observed drawdown at this well, communication between the HJ Horizon and underlying aquifer was present due to this artificial pathway within the casing. Well MU-108 was subsequently plugged and abandoned with cement grout on December 2, 2008. LC ISR tested the hydraulic continuity between the overlying HJ Horizon and the underlying UKM sand during August 2009 to confirm successful abandonment, the details of which are presented in Section 6.5.

While there is a limited degree of communication between the HJ Horizon and overlying and underlying aquifers, the magnitude of response within these adjacent aquifers is generally an order of magnitude less than the observed response within the Production Zone Aquifer. The communication observed at Lost Creek is similar to that observed in other ISR operations where engineering practices were successfully implemented to isolate lixiviant from overlying and underlying aquifers.

In evaluating the response of the overlying and underlying aquifers in those wells instrumented with Level TROLLS®, many wells exhibited an appreciable rise in water level corresponding to the initiation of pumping at PW-102, followed by a subsequent decline (see Figures 6-5 and 6-7). This response is most prominent in those wells located on the north side of the fault. This phenomenon has been described previously in layered confined aquifer systems as the “Noordbergum effect” or “reverse water-level fluctuation (Hsieh, 1996). Conventional groundwater theory does not account for this effect, and must be explained by poroelastic theory. Poroelastic theory considers that “drawing down an aquifer produces time-dependent volumetric contraction and, hence, induced increases in pore pressure in the aquifer, adjacent confining layers, and adjacent aquifers” (Wang, 2000). As the aquifer contracts upon pumping, vertical and horizontal strains are transferred to the aquitard and adjacent aquifer via shear. The increase in pore pressure in adjacent aquifers can result in an initial water level rise, which is eventually canceled by pore-pressure diffusion and the later propagation of drawdown.

6.4.2 SOUTH TEST, PUMPING WELL PW-101

During the pump test, small responses were observed in the overlying and underlying aquifer observation wells. The observed responses correlate with the beginning and ending of the PW-101 pump test. The responses ranged from no response to 1.9 feet in the overlying LFG Sand aquifer, and 0.1 to 5.7 feet in the underlying UKM Sand aquifer (Table 4-4). Within the underlying aquifer wells MU-104 and MU-109, drawdown response was 5.7 feet and 3.9 feet, respectively. Drawdown responses in the remainder of the wells monitoring the underlying aquifer were less than 2.0 feet. Two wells in the uppermost DE Sand aquifer were monitored on the south side of the fault, and e-line measurements indicate no observed response from pumping in this aquifer (Table 4-4). Drawdown contour maps prior to test shut-in for the overlying LFG Sand and underlying UKM Sand are presented in Figures 6-21 and 6-22, respectively. Graphical presentations of well response in these aquifers are included as Figures 6-13 to 6-16. The water level plots for all wells are included in Appendices C-7 and C-8.

Similar to the results of the north test, there was a limited degree of communication between the HJ Horizon and overlying and underlying aquifers. These responses are generally an order of magnitude less than the observed response within the HJ Horizon, and these conditions are similar to other ISR operations where engineering practices were successfully implemented to isolate lixiviant from overlying and underlying aquifers.

It is also noted that increases in water level were observed in response to the start of pumping in many of the underlying and overlying aquifer wells (see Figures 6-13 and 6-15). As discussed previously in Section 6.4.1, this is likely a manifestation of the “Noordbergum effect”, which is an aquifer deformation-induced water level response.

6.5 SUPPLEMENTAL TESTING TO CONFIRM ABANDONMENT AT WELL MU-108

During the course of testing during the north test at pumping well PW-102, a dramatic drawdown response of 24.7 feet was observed in well MU-108, which is completed in the UKM Sand. Drilling records for this well indicated that the underreamer bit was not fully closed upon withdrawal into the casing. Due to the large observed drawdown at this well, communication between the HJ Horizon and underlying UKM Sand was present due to this artificial pathway within the casing. Well MU-108 was plugged and abandoned with cement grout on December 2, 2008.

A short-term pump test was conducted at well KPW-2, completed within the entire KM Sand interval, to observe the response in the overlying HJ Horizon at well MP-108, which is located approximately 15 feet from well MU-108. Figure 6-23 presents the locations of these wells. On June 16, 2009, well KPW-2 was pumped for 8 hours at a constant rate of 68.3 gpm, and well MP-108 was monitored for water level. Both wells were instrumented with In-Situ Level TROLLS® programmed to record depth to water at 5 minute intervals (as testing was conducted for the north and south tests). A graph of water levels in the observation well MP-108 versus water level in the pumping well KPW-2 is presented in Figure 6-24. Drawdown at the end of pumping in the pumping well was measured at 90.7

feet, and no water level drop was observed in the overlying well MP-108. The initial rise observed in well MP-108 concurrent with the start of pumping is likely a manifestation of the “Noordbergum effect”, which is an aquifer deformation-induced water level response.

Due to the fact that no observed water level drop was observed in the HJ Horizon in response to pumping in the underlying aquifer, testing confirms the successful abandonment of well MU-108 and confirms previously existing artificial flow pathways through casing have been sealed.

7.0 ANALYTICAL METHODS AND RESULTS

7.1 ANALYTICAL METHODS

Drawdown data collected from monitor wells (instrumented with Level TROLLS®) were graphically analyzed to determine aquifer properties of Transmissivity and Storativity. The primary analysis method used was Theis (1935). The assumption used in this analysis was that the aquifer is confined and has a saturated thickness of 120 feet (average thickness of the HJ, provided by LC ISR geologists). The use of the Cooper & Jacob time-drawdown (1946) method was evaluated for the pump test data, however, the criteria for validity for this method ($\mu = r^2S / 4Tt < 0.01$ [where r = distance to observation well, S = storativity, T = transmissivity, and t = time since pumping began], Kruseman & de Ridder [1990]) was satisfied by only one well (MP-104, located approximately 331 feet from the pumping well of the south test). The Theis Recovery (1935) analysis was also performed for the pumping well and select observation wells. As noted, minor responses in observation wells across the fault were observed. However, the magnitude of those responses did not warrant quantitative analyses. Water level plots for all the wells are presented in Appendix C.

The test data were analyzed using the Theis method, which is a standard analytical approach to evaluate aquifer characteristics. Assumptions inherent in this method include:

- The aquifer is confined and has apparent infinite extent;
- The aquifer is homogeneous and isotropic, and of uniform effective thickness over the area influenced by pumping;
- The potentiometric surface is horizontal prior to pumping;
- The well is pumped at a constant rate;
- The pumping well is fully penetrating; and,
- Well diameter is small, so well storage is negligible.

These assumptions are reasonably satisfied, with the exception of the uniform thickness of the aquifer and infinite extent of the aquifer due to the presence of boundary conditions (i.e., fault). Locally, the HJ Horizon at LCPA is not homogeneous and isotropic; however, over the scale of both pump tests, the aquifer can be treated in this manner. As previously discussed and verified with the pumping tests, the fault acts as a hydraulic barrier to groundwater flow and therefore limits the effective extent of the aquifer. In this regard, water level responses from all the wells in the HJ Horizon are likely to be impacted by the fault. Due to the presence of the fault, the aquifer is not infinite-acting, and the fault effectively reduces the available aquifer by approximately half. The actual transmissivity of the aquifer, without the impact of the fault, would be higher.

Because of the influence of the fault, the transmissivity determined from this pumping test is viewed as an “effective” transmissivity. The fault will impact all production and restoration operations for this mine unit, therefore the “effective” transmissivity is more suitable for estimating hydraulic impacts of the in-situ operation. A hydraulic conductivity calculated from this “effective” transmissivity will be lower than the actual, or intrinsic, hydraulic conductivity of the aquifer.

The Theis Recovery method was utilized for analysis of recovery data from those wells located relatively close (i.e. within 1000 feet) to the corresponding pumping well. This analysis was not used on the more distant wells because of residual drawdown after the end of pumping.

Because none of the monitor wells were completed within the confining units, a Neuman-Witherspoon (1972) analysis was not performed. Use of the Hantush (1956) leaky aquifer analysis was considered because of the observed response in overlying and underlying aquifers during both the north and south pump tests. The Hantush analysis was not used for the following reasons. The response of underlying and overlying monitor wells indicates some leakage through the confining units during the tests. However, as previously noted, some of the observed responses in the underlying aquifer are directly attributable to an improperly constructed well (MU-108). Also, the Hantush leaky aquifer analysis is designed to evaluate leakage through a single confining unit. In the case of the MU1 pump tests, it is apparent that there is leakage (albeit minor) from above and below the production zone aquifer. Finally, the impact of the fault as a hydraulic barrier dominates the response of the monitor wells in each of the pump tests. The transmissivity calculated from these pump tests is an “effective” transmissivity that reflects the impact of the fault that essentially reduces the available aquifer by approximately one half. The effects of leakage from overlying and underlying units will be negligible compared to the effects of the fault in the calculation of “effective” transmissivity.

The software used to graphically analyze the data was AquiferTest Pro (Version 4.2, Schlumberger Water Services, 2008).

Water level stability data collected during the pre-test and post-test periods along with barometric pressure (Appendices B and C) were used to assess the background trends. No significant trend corrections were warranted for any of the wells.

7.2 ANALYTICAL RESULTS

7.2.1 NORTH TEST, PUMPING WELL PW-102

Transmissivity (T) results from the Theis analysis were calculated using both drawdown and recovery portions of the test data. Transmissivity results from drawdown data for the PW-102 pump test for the HJ Horizon aquifer range from 50.9 to 104.0 ft^2/d, with an average T value of 77.9 ft^2/d (Table 7-1). A contour map of T values from these analyses is presented in Figure 7-2. Transmissivity values from recovery data were calculated from eight monitor wells (including PW-102) and were consistently lower than the T values calculated from drawdown data. Transmissivity values for the recovery data range between 52.2 to 57.5 ft^2/d, with an average T value of 55.4 ft^2/d (Table 7-1).

Based on an average thickness of 120 feet and transmissivity results from drawdown data, hydraulic conductivity (K) ranges from 0.42 to 0.87 ft/day and averages 0.65 ft/day (Table 7-1). Assuming a water viscosity of 1.35 cp (50 degrees F) and a density of 1.0, this equates to a permeability of approximately 320 millidarcies (md). Storativity (S) of the HJ Horizon aquifer ranges from 5.4×10^{-5} to 1.9×10^{-4}, with an average value of 9.3×10^{-5} (Table 7-1). It should be reiterated that these values are considered "effective" because of the impact of the fault on the aquifer response.

Average linear velocity of groundwater flow was also calculated in Table 7-1 from hydraulic conductivity, utilizing an estimated effective porosity of 28% (provided by LC ISR) and the calculated hydraulic gradient from Section 4.3 (0.0052 ft/ft). On the north side of the fault, calculated groundwater velocities ranged from 2.9 to 5.6 ft/year, with an average velocity of 4.4 ft/year.

An example of a type curve match using the Theis method is provided in Figure 7-1. Type curve matches of the HJ Horizon monitor wells analyzed in the pump test are provided in Appendix D-1. Water level data for all monitor wells from background through pumping and recovery are included in Appendix E-1 on a CD ROM. Manually collected e-line data are presented in Appendix E-3.

7.2.2 SOUTH TEST, PUMPING WELL PW-101

Transmissivity (T) results from the Theis analysis were calculated using both drawdown and recovery portions of the test data. Transmissivity results from drawdown data for the PW-101 pump test for the HJ Horizon aquifer range from 69.4 to 129.0 ft^2/d, with an average T value of 92.6 ft^2/d (Table 7-2). A contour map of T values is presented in Figure 7-3. Transmissivity values from recovery data were calculated from nine monitor wells (including PW-101) and were consistently lower than the T values calculated from drawdown data. Transmissivity values for the recovery data range between 58.3 to 108.0 ft^2/d, with an average T value of 70.5 ft^2/d (Table 7-2).

Based on an average thickness of 120 feet and transmissivity results from drawdown data, hydraulic conductivity (K) ranges from 0.58 to 1.08 ft/day and averages 0.77 ft/day (Table 7-2). Assuming a water viscosity of 1.35 cp (50 degrees F) and a density of 1.0, this equates to a permeability of approximately 379 millidarcies (md). Storativity (S) of the HJ Horizon aquifer ranges from 3.6×10^{-5} to 4.2×10^{-4}, with an average value of 1.1×10^{-4} (Table 7-2). It should be reiterated that these values are considered "effective" because of the impact of the fault on the aquifer response.

Average linear velocity of groundwater flow was also calculated in Table 7-2 from hydraulic conductivity, utilizing an estimated effective porosity of 28% (provided by LC ISR) and the calculated hydraulic gradient from Section 4.3 (0.0087 ft/ft). On the south side of the fault, calculated groundwater velocities ranged from 6.6 to 12.1 ft/year, with an average velocity of 8.7 ft/year.

Type curve matches for the HJ Horizon monitor wells analyzed in the pump test are provided in Appendix D-2. Water level data for all monitor wells from background through pumping and recovery are included in Appendix E-2 on a CD ROM. Manually collected e-line data are presented in Appendix E-44.

7.3 TRANSMISSIVITY DISTRIBUTION

The distribution of transmissivity calculated from the MU1 north and south pump tests are presented on Figures 7-2 and 7-3, respectively. For consistency, only transmissivity values determined from the Theis drawdown method are posted. The overall range of transmissivity determined from the north and south tests is relatively small (51 to 129 ft^2/d) relative to typical fluvial depositional systems.

The presentation of the distribution of transmissivity (provided in Attachment MU1 2-1, Figures 7-2 and 7-3), indicates a slight directional bias in transmissivity. A southwest decrease in transmissivity observed on the north side of the Fault appears to be correlative with a slight reduction in the thickness of the HJ Horizon. The HJ Horizon thins west of the pumping well PW-102 (Figure 2-3), which generally corresponds to the decreasing trend observed in T values (Figure 7-2). On the south side of the Fault there is an area of slightly lower transmissivity that trends along wells M-106, M105 and M104 to the southeast. This southeast trend of low transmissivity correlates with the elliptical shape of the drawdown observed on the south side of the Fault during hydrologic testing. Transmissivity appears to increase closer to the Fault in the area of the fault splay (wells UKMO-101, HJT-105 and M-127). This increase in transmissivity may be partially the result of impacts of the fault splay during the south hydrologic test in reducing the drawdown in wells located in the downthrown fault block.

On a regional scale, the observed variation in T is not expected to impact ISR mining and has no apparent regulatory implications. Further, field operations will be modified to achieve mine unit balance in light of the variation in T.

As discussed previously, the T results for the HJ Horizon are considered “effective” because of the barrier effect of the fault. Because of the fault, the aquifer is not infinite-acting and the available aquifer is effectively reduced by half. The T results are representative of the HJ Horizon on the scale of the pump test, and directly apply to design calculations such as water balance. However, the actual transmissivity of the aquifer, without impacts from the fault, would be higher (e.g., by an approximate factor of 1.5 to 2.0). In other words, there would be less drawdown at the pumping well at a given pumping rate, if the fault were not restricting flow to the well.

The K results estimated from these tests (0.42 to 1.08 ft/d) are calculated by dividing the T by the saturated thickness of the aquifer. Similar to the higher “effective” T within MU1 due to the presence of the fault, actual K values are likely higher, on the order of approximately 1.0 to 2.0 ft/d. This range of K values would be most representative for estimating groundwater velocity and travel times with regard to mine unit design, exterior monitor well spacing, excursion control, and excursion recovery.

7.4 RADIUS OF INFLUENCE

7.4.1 NORTH TEST, PUMPING WELL PW-102

Based on the drawdown response observed at the outlying “ring” monitor wells during the north test, the minimum radius of influence (ROI) is greater than 2,600 feet. The ROI is not symmetrical with respect to the pumping well and is truncated due to the presence of the fault. The actual ROI of the test (extending away from the fault) was estimated utilizing distance-drawdown data (i.e., drawdown on an arithmetic scale and distance to the pumping well on a logarithmic scale) (Appendix F). From the distance-drawdown analysis, the ROI for the north test is estimated between 3,100 to 3,300 feet.

Minor drawdown responses in the HJ Horizon were observed on the southern side of the fault (see Table 4-3 and Figure 6-17) that ranged between 0.0 to 2.7 feet, and generally decreased with increasing distance to the pumping well. At distances greater than 2,000 feet, drawdown responses were less than 1 foot.

7.4.2 SOUTH TEST, PUMPING WELL PW-101

Based on the observed drawdown at the outlying “ring” monitor wells during the south test, the minimum ROI is greater than 2900 feet. As observed in the north test, the ROI is truncated by the fault. The actual ROI extending away from the fault was estimated between 3,200 to 3,500 feet utilizing distance-drawdown data (Appendix F).

Minor drawdown responses (less than 1 foot) were observed north of the fault (Table 4-4 and Figure 6-18). Drawdown at well HJT-104 was observed at 2.0 ft, but this well is located north and immediately adjacent to the fault, and only a distance of 400 feet from the pumping well.

7.5 COMPARISON TO PREVIOUS TESTING RESULTS

The following table presents a summary of all hydrologic testing performed in the HJ Horizon on both sides of the fault during 2007 and 2008. Results from the two mine-unit scale pump tests conducted in 2008 compare favorably to previous testing (2007) conducted on both sides of the fault. The table below also shows the larger area of investigation of the 2008 MU1 tests compared to the tests conducted in 2007.

Analytical results of aquifer properties from the MU1 tests were evaluated in observation wells located a distance of approximately three times that of the 2007 tests.

Test	**North Regional Test #1**	**MU1 North Test**	**South Regional Test #2**	**MU1 South Test**
Pumping Well	LC19M	PW-102	LC16M	PW-101
Date	June – July 2007	November 2008	October – November 2007	December 2008
Relationship to Fault	North	North	South	South
Farthest Observ. Well (feet)*	781	2569	866	2945
Test Duration (days)	5.7	2.0	5.5	2.9
Test Rate (gpm)	42.9	70.9	37.4	58.1
Range of T (ft^2/day)	30 – 76	51 – 104	57 – 110	69 – 129
Average T (ft^2/day)	61	79	76	93
Range of Storativity	$6.6x10^{-5}$ – $1.5x10^{-4}$	$5.4x10^{-5}$ – $1.9x10^{-4}$	$3.5x10^{-5}$ – $9.1x10^{-4}$	$3.6x10^{-5}$ – $4.2x10^{-4}$
Average Storativity	$1.1x10^{-4}$	$9.3x10^{-5}$	$2.9x10^{-4}$	$1.1x10^{-4}$

* Distance from farthest observation well to pumping well, on the same side of the fault.

8.0 SUMMARY AND CONCLUSIONS

- The results of the MU1 north and south pump tests conducted on both sides of the Lost Creek Fault demonstrate that the HJ Horizon monitor wells and pumping wells (for the north and south sides of the fault) are in hydraulic communication. Minor communication was observed across the fault during both tests, but responses were an order of magnitude smaller, suggesting that the fault is a partial barrier to groundwater flow within the HJ Horizon. Data from the south test also indicates that the splay to the south of the Lost Creek Fault is a minor barrier to groundwater flow

- On a regional scale, the HJ Horizon on both sides of the Lost Creek Fault has been adequately characterized with respect to hydrogeologic conditions within MU1. Results of the MU1 tests demonstrate that the HJ Horizon has sufficient transmissivity for in-situ recovery mining operations.

- Geological information suggests that the overlying and underlying shales are continuous throughout MU1. Minor responses (order of magnitude or less in relation to responses in wells completed in the HJ Horizon) were observed during the pump test. Communication observed in the LFG and UKM Sands is similar to the responses observed at other ISR facilities where engineering practices are successfully implemented to isolate lixiviant from overlying and underlying aquifers.

- LC ISR is conducting a program of locating, plugging and abandonment of historic wells within MU1 to mitigate the potential for hydraulic communication through improperly abandoned wells.

- The observed response during the north test at well MU-108 (completed in the underlying UKM Sand) of 24.7 feet of drawdown was due to damage of the casing and annular seal during well completion. Drilling records indicate that the underreamer bit was not fully closed upon withdrawal into the casing. This well was subsequently plugged and abandoned and additional pump testing conducted within the underlying aquifer confirmed the abandonment was successful, as an immediately adjacent well to MU-108 completed in the HJ Horizon did not respond to pumping.

9.0 REFERENCES

Cooper, H.H. and Jacob, C.E., 1946. A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well Field History. Transactions, American Geophysical Union, vol. 27, pp. 526-534.

Freeze, R.A., 1969. Regional Groundwater Flow – Old Wives Lake Drainage Basin, Saskatchewan. Canadian Inland Waters Branch, Scientific Series No. 5, 245 pp.

Hantush, M.S., 1956. Analysis of Data from Pumping Tests in Leaky Aquifers. Transactions, American Geophysical Union, vol. 37, pp. 702-714.

Hydro-Engineering, LLC, 2007. Lost Creek Aquifer Test Analyses. Prepared for Ur Energy USA, Inc., March 2007.

Hydro-Search, Inc., 1982. 1982 Hydrogeology Program for the Conoco/Lost Creek Uranium Project. Golden (CO). Prepared for TexasGulf, Inc.

Hseih, P.A., 1996. Deformation-induced Changes in Hydraulic Head During Groundwater Withdrawal, Groundwater, vol. 34, no. 6, pp. 1082-1089.

Kruseman, G.P. and de Ridder, N.A., 1990. Analysis and Evaluation of Pumping Test Data. International Institute for Land Reclamation and Improvement: Wageningen, The Netherlands. Second edition. 377 pp.

Lost Creek ISR, LLC, Petrotek Engineering Corporation, and AATA International, Inc. 2007. Ur Energy Lost Creek Project, Wyoming Department of Environmental Quality Permit to Mine, December 2007

Neuman, S. P. and P. A. Witherspoon, 1972. Field Determination of the Hydraulic Properties of Leaky Multiple Aquifer Systems. Water Resources Research, Vol. 8, No. 5.

Petrotek Engineering Corporation, 2007a. Lost Creek Regional Hydrologic Testing Report #1. Prepared for Lost Creek ISR, LLC, October 2007.

Petrotek Engineering Corporation, 2007b. Lost Creek Regional Hydrologic Test Report #2. Prepared for Lost Creek ISR, LLC, December 2007.

Theis, C. V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol.16, pp.519-524.

Toll, N.J. and Rasmussen, T.C., 2007. Removal of Barometric Pressure Effects and Earth Tides from Observed Water Levels, Groundwater, vol. 45, no. 1, pp. 101-105.

Wang, H. F., 2000. Theory of Linear Poroelasticity with Applications to Geomechanics and Hydrogeology, Princeton University Press, Princeton, NJ, 287 pp.