COLORADO OFFICE
10758 W. CENTENNIAL RD., STE. 200
LITTLETON, CO 80127
TEL: (866) 981-4588
FAX: (720)-981-5643

WYOMING OFFICE
5880 ENTERPRISE DR., STE. 200
CASPER, WY 82609
TEL: (307) 265-2373
FAX: (307) 265-2801

ISR

LOST CREEK ISR, LLC

February 10, 2016

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Re: Response to NRC's April 15, 2015 Letter Regarding the LC East and KM Amendments
Lost Creek ISR Project License SUA-1598; Docket 040-09068

Dear Mr. Glenn,

On September 23, 2014 Lost Creek ISR (LCI) submitted a request to amend the Lost Creek License primarily by adding additional land and geologic horizons to the license (ML14279A431). The NRC requested revisions to the formatting, so on February 2, 2015 LCI submitted revisions to the agency for review (ML15044A175, ML15044A176 and ML15044A177). The NRC sent an additional letter on April 15, 2015 expressing concerns generally pertaining to the hydrologic confinement underlying the KM Horizon (ML15093A261).

In response to the NRC's April 15, 2015 letter, please find attached LCI's comments which include: a point by point response to the issues raised in the NRC's letter, page changes to the application, and a technical memorandum describing the results of a hydrologic model which was developed to simulate in situ recovery from the KM Horizon and the hydraulic control of fluids during mining and groundwater restoration.

If you have any questions please feel free to contact me at our Casper office.

Sincerely,

John Cash
Vice President

Cc: Deputy Director, Division of Decommissioning
Uranium Recovery and Waste Programs
Office of Nuclear Material Safety and Safeguards

Mrs. Theresa Horne, Ur-Energy, Littleton

NMSS01

NRC Comment 1

Page D6-5 of Volume 7 (KM amendment) states:

> *At this time, lower confinement of the KM aquifer remains under investigation.*

LCI Response 1

LCI engaged Petrotek Engineering Corporation to design and run a model which included analysis of the lower confinement of the KM Horizon. Based on the results of the model and additional in-house geologic review, LCI has concluded its review of the lower confinement of the KM (see also LCI Response #4 below). As per the established process, LCI will collect additional site specific geologic and hydrologic information for each subsequent mine unit and submit the information to the NRC for review.

The language that NRC cites above has been removed from Page D6-5 of Volume 7 (KM amendment) and the replacement page is attached for NRC's insertion in the document.

The hydrologic model is included with this submittal for NRC's insertion into the application as Attachment D6-5 of the LC East Technical Report. Revised Table of Contents page D6-ii and page D6-11 are also included with this submittal for NRC's insertion into the document.

NRC Comment 2

Page D6-23 of Volume 8b (LC East amendment) states:

> *L Horizon is the underlying aquifer to the KM Horizon, but will require additional hydrologic characterization.*

NUREG-1569, "Standard Review Plan for In Situ Leach Uranium Extraction License Applications," states in acceptance criterion 2.6.3(4) that the characterization of the site geology and seismology is acceptable if "A geologic and geochemical description of the mineralized zone and the geologic units immediately surrounding the mineralized zone is provided."

LCI Response 2

Significant geologic and hydrologic information had been collected and included in the original application submitted to the NRC. In addition to that information, the hydrologic model discussed above provides insight into the hydrologic properties of the L Horizon and how it will respond to mining in the KM Horizon.

The language that NRC cites above has been removed from Page D6-23 of Volume 8b (LC East amendment) and the replacement page is attached for NRC's insertion in the document.

NRC Comment 3

Page 1 of Volume 8c (LC East amendment) states:

> *The pump test results demonstrated that there was no measureable hydraulic communication between the HJ and KM horizons in any of the five pump test areas. Additionally, there was no measureable hydraulic communication with the underlying N Horizon.*

During these pumping tests, the applicant did not measure the water levels in the L Horizon, which is the aquifer immediately underlying the KM horizon. Therefore, the hydraulic properties of the confining unit that underlies the KM horizon cannot be evaluated based on these tests. The request therefore does not meet acceptance criterion 2.7.3(3) which states: "The applicant should describe all hydraulic parameters used to determine expected operational and restoration performance."

LCI Response 3

The reviewer is correct that the particular pumptests referenced did not monitor the response of the L Horizon to pumping from the KM Horizon. However, several other pumptests at Lost Creek have involved monitoring the L Horizon while pumping from the KM Horizon, including the June 2009 test using pump well KPW-2, the June/July 2009 test using pump well KPW-1A, the April 2010 test using pump well MU-101, the November 2010 test using pump well KPW-3, and the October 2012 test using pump well 5S-KM3 (five spot injection test). Each of these five tests provided valuable data on the hydrologic characteristics of the K shale and the response in the L Horizon to pumping and/or injection in the KM Horizon. A geologic review indicates that the character of the K shale in the vicinity of these five pumptests is consistent with the character of the K shale throughout the Lost Creek and LC East Properties.

As previously mentioned, at least one to two additional pumptests will be performed for each mine unit. These pumptests will involve monitoring the drawdown response in the underlying aquifer (in the case of KM wellfields the L Horizon will be considered the underlying). The results of the pumptests, which will be submitted to the NRC for review, will be used to further refine our understanding of the K shale and potentially guide us to install additional underlying monitor wells if conditions warrant.

Finally, the information collected from the five pumptests was used by Petrotek Engineering Corporation to design and calibrate the hydrologic model. The eleven layer model provides valuable insight into the hydrologic performance expected during operations and restoration.

NRC Comment 4

Page D6-12 of Volume 7 (KM Amendment) states:

> *...the minor communication between the composite KLM Horizon and the overlying and underlying horizons can be managed through operational practices, detailed monitoring, and engineering operations.*

Page D6-25 of Volume 8b (LC East amendment) states:

> *The lower production zone aquifer (KM Horizon) is bounded by a laterally extensive upper confining unit, but a lower laterally extensive confining unit is absent. However, based on testing results to date, it is anticipated that the minor communication between the production \zones and the overlying and*

underlying horizons can be managed through operational practices, detailed monitoring and engineering operations.

The amendment requests do not provide any specific details regarding how the hydraulic communication between horizons will be managed. Acceptance criterion 3.1.3(5)(f)(i) is therefore not met which states, that an impact analysis is acceptable if it describes "The ability to control the migration of lixiviant from the production zones to the surrounding environs."

LCI Response 4

Please see LCI's response to item 1 with regard to the hydrologic model that was designed and run in part to determine the ability to control the migration of lixiviant from the production zones to the surrounding environs. Additionally, Section OP 3 of the LC East Technical report provides information on the methods that will be used to control mining solutions as well as monitor for and correct excursions if they occur. Specifically, hydraulic communication will be managed by maintaining an appropriate hydrologic bleed which will generate a hydrologic sink in the KM Horizon. The hydrologic model accounts for the hydrologic bleed and demonstrates the ability to control mining solutions. Control of lixiviant will be monitored by a series of monitor wells as described in the application. The placement of underlying monitor wells will comply with NRC requirements regarding density of wells but the thickness of the K shale will also be a factor in determining where monitor wells should be placed. Additional monitor wells will be placed in areas where the K shale is the thinnest in order to ensure mining lixiviant is controlled. The exact placement of underlying monitor wells will be provided in each respective mine unit data package submitted to the NRC per license requirements.

medium to coarse-grained arkosic sand, which occurs in multiple stacked units. The sand facies are commonly separated by multiple 'unnamed' shales of variable thickness which represent localized aquitards and aquicludes to vertical groundwater migration within the larger aquifer (see **Plates D5-2a to D5-2h**). The deepest sub-horizon, the Lower HJ (LHJ), is designated as the overlying aquifer to the proposed KM production orebody.

Sagebrush Shale

The Sagebrush Shale represents the confining aquiclude between the HJ production zone and the underlying proposed KM production zone. Its presence is regionally pervasive (see **Plate D5-3a**), and its confining characteristics have been demonstrated through pumping tests as described in later sections of this application.

KM Horizon

The secondary production zone in the Lost Creek Project, and the focus of this application, is the KM Horizon. The Upper KM (UKM) sub-horizon is commonly separated from the Lower KM (LKM) by a shale named the "No Name Shale". At the time of the original Mine Permit application, and prior to an adequate drill data base, LC ISR, LLC believed that the No Name Shale represented a confining aquiclude. Substantial drilling since that time has demonstrated that this is not the case. Rather it is one of several internal aquicludes which may be extensive, but do not show regional continuity.

Hydrogeologically, the KM Horizon can be considered confined with overlying confinement provided by the Sagebrush Shale. Underlying confinement is less apparent. Nominally, the K Shale represents the lower boundary of the KM Horizon. However, there are breaks in the continuity of the K Shale and pump-tests have shown it to be a leaky aquitard.

K Shale

The K Shale represents the lower boundary to the KM Horizon and serves as an aquitard. However, as stated above, it has been demonstrated to be leaky. Stratigraphic evaluations have shown it to be absent in small localities (see **Plate D5-3b**) and at times represented by multiple overlapping but not continuous shales.

L, M and N Horizons

Nominally, the L Horizon represents the underlying aquifer to the KM production orebody. The hydrogeological relationship of these Horizons to the KM is discussed in Attachment D6-5 of the LC East Amendment Technical Report. However, based on previous "Regional" and "Permit Area" scale pump test results, there is some demonstrated hydrogeologic communication between the KM

TABLES

ATTACHMENTS

- The computed aquifer characteristics (T, K and S) for the North and Central test areas are very similar to each other and comparable with values obtained from the Mine Unit 1 Regional and Permit pump tests. However, the computed aquifer characteristics for the South test area were significantly higher (100 to 150%) than those T, K and S values for either the North, Central or MU1 test results.

- The pump test results demonstrate that the HJ and KM Horizons have sufficient transmissivity for ISR operations. Due to the higher transmissivity values observed in Sections 20 and 21, it may be possible to operate mine patterns at higher flow rates or with wider injector/producer spacing in these areas. Modeling and/or field testing will be required to confirm this hypothesis.

- The preliminary findings indicate that the mapped faults, located in Section 21 are not sealed, but act as low-flow boundaries.

- An eleven layer numerical model was generated to simulate hydrologic control during situ recovery from the KM Horizon (see **Attachment D6-5**). The model simulations indicate lixiviant can be controlled within the KM Horizon with no migration into the HJ or L Horizons. The model was also used to "force" and excursion by operating the mine unit out of balance. The model indicates that an excursion into the L Horizon can be successfully recovered using engineering controls. Finally, the model indicates that underlying monitor wells in the L Horizon should be focused on areas where the K shale is the thinnest.

  - averages 115 feet thick;
  - top of unit is 95 to 260 feet bgs;
  - the HJ Horizon is unconfined on the east side of the Permit Amendment Area becoming confined as you move westerly in a down dip direction; and
  - water levels in the HJ Horizon range from 90 to 160 feet bgs.
- Sage Brush Shale (lower confining unit to the HJ Horizon and upper confining unit to the UKM Horizon):
  - laterally continuous across Permit Amendment Area;
  - five to 25 feet thick;
  - top of unit 90 to 285 feet bgs; and
  - confining properties demonstrated from water levels and pump tests.
- KM Horizon (production zone):
  - subdivided into UKM, MKM and LKM Sands;
  - massive coarse sandstones with thin lenticular fine sandstone intervals;
  - top of unit is 210 to 390 feet bgs;
  - UKM Sand is a targeted production zone and first underlying aquifer to the HJ production zone;
  - UKM Sand is 30 to 60 feet thick;
  - water levels in the UKM Sand are generally 145 to 175 feet bgs;
  - L Horizon is the underlying aquifer to the KM Horizon.

D6.5.2.2 Potentiometric Surface and Hydraulic Gradients

Potentiometric surfaces for the FG, HJ, KM and N Horizons are illustrated as contour maps on **Figures 2-5 to 2-8, Attachment D-4** and also on Cross Sections in **Plates D5.2-a to D5.2-j**. Depiction of these surfaces on the cross sections were generated by tracking the intersection of the plane of the cross section profile with the potentiometric contours for the given horizons.

Potentiometric surfaces of the HJ and KM Horizons indicates that groundwater flow across the Permit Amendment Area is to the west-southwest under hydraulic gradients between 0.005 to 0.018 ft/ft (29 to 95 ft/mi), which is generally consistent with the regional flow system. **Figures 2-6** and **2-7 Attachment D-4**, show the groundwater flow direction across the Permit Amendment Area based on the potentiometric surface.

Groundwater flow direction and hydraulic gradients for the overlying (FG) and underlying (N) Horizons are generally similar to that of the HJ and KM Horizons. Groundwater flow is toward the west-southwest at hydraulic gradients between 0.008 ft/ft to 0.019 ft/ft as shown in the potentiometric maps for the FG and N Horizons (**Attachment D-4, Figures 2-5** and **2-8**, respectively). The potentiometric heads decrease with depth. Differences in water level elevations between the FG, HJ, KM and

ATTACHMENT D6-5

Simulation and Assessment of Uranium In Situ Recovery from the KM Horizon, Lost Creek Project

Prepared by Petrotek Engineering Corporation

Lost Creek Project
LC East Amendment Technical Report
February 2016

Technical Memorandum

To: Lost Creek, ISR, LLC.

From: Petrotek Engineering Corporation

Date: January 26, 2016

Subject: Simulation and Assessment of Uranium In Situ Recovery from the KM Horizon, Lost Creek Project

Executive Summary

A numerical model was developed to simulate In Situ Recovery (ISR) of uranium from the KM Horizon of the Lost Creek Project (LCP) in Sweetwater County, Wyoming. The focus of the model was on the demonstration of hydraulic control, both horizontally and vertically, of production and restoration fluids throughout mining.

The model contains eleven layers representing the hydrostratigraphic interval from the HJ Horizon down through the N Horizon, with a total thickness of approximately 550 feet. The KM Horizon was subdivided into three layers within the model to account for the heterogeneity that may be present within that hydrostratigraphic unit. The model was calibrated to static potentiometric conditions and two separate pumping tests conducted within the KLM Horizon.

A series of simulations were run using the calibrated model to assess potential hydraulic impacts of ISR from the KM Horizon. Wellfields were simulated in each of the three separate model layers that represent the KM Horizon (each of which comprise a unique distribution of hydraulic conductivity). This provides a high degree of variability in potential outcomes.

The simulated wellfields consist of a series of repeating 5-spot well patterns. The wellfield consists of a total of 9 well patterns arranged in a 3 by 3 square configuration consisting of 9 extraction wells and 16 injection wells. Each extraction well is simulated at a rate of 20 gpm during production. The injection wells were assigned values based on their location within the 5-spot pattern such that the total injection rate is 99 percent of the total extraction rate. This amounts to a 1 percent bleed (overproduction) in order to maintain an inward gradient through production. The simulated wellfields are substantially smaller than what would be utilized during actual production of the KM Horizon. The simulation of a smaller wellfield than what will be actually employed was done for computational efficiency, and to allow more focus on individual well pattern hydraulics and vertical movement of injectate.

Particle tracking was used to simulate the flowpaths of injectate throughout production and restoration. Results of the ISR simulations indicate that the maximum horizontal flare within the KM Horizon (as determined from the injectate flowpaths) was less than 115 ft from the edge of the wellfield. Horizontal flare is defined as the movement of injectate outside of the wellfield boundary, but within the production zone, during production operations. Vertical flare is the movement of injectate outside of the production zone (either upward or downward) during production operations.

The model simulations overestimate the total flare that will occur during ISR operations for the following reasons. First, as previously indicated, the simulated wellfields are smaller than what will be utilized during actual production of the KM Horizon. Horizontal flare has been demonstrated to be scale dependent (Lewis Water Consultants,1999). Smaller wellfields typically have a higher ratio of perimeter length to total area than do larger wellfields. This corresponds to a greater ratio of exterior injection wells to interior injection wells, which usually results in a higher simulated horizontal flare. The flare resulting from these simulations is anticipated to be higher than what will occur in actual operation because of the smaller size of the simulated wellfields. Secondly, for these simulations extraction and injection was maintained at the same ratio and rates, regardless of the hydraulic conductivity of the zone that the wells are completed in, or the response of the aquifer (drawdown or rise). During actual operations, the rates would be adjusted to avoid excessive drawdown or rise in individual wells during production or restoration. However, for purposes of this modeling demonstration, the scenarios that are simulated provide an opportunity to assess hydraulic impacts under extreme conditions. The simulated flare is greater than what would occur if the wells located in the areas of low permeability were adjusted to lower flow rates to prevent excessive drawdown or rise during production.

In each simulation, groundwater sweep (GWS) was effective in reversing the hydraulic gradient and altering the injectate flowpaths back toward the wellfield. None of the ISR simulations indicated vertical flare into the overlying HJ Horizon or the underlying L Horizons when operations were conducted under balanced flow conditions.

An excursion scenario was developed in which a portion of the K Shale was absent and an injection well was operating “out of balance” at twice the rate compared to balanced simulations. In this simulation, some injectate was forced into the underlying L Horizon during production. However, GWS was effective in recovering the excursion. The excursion simulations confirm that application of engineering controls should be adequate to successfully recover an excursion into the underlying aquifer.

Based on the modeling results, placement of L Horizon monitor wells should coincide with areas where the K shale is known or suspected to be thin or possibly absent. The modeling demonstrates that it is difficult to simulate an excursion if there is a competent confining unit. The location of L Horizon monitor wells should be based on geologic interpretation of the K Shale, and not designed off a uniformly spaced grid. Placement of L Horizon monitor wells in areas where there is substantial shale/claystone thickness is unlikely to provide effective or efficient monitoring and should be avoided.

If the L Horizon is adequately monitored, no additional monitoring in the deeper M Horizon should be required. If an excursion to the L Horizon were to occur, it would be detected in the L Horizon monitor wells first. The probability of flare extending all the way through the L Horizon and the LM Shale and into the M Horizon (a vertical distance of over 100 feet) within the timeframes anticipated for production is very low.

Introduction

Lost Creek ISR, LLC (LC ISR) intends to extract uranium from the KM Horizon in the Lost Creek and Lost Creek East Project areas (LCP) using In Situ Recovery (ISR) mining. The LCP is located in Sweetwater County, in the northeastern portion of Great Divide Basin, Wyoming. LC ISR is currently producing uranium from the shallower HJ Horizon under a Source Materials License issued by the Nuclear Regulatory Commission and a Permit to Mine issued by the Wyoming Department of Environmental Quality.

Hydrologic testing has demonstrated some degree of vertical hydraulic communication between the KM Horizon and the underlying L and M Horizons. Petrotek Engineering Corporation (Petrotek) has developed a numerical model to simulate ISR mining of uranium from the KM Horizon to assess potential hydraulic impacts to the L and M Horizons. This report documents the development and results of the numerical modeling.

Purpose and Objectives

The numerical groundwater flow model was developed to support LC ISR in permitting, planning and operation of KM production within Resource Area 3 (RA3), which is considered to be representative of the entire LCP. The numerical model is used to assess potential impacts of ISR mining on the KM Horizon and underlying hydrostratigraphic units. Objectives of the numerical model include the following:

- simulate ISR mining of the KM Horizon within RA3;
- assess the movement of production and restoration fluids throughout ISR mining and restoration of the KM Horizon;
- evaluate the ability to hydraulically control those fluids under normal operating conditions; and
- evaluate the capability to recover an excursion to an underlying aquifer.

The model was developed to allow adequate discretization within the wellfields such that the impacts of individual wells can be discerned. This feature of the model will enable its use as a tool to assist LC ISR in the day-to-day operation of the ISR project.

Conceptual Model

LC ISR proposes to recover uranium from the KM Horizon within RA3 of the LCP. Uranium ISR mining is currently being successfully applied in the shallower HJ Horizon within Mine Unit 1. **Figure 1** shows the location of the two uranium production areas which partially overlap each other.

Hydrostratigraphy

Groundwater modeling is focused on the simulation of uranium ISR from the KM Horizon, and potential hydraulic impacts to underlying hydrostratigraphic units. The KM Horizon is a uranium-bearing interval within the Eocene-age Battle Spring Formation, and is the target production zone for RA3 of the LCP.

The hydrostratigraphic units within the Battle Spring Formation in the LCP that are of interest with respect to this modeling project are (in descending order):

- HJ Horizon(overlying aquifer),
- Sagebrush Shale (overlying confining unit),
- KM Horizon (production zone aquifer),
- K Shale (underlying confining unit),
- L Horizon (underlying aquifer),
- LM Shale,
- M Horizon,
- MN Shale, and
- N Horizon.

Figure 2 illustrates the vertical relationship of the hydrostratigraphic units included in the numerical model.

A summary description of these units is provided below. Description of unit thicknesses are based on geologic correlations and interpretations made by LC ISR geologists from electric logs of borings throughout the LCP. A summary of the geologic tops/picks used to generate the thicknesses of the hydrostratigraphic units included in the model is provided in **Attachment A**. The table does not include every boring that has been analyzed by LC ISR geologists, but provides a representative sampling of subsurface conditions, with an emphasis on the area of RA3.

The Production Zone evaluated in this modeling effort is the KM Horizon, which is a component of the composite KLM Horizon. The composite KLM Horizon is an informal unit that comprises the KM Horizon, the L Horizon and the M Horizon. Previous hydrologic testing (Petrotek 2009a, 2013a and 2013b) has indicated some degree of hydraulic communication between the hydrostratigraphic units of the composite KLM Horizon.

Similar to the other horizons in the LCP, the KM Horizon consists of multiple sandstone units interbedded with mudstones. The KM Horizon averages approximately 115 feet in thickness within RA3. Previous hydrologic testing (Petrotek 2009a, 2013a and 2013b) has indicated some degree of hydraulic communication between the KM Horizon and underlying hydrostratigraphic units within the LCP.

The KM Horizon is bounded above by the confining unit identified as the Sagebrush Shale. The Sagebrush Shale is continuous throughout the LCP, and ranges from 3 to 40 feet thick within RA3. Similar to other shale units, the Sagebrush Shale commonly consists of a composite of multiple shales which complexly interbed with overlying and underlying sandstone units.

Above the Sagebrush Shale is the HJ Horizon, which represents the overlying aquifer in this study. The HJ Horizon consists of multiple sandstone units interbedded with mudstones. The HJ Horizon is continuous throughout the LCP and ranges from 100 to 150 feet thick, with an average thickness of approximately 120 feet. This unit is also the current Production Zone in Mine Unit 1, which partially overlaps RA3.

Beneath the KM Horizon is a low permeability unit identified as the K Shale. The K Shale is a sequence of interbedded shales/mudstones, silts and sands. The K Shale is continuous throughout RA3 and ranges from 2 to 38 feet thick. The average net shale thickness within the K Shale interval is 15 feet (2015 personal communication with LC ISR geologists). The K Shale is the confining layer that separates the underlying L Horizon and the Production Zone KM Horizon.

The underlying aquifer is designated as the L Horizon. The L Horizon consists of multiple sandstone units interbedded with mudstones. The total thickness of the L Horizon ranges from 40 to 110 feet, averaging approximately 80 feet within RA3. The L Horizon is continuous throughout RA3 and the LCP.

Underlying the L Horizon is a low permeability unit identified as the LM Shale. The LM Shale is a sequence of interbedded shales/mudstones, silts and sands. The LM Shale is continuous throughout RA3 and ranges from 3 to 45 feet thick, with typical thickness of 15 to 20 feet. The LM Shale is the confining layer that separates the L Horizon and the M Horizon.

The M Horizon is the deepest stratigraphic unit within the composite KLM Horizon. The M Horizon consists of multiple sandstone units interbedded with shales/mudstones. This unit is from 85 to 97 feet thick within RA3.

The MN Shale is a zone of interfingering layers of mudstone, siltstone, and shale that separates the M Horizon from the deeper N Horizon. It ranges from approximately 5 to 40 feet thick, with a typical thickness of about 10 to 20 feet.

Beneath the MN Shale is the N Horizon. Based on limited data, the total thickness of the N Horizon is approximately 100 feet.

Structure

Within the LCP, the Battle Spring Formation dips to the west at approximately three degrees. A series of normal faults are located within the LCP. The main fault, identified as the Lost Creek Fault, is oriented in a west-southwest to east-northeast direction that cuts across RA3. The main fault (identified as the Lost Creek Fault) bisects the northwestern portion of RA3, and is downthrown to the south, with displacement of approximately 60 to 70 feet. A subsidiary splay fault splits from the main fault to the south for a limited distance in the central portions of RA3 (**Figure 1**). Displacement on the splay fault is 20 feet or less.

Hydrology

LC ISR and Petrotek performed multiple hydrologic studies and tests to characterize the aquifer properties of the KM Horizon and the overlying and underlying hydrostratigraphic units. Some of the key reports describing these hydrologic studies include “Lost Creek Hydrologic Testing-KM Horizon Hydrologic Testing” (Petrotek 2009a), “Lost Creek Hydrologic Testing-Mine Unit 1 North and South Tests” (Petrotek 2009b), “Lost Creek Hydrologic Test, Composite KLM Horizon Regional Pump Test. October 2011” (Petrotek, 2013a), and “Lost Creek Hydrologic Test, Composite KLM Horizon 5-Spot Testing, October 2012” (Petrotek, 2013b).

Key findings of those studies are summarized below.

- Potentiometric data from the HJ, KM, L, and M Horizons indicate a west-southwest groundwater flow direction. **Figure 3** shows the potentiometric surface of the KM Horizon in October 2011.
    - There are insufficient data points in the N Horizon to make a determination of flow direction in that unit although it is assumed to be similar to that of the overlying hydrostratigraphic units.
- Horizontal hydraulic gradients are on the order of 0.004 to 0.007 ft/ft for the KM Horizon, 0.005 to 0.009 ft/ft for the HJ Horizon, and 0.004 to 0.006 ft/ft for the L and M Horizons.
- Vertical hydraulic gradients exist between the HJ, KM, L, M and N Horizons.
    - Potentiometric heads generally decrease with depth indicating a net downward vertical potential.

  - In most areas, the difference in potentiometric heads is greatest between the HJ Horizon and the deeper Horizons. The vertical hydraulic gradient between the HJ Horizon and the KM Horizon is typically from 0.1 to 0.3 ft/ft.
  - Potentiometric differences between the KM, L and M Horizons tend to be smaller, consistent with pumping test data that indicate vertical communication between these units. The vertical gradients between the KM Horizon and the L and M Horizons are from 0.02 and 0.1 ft/ft.
  - Based on two control points, the potentiometric heads in the N Horizon are approximately 5 feet lower than in the M Horizon.
- The Lost Creek fault acts as a partial barrier to groundwater flow within the HJ, KM, L and M Horizons.
  - The ability of the fault to impede groundwater flow appears to be greater in the HJ Horizon than in the KM Horizon, based on potentiometric data and pumping test results.
- Aquifer properties of the KM Horizon were estimated from the KM Horizon Regional Pump Test (Petrotek 2013a) and the 5-Spot Test (Petrotek 2013b).
  - Transmissivity of the KM Horizon ranges from 100 to 260 ft^2/d.
  - Hydraulic conductivity in the KM Horizon ranges from 0.9 to 2.2ft/d.
  - Storativity of the KM Horizon ranges from 3.5E-05 to 4.2E-04.
  - Notable drawdown response was observed in the underlying L and M Horizon observation wells during these tests. The aquifer properties for the KM Horizon were calculated assuming a non-leaky aquifer system (i.e., no contribution from anything other than the KM Horizon). Therefore, the values cited above for the KM Horizon should be considered as overestimates of the actual aquifer properties for that unit.
- Pumping tests demonstrate lateral hydraulic communication within the KM Horizon, with some restriction of flow across the Lost Creek Fault.
- Aquifer properties of the HJ Horizon were estimated from the Mine Unit 1 Hydrologic Tests (Petrotek 2009b).
  - Transmissivity of the HJ Horizon ranges from 50 to 130 ft^2/d.
  - Hydraulic conductivity of the HJ Horizon ranges from 0.4 to 1.1ft/d.
  - Storativity of the HJ Horizon ranges from 3.6 E-05 to 4.2 E-04.
- Pumping tests demonstrate lateral hydraulic communication within the HJ Horizon, with some restriction of flow across the Lost Creek Fault.
- Pumping tests demonstrate limited hydraulic communication between the KM Horizon and the overlying HJ Horizon, similar in magnitude to responses observed at other ISR facilities where engineering practices are successful in containing lixiviant within the Production Zone.

- Aquifer properties of the L, M and N Horizons were not determined directly as no pumping tests were conducted in those units. However, geologically these units appear very similar to the HJ and KM Horizons, and are assumed to have similar values of transmissivity, hydraulic conductivity and storativity.
- Pumping tests demonstrate quantifiable hydraulic communication between the KM Horizon and the underlying L and M Horizons.
    - Drawdown propagation decreases with depth below the KM Horizon.
- A 5-Spot hydrologic test in the KM Horizon, which included a nearly balanced extraction and injection condition (similar to what would occur in typical ISR), indicated minimal response in the underlying L and M Horizons.

There are no known sources of groundwater discharge, other than pumping wells, within the LCP. No direct recharge via infiltration of precipitation or streamflow to the HJ through N Horizons occurs within the LCP (there are a couple of shallower aquifers above the HJ Horizon). Recharge to the HJ through N Horizons occurs either from regional lateral flow within the specific units or from interflow between adjacent overlying or underlying units.

As previously indicated, the KM Horizon hosts uranium mineralization, and is the target Production Zone for RA3. Pumping tests have shown a notable degree of hydraulic communication between the KM, L and M Horizons.

Based on discussions with LC ISR, the typical completion interval for well patterns within RA3 will be 18 feet thick. Anticipated production rates will be 20 gallons per minute (gpm) per well pattern, all of which will be reinjected with the exception of an approximate net 1.0 percent bleed (overproduction).

Model Code

The model code used to simulate the hydraulic effects of ISR mining of the KM horizon isMODFLOW-2000 (Harbaugh et al 2000). MODFLOW-2000 is a public domain computer code developed by the U.S. Geological Survey that numerically solves the groundwater flow equation for a porous medium using a finite difference method. MODFLOW-2000 is an enhanced version of the widely used MODFLOW code that has been updated several times (McDonald and Harbaugh 1988, and Harbaugh and McDonald 1996). Like its predecessors, MODFLOW-2000 simulates groundwater flow using a block-centered, finite-difference approach that is capable of a wide array of boundary conditions. The code can simulate aquifer conditions as unconfined, confined, or a combination of the two. MODFLOW-2000 also supports variable thickness layers (i.e. variable aquifer bottoms and tops). Documentation of all aspects of the MODFLOW-2000 code is provided in the user manuals (Harbaugh and others 2000).

A particle-tracking code is utilized that readily incorporates information collected from the MODFLOW groundwater flow model. The code is MODPATH, Version 5 (Pollock, 1994), which is designed to use the output head files from MODFLOW to calculate particle velocity changes over time in three dimensions. MODPATH is used to provide computations of groundwater seepage velocities and groundwater flow directions at the site. MODPATH is also a public domain code that is well accepted in the scientific community. Full documentation of the MODPATH code is provided in the MODPATH users guide (Pollock 1994). Dispersion and diffusion are not examined as part of this modeling effort.

The pre/post-processor Groundwater Vistas (Environmental Simulations 2011) is used to assist with input of model parameters and output of model results. Groundwater Vistas serves as a direct interface with MODFLOW which enhances model processing. Groundwater Vistas provides an extensive set of tools for developing, modifying and calibrating numerical models and allows for ease of transition between the groundwater flow and particle tracking codes. Full description of the Groundwater Vistas program is provided in the “Guide to Using Groundwater Vistas, Version 6.0” (Environmental Simulations 2011).

Calibration of the models was accomplished using the model independent parameter estimation software PEST. PEST is a non-linear parameter estimation package based on weighted least squares and a robust implementation of the Gauss-Marquardt-Levenburg method. Full documentation of the PEST code is provided in the “PEST User Manual, 5th Edition” (Doherty 2010).

Model Development

The primary objective of the model is to assess potential hydraulic impacts of ISR production from the KM Horizon on the underlying L and M Horizons. The model development focused on the vertical relationship between the KM Horizon and the underlying L, M and N Horizons within the area of the proposed KM Mine Unit (RA3). However, the overlying HJ Horizon and the deeper N Horizon were also included in the model development in order to assess any potential impacts to those units.

The model domain is rotated 45 degrees east of north to align the x-axis of the model with the predominant groundwater flow direction (to the southwest). The x-axis and y-axis model dimensions are 10,210 and 9,000 feet, respectively. The 5-Spot Test site is located in the center of the model domain. The extent of the model domain is illustrated on **Figure 4**.

The model grid was designed to provide adequate spatial resolution within the proposed KM Mine Unit in order to simulate response of the aquifer to typical extraction and injection rates anticipated for ISR production of the KM Horizon. Cell dimensions within the vicinity of the 5-Spot Test are 6.25 feet by 6.25 feet. Cell dimensions are gradually increased to a maximum size of 100 feet by 100 feet near the edges of the model. The model consists of 208 rows and 294 columns with 11 layers and contains 672,672 cells.

The eleven layers of the model represent, from shallowest to deepest, the following:

- HJ Horizon,
- Sagebrush Shale,
- KM Horizon
    - (divided into three layers representing an upper, middle and lower portion of that unit),
- K Shale,
- L Horizon,
- LM Shale,
- M Horizon,
- MN Shale, and
- N Horizon.

Figure 2 shows the relationship of the model layers. Within the project area, the top and bottom elevation of each of the stratigraphic units included in the model are based on interpretations and correlations provided by LC ISR geologists. The geologic dips of the stratigraphic units are projected out to the limits of the model domain. It is assumed that each of the units included in the model extends out to the edge of the model domain (that there are no stratigraphic pinchouts). The top and bottom elevation of the KM Horizon across the model domain are shown on **Figures 5**, and **6**, respectively.

Boundary conditions imposed on a numerical model define the external geometry of the groundwater flow system being studied as well as internal sources and sinks. Descriptions of the types of boundary conditions that can be implemented with the MODFLOW code are found in McDonald and Harbaugh (1988). The general-head boundary (GHB) condition was used to represent groundwater flow into and out of the model domain along the perimeter of the model domain. GHBs were used to establish the hydraulic gradient for the HJ, KM, L, M, and N Horizons across the model domain. GHBs were used because the groundwater elevation at those boundaries can change in response to simulated stresses. The values of head assigned to the GHBs on the model were based on the projection of the potentiometric surface for each of those Horizons, as determined from the October 2011 water level measurements. GHBs are placed along the northeast and southwest boundaries of the model domain.

The well package of MODFLOW was used to simulate pumping from the KM Horizon during model calibration and production simulations. Rates and locations of simulated wells are described in the calibration and production simulation sections of this report.

Aquifer Properties

Aquifer properties that were considered in the development of the model, in addition to top and bottom elevation of the various modeled units, include hydraulic conductivity and storativity and porosity. MODFLOW-2000 utilizes the specific storage coefficient (which is defined as the storativity divided by the saturated thickness of the aquifer).

Hydraulic conductivity and storativity were estimated during the calibration process as described in the following section.

A uniform porosity of 25 percent was assumed, based on communication with LC ISR geologists. Porosity is only used in the calculation of groundwater velocity in the particle tracking function of MODPATH.

The faults within the LCP previously described are simulated within the KM model by the use of discrete hydrologic conductivity zones. The numeric values of these zones were varied as part of the calibration process as described below.

Calibration

Groundwater flow model calibration is an integral component of groundwater modeling applications. Calibration of a numerical groundwater flow model is the process of adjusting model parameters to obtain a reasonable match between field measured values and model predicted values of heads and fluxes (Woessner and Anderson 1992). The calibration procedure is generally performed by varying estimates of model parameters (hydraulic properties) and/or boundary condition values from a set of initial estimates until an acceptable match of simulated and observed water levels, drawdown and/or flux is achieved. Calibration can be accomplished using trial and error methods or automated techniques (often referred to as inverse modeling). The KM groundwater model was calibrated using a combination of trial and error, and inverse modeling methods (using PEST).

The adequacy of model calibration is judged by examining model residuals. A residual, as defined for use in this modeling report, is the difference between an observed water level measurement and the water level predicted by the model. The KM model was calibrated to both absolute groundwater elevations, as well as the net change in water levels measured during pumping tests (drawdown). The objective of model calibration should be the minimization of the residual mean, residual standard deviation, and residual sum of squares (RSS) (Duffield et al 1990). The mean residual is the arithmetic average of all the differences between observed and computed water levels.

A positive sign indicates that the model has under-predicted the observed drawdown level and a negative sign indicates over-prediction. The residual standard deviation quantifies the spread of the differences between observed and predicted drawdown around the mean residual. The ratio of residual standard deviation to the total head change across the model domain should be small, indicating the residual errors are only a small part of the overall model response (Woessner and Anderson 1992). The RSS is computed by adding the square of each residual and is another measure of overall variability. The overall objective during the calibration process is to minimize the residuals, and the statistics based on the residual, while maintaining aquifer properties within the range of reasonably expected values.

Calibration Simulations

The KM Horizon numerical model was calibrated to water level measurements collected at the site in October 2011 and drawdown data from two separate KM pumping tests, one conducted in October 2011 and the other in October 2012. Calibration of the groundwater model to multiple data sets and types increases the confidence that the model can adequately represent hydrologic conditions at the site.

The October 2011 measurement round represents the most complete water level data set collected at the site, and includes monitoring wells completed in the HJ, KM, L, M, and N Horizons. Water level measurements from 83 monitor wells were included in the calibration. The October 2011 water level data were used to calibrate the model to "steady state" groundwater flow conditions (non-pumping) in the HJ, KM, L, M, and N Horizons within the LCP. The October 2011 water level measurements were conducted prior to the regional KM hydrologic test described below.

Drawdown data from the regional Composite KLM Horizon hydrologic test conducted in October 2011 were also used to calibrate the model. For the 2011 Composite KLM Horizon test, well KPW-3 (completed in the KM Horizon) was pumped for a period of 4.9 days at an average rate of 70 gpm. Wells completed in the KM, HJ, L, M and N Horizons were monitored during the test. The total drawdown measured in 77 monitoring wells and in the pumping well were used as calibration targets. Details of that test are found in the report "Lost Creek Hydrologic Test, Composite KLM Horizon Regional Pump Test, October 2011" (Petrotek, 2013a). **Table 1** provides data for the wells used in the calibration of the steady state portion of the model and in the calibration of the model to the 2011 Composite KLM Horizon Test.

Additionally, the KM Horizon model was calibrated to drawdown data from the 5-Spot Hydrologic Test conducted in October 2012. Well 5S-KM3 (completed in the upper portion of the KM Horizon) was pumped for 3.1 days at an average rate of 28.5 gpm.

Wells completed in the HJ, KM, L, M and N Horizons were monitored during the test. Because there were a number of relatively closely spaced wells that were monitored during the 5 Spot Test, the model grid was minimized in that portion of the model (with cell sizes of 6.25 ft by 6.25 ft). This allowed for better resolution of the flow field and drawdown resulting from the 5-Spot pumping test. The total drawdown measured in 8 monitor wells and the pumping well were used as calibration targets. Details of that test are found in the report “Lost Creek Hydrologic Test, Composite KLM Horizon 5-Spot Testing, October 2011” (Petrotek, 2013b). **Table 2** provides data for the wells used in the calibration of the model to the Composite KLM Horizon 5-Spot Test.

The calibration simulation was set up with four stress periods. The initial period represents groundwater flow within the Composite KLM Horizon (and the overlying HJ Horizon and underlying N Horizon) under steady-state (non-pumping) conditions. The second stress period simulates the October 2011 regional Composite KLM Horizon hydrologic test. The third period represents an equilibration period, where water levels were allowed to return to steady state conditions. The fourth stress period represents the 5-Spot KM extraction test conducted in October 2012.

Each of the model layers were assigned discrete zones of hydraulic conductivity (**Table 3).** Increased discretization (i.e. a larger number of zones) was utilized in the model layers where there were more water level measurements (i.e., where there were more monitoring wells). This allowed for greater flexibility during parameter estimation in fitting the simulated values to the actual observed measurements. The model layers representing the production zone and overlying and underlying aquifers (HJ, KM, L, and M Horizons) were subdivided into numerous hydraulic conductivity units (generally between 10 and 20 zones). The model layers representing the confining units (Sagebrush Shale, K Shale, L-M Shale and the M-N Shale) were only assigned a few zones because there were no observations (water level measurements) in any of those layers. No wells are completed in those units. The N horizon was also only assigned a few discrete hydraulic conductivity zones as there are only two wells completed in that interval.

As previously indicated, the KM Horizon averages approximately 115 feet in thickness within RA3 and consists of multiple sandstone units interbedded with mudstones. As is typical in many uranium roll front deposits, mineralization within the KM Horizon is present in stacked ore zones. During ISR production, well patterns will be completed over discrete intervals of typically 15 to 20 feet. In order to allow for a more representative simulation of mining of the KM Horizon using ISR (wherein wellfields would only be completed over a portion of the total KM Horizon thickness), the KM Horizon was subdivided into three separate layers. To represent the vertical heterogeneity that would be expected in a hydrostratigraphic interval characterized by interbedded sands and mudstones, the hydraulic conductivity zones within the three layers of the KM Horizon were allowed to vary independently during calibration. The heterogeneity simulated in the model provides a reasonable representation of subsurface conditions exhibited in borehole logs.

It should also be noted that the extraction well and the four injection wells used in the 5-Spot Test (Petrotek 2013b) were all completed in only the upper portion of the KM Horizon. Subdividing the KM Horizon into 3 distinct layers allowed for a more representative calibration to the 5-Spot Test.

The faults were represented as discrete hydraulic conductivity zones in each of the model layers. Evidence from the water level measurements and pumping tests indicates that the transmissive nature of the faults varies with depth and hydrostratigraphic interval. For example, the main Lost Creek Fault that bisects Mine Unit 1 is a greater barrier to groundwater flow in the HJ Horizon than in the KM Horizon (Petrotek 2013a).

A total of 113 hydraulic conductivity zones were included in the model. **Figures 7** through **9** show the final distribution and values of hydraulic conductivity following completion of model calibration for the 3 layers representing the KM Horizon. **Table 3** summarizes the layer and value for each hydraulic conductivity zone.

The storage coefficient was also set up as separate zones within the model. However, initial attempts at calibration revealed that the parameter estimation process was not very sensitive to the storage coefficient. Therefore, a single value was used in each of the layers with the exception of the layers representing the KM Horizon (Layers 3, 4 and 5). A separate zone was assigned in the vicinity of the two pumping wells in each of those layers. **Table 4** summarizes the layer and value for each storage coefficient zone.

Calibration Results

The calibration simulation was set up to replicate the pumping rate and duration for each of the two pumping tests previously described. The drawdown in the pumping wells and observation wells at the end of each of the two pumping tests were used as calibration targets.

Calibration was achieved by first comparing field-measured (observed) water levels in the observation/monitoring wells with heads predicted by MODFLOW-2000 for the same wells under simulated steady state conditions of the HJ, KM, L, M and N aquifers. Then, the model results were compared to the final drawdown at the end of the October 2011 and 2012 pumping tests. Initial trial and error methods were used to provide a generalized “match” to the water level and drawdown observations. PEST was used to optimize the calibration for each of the three simulated conditions (steady state and two pumping tests). The hydraulic conductivity zones, and GHB heads were adjusted until the best fit to the average potentiometric surface observed in the monitor wells was achieved.

The potentiometric surface of the steady state portion of the final calibration simulations for the HJ, KM, L and M Horizons are shown on **Figures 10** through **13**. The potentiometric surface for the N Horizon is not shown because there are only two wells completed in that hydrostratigraphic interval. Calibration residuals for the steady state targets for each of the Horizons are shown on the figures. A plot of the observed versus simulated heads for all of the steady state targets is shown on **Figure 14**. Calibration statistics from the steady state calibration simulation are listed in **Table 5**.

The simulated drawdown in the KM Horizon at the end of the October 2011 KM Regional test and the end of the 2012 5-Spot Test are shown on **Figures 15** and **16**, respectively. The difference between the simulated and observed drawdown values at the target locations are also shown on the figures. One of the wells monitored during the 5 Spot Test had more than twice as much drawdown as other observation wells that were a similar distance from the pumping well (well M-UKM1, **Table 7**). Extensive efforts to match the anomalous drawdown at the well were unsuccessful. Rather than skew the calibration to fit the single anomalous observation at the expense of the hundreds of other observations used in the overall calibration, the decision was made to weight that drawdown target much lower than the other drawdown observations. A plot of the observed versus simulated drawdown for the October 2011 and October 2012 pumping tests are shown on **Figures 17** and **18**, respectively. Calibration statistics from the October 2011 KM regional Test and the 2012 5-Spot Test simulation are listed in **Table 6** and **7**, respectively.

The calibration simulation provides a reasonably good match to each of the three target sets. The residual mean, the difference between the observed and simulated target value, was generally small for each target. The input and output files for the calibration simulation are provided electronically in **Attachment B**.

ISR Production/Restoration Simulations

The primary objective of this modeling effort is to assess potential hydraulic impacts of ISR from the KM Horizon on the overlying and underlying aquifers. The previously calibrated model was modified in order to simulate ISR scale production and restoration operations. The initial condition for the ISR simulations was based on the potentiometric surface determined from the steady state portion of the calibration simulation. The hydraulic conductivity, specific storage and the GHB heads were adjusted in the calibration simulation to provide a reasonable match to potentiometric surface data representative of steady-state conditions and to drawdown data from two separate pumping tests. The calibrated model was then used to simulate ISR production and restoration from the KM Horizon.

The simulated wellfields consist of a series of repeating 5-spot well patterns. The well package of MODFLOW was used to simulate extraction and injection in the 5-spot well patterns of the wellfields. The wellfield consists of a total of 9 well patterns arranged in a 3 by 3 square configuration consisting of 9 extraction wells and 16 injection wells (**Figure 19**). The distance from the extraction well to each of the injection wells is approximately 70 ft., and the distance between extraction wells in each well pattern is approximately 100 ft.

Note that the simulated wellfield is substantially smaller than what would be utilized during actual production of the KM Horizon. In fact, a single header house in RA3 would include more than double the number of wells that are simulated in these models (and the entire wellfield would be comprised of multiple header houses). The simulation of a smaller wellfield than what will be actually employed was done for computational efficiency, and to allow more focus on individual well pattern hydraulics. One downside to this approach is that wellfield flare (the area contacted by lixiviant that is outside of the wellfield footprint) is somewhat scale dependent. Smaller wellfields generally show higher apparent wellfield flare than larger ones (Lewis Water Consultants 1999). This is true because wellfield flare tends to occur predominately along the outer edges of the wellfield, where the hydraulic control is not as strong and the injection into the outermost injection wells is more likely to move, at least temporarily, outside of the wellfield footprint. In general, smaller wellfields have a higher ratio of perimeter length to total area than do larger wellfields. This corresponds to a greater ratio of exterior injection wells to interior injection wells, which usually results in a higher simulated wellfield flare.

As previously described, in the calibration simulation the grid size was smallest in the area of the 5-Spot Test (6.25 ft. by 6.25 ft.). In order to allow adequate discretization within the wellfields such that the impacts of individual wells can be discerned, the finer grid size in the vicinity of the 5-Spot Test was expanded slightly. This was accomplished by splitting several of the rows and columns in the model in the vicinity of the 5-Spot Test. As a result, the model domain increased to a total of 238 rows and 320 columns. However, the total dimensions of the x-axis and y-axis of the model (10,210 and 9,000 feet, respectively) remained the same as for the calibration simulation. This allowed for placement of the entire 9 well pattern wellfield within the finer grid portion of the model.

Multiple simulations were run in which the wellfield was placed in either the upper (layer 3), middle (layer 4), or lower (layer 5) portion of the KM Horizon. Each of the simulations provided a different set of conditions with respect to overlying and underlying (and lateral) conditions relative to the wellfield. For the simulation of a wellfield in the upper KM Horizon, the overlying hydrostratigraphic unit is the Sagebrush Shale and the lower hydrostratigraphic unit is the middle KM Horizon. For the simulation of a wellfield in the middle KM Horizon, the overlying hydrostratigraphic unit is the upper KM Horizon and the lower hydrostratigraphic unit is the lower KM Horizon. The simulation of the wellfield in the lower KM Horizon represents an upper boundary of the middle KM Horizon and a lower bounding unit of the K Shale. Because the hydraulic conductivity zone values are different in each of the three layers of the KM Horizon, each simulation represents variable hydrologic conditions for ISR operations. The relative position of the 9 well pattern wellfield relative to RA3 is shown on **Figure 19**.

Each extraction well is simulated at a rate of 20 gpm during production. The injection wells were assigned values based on their location within the 5-spot pattern such that the total injection rate is 99 percent of the total extraction rate. This amounts to a 1 percent bleed (overproduction) in order to maintain an inward gradient through production. The rates for the extraction/injection wells during production are summarized below.

- Extraction - 20.0 gpm
- Interior Injection - 19.8 gpm
- Exterior Side Injection - 9.9 gpm
- Exterior Corner Injection - 4.95 gpm

Based on discussions with LC ISR personnel, production is anticipated to continue for each well pattern until 50 pore volumes (PVs) are recovered. A pore volume (PV) for purpose of determining the duration of production is calculated as the area inside of a well pattern multiplied by the completion thickness, multiplied by the effective porosity. Each of the well patterns has dimensions of approximately 100 feet by 100 feet, with a thickness of 18 feet and an effective porosity of 25 percent. Therefore a single PV is calculated as:

1 PV =100ft x 100ft x 18ft x 0.25 = 45,000 ft^3 = 45,000 ft^3 x 7.48 gal/ft^3 = 336,600 gallons,

and

50 PV = 336,600 gal x 50 = 16,830,000 gallons.

The duration of production, at the simulated rate of 20 gpm per pattern, is calculated as:

16,830,000 gal ÷ 20 gpm = 841,500 minutes = 841,500 min ÷ 1,440 min/day= 584.4 days.

The production period for each simulation was run for 585 days.

The simulated production period of 585 days was immediately followed by simulation of aquifer restoration. LC ISR has indicated that restoration at RA3 will include groundwater sweep (GWS) for an equivalent of 1/3 of a PV followed by reverse osmosis (RO) treatment and reinjection for 6 PVs. For purposes of this modeling effort, only GWS was simulated, although for a total of 4 PV instead of 1/3 PV. The longer simulation of GWS than is actually planned provides a better representation of the extended period of restoration (and maintenance of an inward hydraulic gradient) that will occur with the inclusion of RO.

The GWS extraction rate was simulated at 10 gpm per extraction well (half of the production extraction rate). Using the same PV calculation as previously results in a restoration time as follows:

4 PV=4 x 336,600 gal ÷ 10 gpm=134,640 minutes=134,640 min ÷ 1,440 min/day=93.5 days.

The restoration period for each simulation was rounded up to 100 days.

Particle tracking is utilized to assess the simulated movement of production and restoration fluids during ISR operations. The MODPATH code is used to simulate the movement of particles (Pollock 1994). Particles are placed at each of the injection wells at multiple depth intervals within the layer of injection. The starting position of the particles in the model cells with injection wells are in the middle of the layer and at the 0.3 and 0.7 fractional portion of the layer. (For example, if a layer was 30 feet thick, then the particles are released at 9 feet, 15 feet and 21 feet from the bottom of the layer).

ISR Simulation Results

A series of simulations were run to assess potential hydraulic impacts of ISR from the KM Horizon. Simulating distinct wellfields in the three separate model layers that represent the KM Horizon (each of which comprise a unique distribution of hydraulic conductivity), provides a high degree of variability in potential outcomes.

Upper KM Horizon ISR Simulation

One ISR simulation includes a wellfield in the upper KM Horizon (layer 3 of the model). In this simulation, the overlying hydrostratigraphic unit is the Sagebrush Shale (layer 2) and the lower hydrostratigraphic unit is the middle KM Horizon (layer 4). During the production period, the total extraction from the 9 pattern wellfield is 180 gpm. Total injection during the production period is 178.2 gpm, for a net 1 percent bleed. During GWS, each of the extraction wells are simulated at a rate of 10 gpm for a total wellfield recovery rate of 90 gpm. The injection wells are not pumped during simulation of GWS.

Figure 20 shows the simulated drawdown within the upper KM Horizon in the vicinity of the wellfield at the end of production. The pattern of drawdown appears very irregular with relatively large changes in water levels occurring in the southeast corner of the wellfield and comparatively smaller changes to the northwest. The drawdown pattern is more readily understood when the hydraulic conductivity zones for this model layer in the wellfield area also shown (**Figure 21**). The area with the largest net change in water levels coincide with the zones of considerably lower hydraulic conductivity values. In actual field conditions, the operator would recognize that the wells completed in this low permeability area would be unable to sustain the 20 gpm production/injection rates that were planned for this wellfield and would reduce the flow accordingly. However, for purposes of this modeling demonstration, the scenario that is simulated provides an opportunity to assess hydraulic impacts under extreme conditions.

In the upper KM Horizon ISR simulation, the extraction well showing the greatest impact at the end of production has over 125 feet of drawdown (**Figure 20**). The injection well with the largest net change shows a rise of almost 300 feet. At the end of GWS, most of the wellfield shows over 60 feet of drawdown (**Figure 22**).

Particle tracking is used to identify flowpaths of injectate as the fluids move from the injection well toward the extraction wells. **Figure 23** indicates injectate flowpaths in the upper KM Horizon through the production phase. The figure indicates that some particles near the southeast portion of the wellfield (in the area of very low permeability) appear to be moving away from the wellfield at the end of production. Essentially all of the particles that have moved outside of the wellfield outline during production originated from injection wells located along the outer edge of the simulated wellfield. As previously described, the small size of the simulated wellfield results in a larger than anticipated horizontal flare (movement of particles outside of the footprint of the wellfield). If a larger wellfield were simulated, the ratio of exterior injection wells to interior injection wells would be smaller, resulting in a relative reduction in the horizontal flare factor. The horizontal flare factor is the ratio of total area contacted by lixiviant within the production zone to the area inside the footprint of the wellfield.

The maximum distance traveled by any particle outside of the wellfield is approximately 100 feet. The effectiveness of GWS in recovering those particles that moved outside of the wellfield within the upper KM Horizon during production is shown on **Figure 24**. The hydraulic gradient around the entire perimeter of the wellfield is inward toward the wellfield. This figure only shows the continuation of flowpaths of particles that were not captured by the extraction wells during production. During GWS, each of the particles are moving back toward the wellfield.

Within the middle KM Horizon there is a net drawdown of 0.5 to 7 feet within the footprint of the upper KM Horizon wellfield at the end of production (**Figure 25**). There are several particles that have migrated from the upper KM Horizon into the middle KM Horizon during production (**Figure 25**). However, almost all of the particles are moving inward to the wellfield as they are still within the capture zone of the extraction wells. **Figure 26** shows a cross-sectional view (along row 115 of the model) of the particle tracking at the end of production. One particle flowpath skims the upper surface of the lower KM Horizon. **Figure 27** shows a cross-sectional view at the end of the simulated GWS of the particles that were still active (not captured by extraction wells) after completion of production. Almost all of the particles have moved back into the upper KM Horizon wellfield footprint at the end of the simulated GWS. At no time during production or GWS did any particles enter into the overlying Sagebrush Shale.

Middle KM Horizon ISR Simulation

An ISR simulation was run that includes a wellfield placed in the middle KM Horizon (layer 4 of the model). In this simulation, the overlying hydrostratigraphic unit is the upper KM Horizon and the lower hydrostratigraphic unit is the lower KM Horizon. Extraction and injection rates were identical to the upper KM Horizon ISR simulation previously described.

The simulated drawdown within the middle KM Horizon in the vicinity of the wellfield at the end of production is illustrated in **Figure 28**. The pattern of drawdown indicates relatively larger changes in water levels occurring in the southeast portion of the wellfield and comparatively smaller changes to the west. As was the case for the upper KM Horizon simulation, the hydraulic conductivity is substantially higher in the west-northwest portion of the wellfield in this model layer. In the middle KM Horizon ISR simulation, the extraction well showing the greatest impact at the end of production has approximately 90 feet of drawdown (**Figure 28**). Some of the interior injection wells have over 60 feet of rise in water levels at the end of production.

Particle tracking is used to identify injectate flowpaths in the middle KM Horizon during production (**Figure 29**). Some particles along the southeast edge of the wellfield appear to be moving away from the wellfield at the end of production. Again, that area coincides with the simulation of lower permeability units. The maximum distance traveled at the end of production is approximately 110 feet outside of the wellfield. **Figure 30** shows the particle traces after the 100 days of GWS. As in the previous simulation, this figure only shows the flowpaths for particles that were not captured by extraction wells during the production simulation. In every case, the particles are moving back toward the wellfield.

For these simulations, extraction and injection was maintained at the same ratio and rates, regardless of the hydraulic conductivity of the zone that the wells are completed in, or the response of the aquifer (drawdown or rise). During actual operations, the rates would be adjusted to avoid excessive drawdown or rise in individual wells during production or restoration. However, as was the case for the upper KM simulations, for purposes of this modeling demonstration, the scenario that is simulated provides an opportunity to assess hydraulic impacts under extreme conditions. The horizontal flare is greater than what would occur if the wells located in the areas of low permeability were adjusted to lower rates to prevent excessive drawdown or rise during production.

Hydraulic impacts to the overlying upper KM Horizon during production of the middle KM Horizon are shown on **Figure 31**. The maximum drawdown in the upper KM Horizon is less than 8 feet of hydraulic head and the maximum rise is less than 1 foot. Particle tracking indicates some injectate migrates from the middle KM Horizon into the upper KM Horizon during production (**Figure 31**). However, all of the particles are moving inward to the wellfield by the end of production as they are within the capture zone of the extraction wells.

Hydraulic impacts to the underlying lower KM Horizon during production of the middle KM Horizon are shown on **Figure 32**. The net change in water levels within the lower KM Horizon is less than a few feet at the end of production. A few particles move into the lower KM Horizon during production southeast of the wellfield, but only cover a very limited area (**Figure 32**).

The effect of GWS following production from the middle KM Horizon wellfield is shown in cross-sectional view of the particle tracking (**Figure 33**). Only particles that were not captured by extraction wells at the end of production are shown on the figure. The particle tracks are generally limited to the middle and upper KM Horizon Layers, with a very minor intrusion into the lower KM Horizon. No particles move into the underlying K Shale or the overlying Sagebrush Shale during production or GWS.

Lower KM Horizon ISR Simulation

An ISR simulation was run that includes a wellfield in the lower KM Horizon (layer 5 of the model). In this simulation, the overlying hydrostratigraphic unit is the middle KM Horizon and the lower hydrostratigraphic unit is the K Shale. Extraction and injection rates were identical to the upper KM Horizon ISR simulation that was previously described.

The simulated hydraulic impacts within the lower KM Horizon indicate relatively larger changes in water levels occurring in the east side of the wellfield and comparatively smaller changes to the southwest (**Figure 34**). This is the result of a slightly higher hydraulic conductivity zone present in the southwest portion of the wellfield in this model layer. In the lower KM Horizon ISR simulation, the extraction well showing the greatest impact at the end of production has approximately 140 feet of drawdown (**Figure 34**). Some of the interior injection wells have over 130 feet of rise in water levels at the end of production.

Injectate flowpaths in the lower KM Horizon at the end of the production indicate that some particles along each side of the wellfield appear to be moving away from the wellfield at the end of production (**Figure 35**). The maximum distance traveled at the end of production is approximately 105 feet outside of the wellfield. **Figure 36** shows the particle traces after the 100 days of GWS. All of the particles that were not already captured during production are moving back toward the wellfield during GWS.

Hydraulic impacts to the overlying middle KM Horizon at the end of production from the lower KM Horizon are shown on **Figure 37**. The maximum drawdown in the middle KM Horizon is less than 3 feet of hydraulic head and the maximum rise is less than 4 foot. Particles have migrated from the lower KM Horizon into the middle KM Horizon along the north and southeast sides of the wellfield during production (**Figure 37**). However, all of the particles are moving inward to the wellfield and are within the capture zone of the extraction wells.

Within the K Shale, the net change in water levels is generally less than 10 feet at the end of production from the lower KM Horizon (**Figure 38**). A few particles move into the K Shale during production but only cover a very limited area (**Figure 38**).

The effect of GWS following production from the lower KM Horizon wellfield is shown in cross-sectional view of the particle tracking (**Figure 39**). Only particles that were not captured by extraction wells at the end of production are shown on the figure. The particle tracks are generally limited to the lower and middle KM Horizon Layers, with a very minor intrusion into the K Shale. All particles are moving toward the lower KM Horizon wellfield. No particles move into the underlying L Horizon or the overlying upper KM Horizon during production or GWS.

The input and output files for each of the three production simulations are provided electronically in **Attachment A**.

Excursion Simulations

One of the stated objectives of this modeling effort is to evaluate the capability to recover an excursion to an underlying aquifer. In each of the previous production/restoration simulations there was no indication of an excursion into either the overlying HJ Horizon or the underlying L Horizon. It is less likely that an excursion into the HJ Horizon would occur under normal operating conditions, based on the large head differences between that unit and the KM Horizon and the regional extent and integrity of the Sagebrush Shale. Furthermore, there is existing capability to contain an excursion from the KM Horizon to the HJ Horizon with the existing wellfield network already in place for ISR mining of the HJ Horizon. Therefore, no additional evaluation of recovery of an excursion from the KM Horizon to the HJ Horizon is conducted in this investigation.

A separate simulation was developed to evaluate if an excursion into the L Horizon from KM Horizon production could be effectively recovered. In the calibrated model, the vertical hydraulic conductivity of the K Shale in the vicinity of the KM Horizon wellfields was relatively high for a shaley unit (at 0.146 ft/d). Nevertheless, the production simulations using the calibrated model were unable to create an excursion to the L Horizon under typical operating conditions. There was some excursion into the K Shale under the simulation of the wellfield in the lower portion of the KM Horizon, but the extent was minimal and was restricted to the upper most portion of the K Shale.

In order to simulate an excursion into the L Horizon, a scenario was constructed in which a portion of the K Shale directly beneath the KM Horizon wellfield was given the same hydraulic conductivity values as the L Horizon. In effect, this simulated the absence of a confining unit between the L Horizon and KM Horizon. **Figure 40** shows the hydraulic conductivity zone distribution in the K Shale for this simulation and the projection of the KM Horizon wellfield. Additionally, the simulation was run “out of balance” wherein the most southern injection well was run at twice the rate as in the previous simulations (10 gpm vs. 5 gpm).

Injectate flowpaths indicate an excursion into the L Horizon directly east of the “out of balance” well during production (**Figure 41**). However, note that the particles that have moved into the L Horizon during the excursion simulation are moving toward the wellfield. Although the particles have moved out of the production zone, they are still within the capture zone of the wellfield extraction wells and would eventually be drawn back into the wellfield (assuming production continued for a sufficient period of time). Following production, a simulation was run using the same GWS recovery rates as in the previous simulations (9 wells extracting at 10 gpm each for 100 days) to determine if that would be sufficient to recover the excursion. The results of the particle tracking are shown in cross-sectional view (**Figure 42**). Based on examination of the MODPATH output files, at the end of the simulated GWS all of the particles have either migrated back into the KM Horizon (layer 5) or into the K Shale (layer 6). No particles remain in the L Horizon (layer 7).

A second recovery scenario was simulated in which the “out of balance” well was used during GWS, extracting at a rate of 10 gpm. Results of that simulation indicate that all of the excursion particles that were in the L Horizon during production have been pulled back up into the KM Horizon or very near the top of the K Shale by the end of GWS (**Figure 43**).

The excursion simulation demonstrates that if an excursion were to occur, recovery can be accomplished using rates that are typical for GWS. Conversion of existing injection wells to extraction wells during recovery will increase the effectiveness of the recovery.

The input and output files for the excursion simulations are provided electronically in **Attachment B**.

Summary

A numerical model was developed to simulate ISR of uranium from the KM Horizon of the Lost Creek Project in Sweetwater County Wyoming. The focus of the model was on the demonstration of hydraulic control, both horizontally and vertically, of production and restoration fluids throughout mining. The model was initially calibrated to static potentiometric conditions and two separate pumping tests conducted within the KLM Horizon.

The model contains eleven layers representing the hydrostratigraphic interval from the HJ Horizon down through the N Horizon, with a total thickness of approximately 550 feet. The parameter estimator code PEST (Doherty 2010) was coupled with the USGS MODFLOW-2000 (Harbaugh et al 2000) groundwater flow code to calibrate the model to observed drawdown data from a regional KM Horizon pumping test and a 5-spot pumping test.

The KM Horizon was subdivided into three layers within the model to account for the heterogeneity that may be present within that hydrostratigraphic unit. Calibration of the model resulted in a large range of hydraulic conductivity values within the KM Horizon layers.

A series of simulations were run using the calibrated model to assess potential hydraulic impacts of ISR from the KM Horizon. Wellfields were simulated in each of the three separate model layers that represent the KM Horizon (each of which comprise a unique distribution of hydraulic conductivity). This provided a high degree of variability in potential outcomes.

Each wellfield was designed as a series of repeating 5-spot well patterns that contained nine extraction wells and sixteen injection wells. The extraction wells were simulated at a rate of 20 gpm. Injection rates varied depending on the position of the injection well relative to the well patterns. Production was simulated with an approximate net 1 percent bleed (overproduction) for the entire wellfield. Production was simulated for a period of 585 days.

The simulated wellfields are substantially smaller than what would be utilized during actual production of the KM Horizon. The simulation of a smaller wellfield than what will be actually employed was done for computational efficiency, and to allow more focus on individual well pattern hydraulics and vertical movement of injectate. However, horizontal flare has been demonstrated to be scale dependent (Lewis Water Consultants,1999). Smaller wellfields generally show higher apparent horizontal flare than larger ones. Horizontal flare occurs predominately along the outer edges of the wellfield. Smaller wellfields typically have a higher ratio of perimeter length to total area than do larger wellfields. This corresponds to a greater ratio of exterior injection wells to interior injection wells, which usually results in a higher simulated horizontal flare. The horizontal flare resulting from these simulations is anticipated to be higher than what will occur in actual operation because of the smaller size of the simulated wellfields.

Restoration was simulated using GWS (extraction only). GWS was simulated for 100 days with nine extraction wells, each operating at 10 gpm.

Particle tracking (using the USGS code MODPATH) was used to monitor the flowpaths of injectate throughout production and GWS.

Results of the ISR simulations indicate that the maximum horizontal flare within the KM Horizon (as determined from the injectate flowpaths) was less than 115 ft from the edge of the wellfield. For these simulations, extraction and injection was maintained at the same ratio and rates, regardless of the hydraulic conductivity of the zone that the wells are completed in or the response of the aquifer (drawdown or rise). During actual operations, the rates would be adjusted to avoid excessive drawdown or rise in individual wells during production or restoration. For purposes of this modeling demonstration, the scenarios that are simulated provide an opportunity to assess hydraulic impacts under extreme conditions. The simulated flare is greater than what would occur if the wells located in the areas of low permeability were adjusted to lower rates to prevent excessive drawdown or rise during production.

In each case (simulation of wellfields in the upper, middle and lower portion of the KM Horizon), GWS was effective in reversing the hydraulic gradient and altering the injectate flowpaths back toward the wellfield.

There was some vertical flare between the KM Horizon subunits during production. However, GWS was generally effective in pulling the injectate back into the producing zone.

The geologic heterogeneity and complexity that is common to ISR deposits was simulated in the model through the use of multiple layers and multiple hydraulic conductivity units within the KM Horizon. However, there are numerous smaller scale low permeability units throughout the KM Horizon that are not accounted for in the scale of the model. The additional layering of low permeability units will further limit vertical flare during production of the KM Horizon.

None of the ISR simulations indicated vertical flare into the overlying HJ Horizon or the underlying L Horizons when operations were conducted under balanced flow conditions.

An excursion scenario was developed in which a portion of the K Shale was absent and an injection well was operating “out of balance” at twice the rate compared to balanced simulations. In this simulation, some injectate was forced into the underlying L Horizon during production.

Following production, a simulation was run using the same GWS recovery rates as in the previous simulations to determine if that would be sufficient to recover the excursion. At the end of the simulated GWS, all of the particles either migrated back into the KM Horizon or into the K Shale. No particles remained the L Horizon.

An additional recovery simulation was run wherein the “out of balance” injection well was used as an extraction well during GWS. That well was also simulated at 10 gpm. This increased the hydraulic gradient between the excursion area and the wellfield. Results of the enhanced GWS simulation indicated more rapid and more efficient capture of the flare than in the previous GWS simulation. These simulations confirm that application of engineering controls should be adequate to successfully recover an excursion into the underlying aquifer. The rate of recovery is generally proportional to the changes in hydraulic gradients that are applied.

Although not specifically included in the modeling of the KM Horizon, some recommendations regarding monitoring of the underlying aquifers are provided. Placement of L Horizon monitor wells should coincide with areas where the K Shale is known or suspected to be thin or possibly absent. As demonstrated in the modeling, it is difficult to simulate an excursion if there is a competent confining unit, even if the vertical hydraulic conductivity is relatively high (as might be the case for a silty K Shale unit instead of a shaley unit). The location of L Horizon monitor wells should be based on geologic interpretation of the K Shale, and not designed based on a uniformly spaced grid. Placement of L Horizon monitor wells in areas where there is substantial shale/claystone thickness would be unwarranted and is unlikely to provide consequential monitoring.

If the L Horizon is adequately monitored, no additional monitoring in the deeper M Horizon should be required. Based on the modeling, the likelihood of vertical flare reaching the L Horizon appears small. If an excursion to the L Horizon were to occur, it would be detected in the L Horizon monitor wells first. The probability of flare extending all the way through the L Horizon and the LM Shale and into the M Horizon (a vertical distance of over 100 feet) within the timeframes anticipated for production is very low.

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Table 1. Well Information, 2011 KM Regional Test and Water Level Monitoring, Lost Creek Uranium ISR Project

Well	Type of Well	Completion Zone	MP Elev (ft amsl)	Easting (NAD83) (feet)	Northing (NAD83) (feet)	Screened Interval (ft bgs)	Casing ID (in)	Screen Length (feet)
5S-HJ1	Overlying Obs. Well	HJ Horizon	6947.19	2214013	595593	460-480	4.5	20
HJMP-105	Overlying Obs. Well	HJ Horizon	6937.40	2211252	595778	425-465	4.5	40
HJMP-108	Overlying Obs. Well	HJ Horizon	6952.08	2211786	596015	400-440	4.5	40
HJMP-109	Overlying Obs. Well	HJ Horizon	6939.73	2212215	595535	478-508	4.5	30
HJT-101	Overlying Obs. Well	HJ Horizon	6937.56	2210880	595314	437-477	4.5	40
HJT-102	Overlying Obs. Well	HJ Horizon	6939.15	2211206	595401	390-420	4.5	30
HJT-103	Overlying Obs. Well	HJ Horizon	6938.22	2211500	595374	423-453	4.5	30
HJT-104	Overlying Obs. Well	HJ Horizon	6940.15	2211973	595596	410-460	4.5	50
M-103A	Overlying Obs. Well	HJ Horizon	6946.00	2214017	594642	364-378, 395-408, 414-434, 440-465	4.5	72
M-104	Overlying Obs. Well	HJ Horizon	6942.11	2213540	594556	368-382, 400-415, 415-426, 437-453	4.5	56
M-109	Overlying Obs. Well	HJ Horizon	6921.72	2211177	594662	379-391, 403-423	4.5	30
M-111	Overlying Obs. Well	HJ Horizon	6909.59	2210267	594443	370-379, 390-409, 416-429, 445-460	4.5	56
M-113	Overlying Obs. Well	HJ Horizon	6928.01	2209307	594502	396-406, 417-439, 447-463, 472-480	4.5	56
M-114	Overlying Obs. Well	HJ Horizon	6930.75	2208939	594825	410-420, 429-449, 465-485	4.5	50
M-115	Overlying Obs. Well	HJ Horizon	6939.10	2208876	595312	428-451	4.5	23
M-117	Overlying Obs. Well	HJ Horizon	6944.80	2209305	596139	435-453, 461-480	4.5	37
M-119	Overlying Obs. Well	HJ Horizon	6948.65	2210263	596294	432-450	4.5	18
M-121	Overlying Obs. Well	HJ Horizon	6951.71	2211196	596586	393-404, 436-455, 468-491	4.5	51
M-123	Overlying Obs. Well	HJ Horizon	6951.85	2212163	596638	422-444, 465-495	4.5	52
M-125	Overlying Obs. Well	HJ Horizon	6947.76	2212967	596102	367-397, 404-419	4.5	45
M-127	Overlying Obs. Well	HJ Horizon	6947.66	2213929	595946	408-418, 435-450, 450-471, 480-495	4.5	61
MP-101	Overlying Obs. Well	HJ Horizon	6942.02	2213872	595185	420-438	4.5	18
MP-102	Overlying Obs. Well	HJ Horizon	6941.02	2213296	595391	408-458	4.5	50
MP-103	Overlying Obs. Well	HJ Horizon	6935.48	2212706	595372	370-400	4.5	30
MP-104	Overlying Obs. Well	HJ Horizon	6939.85	2212004	595507	423-463	4.5	40
MP-108	Overlying Obs. Well	HJ Horizon	6937.94	2210879	595460	405-435	4.5	30
MP-111	Overlying Obs. Well	HJ Horizon	6936.28	2209948	595352	391-410	4.5	19
MP-113	Overlying Obs. Well	HJ Horizon	6923.19	2209858	594941	447-466	4.5	19
UKMO-101	Overlying Obs. Well	HJ Horizon	6942.32	2212406	595647	465-490	4.5	25
UKMO-103	Overlying Obs. Well	HJ Horizon	6952.11	2212820	596261	409-439	4.5	30

Table 2. Well Information, 2012 5-Spot Test, Lost Creek Uranium ISR Project

Well ID	Well Type	Completion Zone	Easting (NAD83)	Northing (NAD83)	TOC Elev (ft amsl)	Drilled TD (ft bgs)	Cased Depth (ft bgs)	Casing ID (in)	Screen Interval (ft bgs)	Screen Length (feet)
5S-HJ1	Obs. Well	HJ Horizon	2,214,013	595,593	6,945.83	480	460	4.5	460-480	20
5S-KM3	Recovery Well	KM Horizon	2,213,986	595,579	6,945.87	540	520	4.5	520-540	20
5S-KM1	Inj/Obs. Well	KM Horizon	2,213,950	595,640	6,946.20	540	525	4.5	525-545	20
5S-KM2	Inj/Obs. Well	KM Horizon	2,214,046	595,610	6,946.02	540	520	4.5	520-540	20
M-UKM1	Inj/Obs. Well	KM Horizon	2,214,017	595,516	6,945.22	550	520	4.5	520-540	20
KPW-1A	Inj/Obs. Well	KM Horizon	2,213,927	595,550	6,947.58	540	520	5	519-539 575-610	20 35
5S-KM4	Obs. Well	KM Horizon	2,213,955	595,563	6,945.59	540	520	4.5	520-540	20
KMU-1	Obs. Well	L Horizon	2,214,011	595,543	6,946.00	740	650	4.5	650-675	25
M-M1	Obs. Well	M Horizon	2,213,989	595,526	6,945.82	780	750	4.5	750-770	20
5S-N1	Obs. Well	N Horizon	2,213,940	595,615	6,946.29	900	850	4.5	850-870	20

NAD83 - North American Datum, 1982-Wyoming State Plane, West Central-feet
TOC Elev - top of casing elevation
TD - total depth
ft amsl - feet above mean sea level
ft bgs - feet below ground surface
in - inches

Table 1. Well Information, 2011 KM Regional Test and Water Level Monitoring, Lost Creek Uranium ISR Project

Well	Type of Well	Completion Zone	MP Elev (ft amsl)	Easting (NAD83) (feet)	Northing (NAD83) (feet)	Screened Interval (ft bgs)	Casing ID (in)	Screen Length (feet)
KPW-3	PZ Pump Well	KM Horizon	6940.17	2213891	595227	515-550, 565-590	5.5	60
HJMU-109	PZ Obs. Well	KM Horizon	6939.60	2212225	595540	524-574	4.5	50
HJMU-110	PZ Obs. Well	KM Horizon	6948.02	2212005	595900	492-537	4.5	45
KMP-1	PZ Obs. Well	KM Horizon	6936.26	2216968	594503	430-450, 460-475, 490-505	4.5	50
KMP-2	PZ Obs. Well	KM Horizon	7016.47	2216654	599180	525-545, 550-560, 570-590	4.5	50
KMP-3A	PZ Obs. Well	KM Horizon	6966.18	2214149	596543	500-530, 545-565	4.5	50
KMP-4	PZ Obs. Well	KM Horizon	6971.19	2211256	597607	580-600	4.5	20
KMP-5	PZ Obs. Well	KM Horizon	6916.21	2210070	594057	525-554, 560-585	4.5	54
KPW-1A	PZ Obs. Well	KM Horizon	6947.58	2213927	595550	520-565, 575-610	4.5	80
KPW-2	PZ Obs. Well	KM Horizon	6936.50	2210879	595477	500-507, 526-545, 555-590	4.5	60
LC17M	PZ Obs. Well	KM Horizon	6937.18	2212869	595542	529-565	4.5	36
LC20M	PZ Obs. Well	KM Horizon	6950.78	2211684	596034	511-543	4.5	32
LC24M	PZ Obs. Well	KM Horizon	6944.60	2212886	595906	478-531	4.5	53
M-KM1	PZ Obs. Well	KM Horizon	6951.56	2215130	595555	505-520, 550-580	4.5	45
M-KM2	PZ Obs. Well	KM Horizon	6946.90	2213993	594514	505-530, 565-580	4.5	40
M-KM3A	PZ Obs. Well	KM Horizon	6945.74	2214543	595505	510-550, 580-605	4.5	65
MU-101	PZ Obs. Well	KM Horizon	6941.08	2213855	595183	520-540	4.5	20
MU-102	PZ Obs. Well	KM Horizon	6941.86	2213286	595382	525-555	4.5	30
MU-103	PZ Obs. Well	KM Horizon	6935.83	2212706	595380	525-565	4.5	40
MU-104	PZ Obs. Well	KM Horizon	6939.77	2212006	595493	550-580	4.5	30
MU-106	PZ Obs. Well	KM Horizon	6944.19	2211479	595964	500-550	4.5	50
MU-107	PZ Obs. Well	KM Horizon	6937.53	2210977	595802	500-540	4.5	40
MU-109	PZ Obs. Well	KM Horizon	6934.35	2210941	595221	525-545	4.5	20
MU-110	PZ Obs. Well	KM Horizon	6940.98	2210162	595639	520-540	4.5	20
MU-112	PZ Obs. Well	KM Horizon	6938.31	2209564	595529	515-535	4.5	20
MU-113	PZ Obs. Well	KM Horizon	6925.41	2209839	594942	530-550	4.5	20
M-UKM1	PZ Obs. Well	KM Horizon	6946.51	2214017	595516	520-540	4.5	20
UKMP-101	PZ Obs. Well	KM Horizon	6941.97	2212410	595633	547-577	4.5	30
UKMP-103	PZ Obs. Well	KM Horizon	6954.34	2212808	596263	496-536	4.5	40
UKMU-103	PZ Obs. Well	KM Horizon	6952.21	2212808	596251	558-588	4.5	30

Table 1. Well Information, 2011 KM Regional Test and Water Level Monitoring, Lost Creek Uranium ISR Project

Well	Type of Well	Completion Zone	MP Elev (ft amsl)	Easting (NAD83) (feet)	Northing (NAD83) (feet)	Screened Interval (ft bgs)	Casing ID (in)	Screen Length (feet)
KMU-2	PZ Obs. Well	L Horizon	6952.99	2215179	595572	625-650	4.5	25
KMU-3	PZ Obs. Well	L Horizon	6965.36	2214220	596506	630-650	4.5	20
KMU-4	PZ Obs. Well	L Horizon	6943.22	2211051	595488	605-635	4.5	30
M-L1	PZ Obs. Well	L Horizon	6941.45	2213855	595210	650-670	4.5	20
M-L2	PZ Obs. Well	L Horizon	6946.59	2214551	595530	655-675	4.5	20
M-L3	PZ Obs. Well	L Horizon	6934.90	2212651	595362	660-670, 680-690	4.5	20
M-L4	PZ Obs. Well	L Horizon	6944.86	2213937	594454	640-665	4.5	25
M-L5	PZ Obs. Well	L Horizon	6945.26	2211589	595995	630-650	4.5	20
M-M1	PZ Obs. Well	M Horizon	6947.34	2213989	595526	750-770	4.5	20
M-M2	PZ Obs. Well	M Horizon	6941.97	2213830	595194	725-745	4.5	20
M-M3	PZ Obs. Well	M Horizon	6947.75	2214552	595550	750-770	4.5	20
M-M4	PZ Obs. Well	M Horizon	6945.79	2214044	594453	725-745	4.5	20
M-M5	PZ Obs. Well	M Horizon	6952.97	2215196	595540	730-760	4.5	30
M-M6A	PZ Obs. Well	M Horizon	6964.46	2214200	596525	715-730	4.5	15
M-M7	PZ Obs. Well	M Horizon	6933.45	2212691	595346	745-770	4.5	25
M-M8	PZ Obs. Well	M Horizon	6947.71	2211634	596001	720-740	4.5	20
M-N1	Underlying Obs. Well	N Horizon	6942.42	2213777	595217	825-850	4.5	25
5S-N1	Underlying Obs. Well	N Horizon	6947.66	2213940	595615	850-870	4.5	20

Table 3. Hydraulic Conductivity Zones, KM Horizon Model, Lost Creek Uranium ISR Project

Zone Number	Kx	Kz	Model Layer	Zone Number	Kx	Kz	Model Layer
	(ft/d)	(ft/d)			(ft/d)	(ft/d)	
1	9.786E-01	9.200E-02	1	58	4.335E-02	1.084E-02	2
2	2.970E+00	3.213E-01	1	59	1.000E+01	1.634E-02	5
3	7.028E-01	1.001E-02	1	60	1.000E+00	1.000E-01	Not Used
4	1.647E+00	6.038E-01	1	61	1.000E+00	1.000E-01	Not Used
5	5.176E+00	8.000E-01	1	62	7.600E-05	2.100E-05	Not Used
6	1.735E+00	4.000E-02	1	63	1.571E+00	8.258E-03	11
7	5.991E-01	3.032E-02	1	64	4.600E+00	5.233E-04	5
8	9.471E-01	1.109E-02	1	65	4.068E+00	3.941E-01	7
9	2.704E+00	2.249E-02	1	66	1.169E+00	7.583E-04	7
10	2.952E+00	1.693E-01	1	67	2.464E-03	1.158E-01	1
11	6.515E-02	1.000E-01	1	68	3.000E-01	3.472E-01	4
12	4.846E-02	2.992E-01	1	69	8.130E-01	4.585E-01	4
13	5.819E-01	2.009E-01	1	70	1.816E-02	2.662E-04	4
14	9.122E-02	6.408E-03	All except 1, 2	71	2.778E+00	2.284E+00	4
15	2.916E-03	1.253E-02	All except 1, 2	72	9.160E-01	1.127E-01	4
16	6.503E-01	1.506E-01	11	73	1.708E+00	1.728E-02	4
17	6.306E+00	2.000E-02	11	74	8.119E-02	6.995E-04	4
18	4.832E-02	8.810E-01	10	75	1.624E-02	1.362E+00	4
19	4.688E-02	1.094E-06	10	76	1.617E+00	6.792E-04	4
20	3.597E-01	6.014E-02	8	77	3.740E+00	9.649E-02	4
21	2.023E+00	2.179E-01	8	78	7.117E+00	2.641E-02	4
22	2.329E-03	3.165E-03	6	79	4.147E+00	1.670E-03	4
23	1.118E-01	1.468E-01	6	80	1.000E+00	1.000E-01	Not Used
24	7.288E-05	9.597E-07	2	81	4.661E-01	1.957E-01	3
25	7.758E-05	1.553E-04	2	82	5.050E-01	6.541E-01	3
26	9.971E-03	2.465E-06	9	83	1.111E+00	6.901E-06	3
27	1.287E-01	1.256E-03	9	84	1.877E+00	3.245E+00	3
28	5.733E-01	8.115E-06	9	85	7.893E-01	1.366E-01	3
29	6.006E-02	5.358E-01	9	86	6.897E-01	8.049E-04	3
30	7.049E-01	1.098E-02	9	87	6.776E-01	2.547E-05	3
31	3.957E-01	1.517E-03	9	88	5.496E-02	9.606E-01	3
32	3.324E+00	9.856E-05	9	89	6.487E-01	4.219E-03	3
33	2.176E-01	3.072E-04	9	90	5.941E-03	2.507E-01	2
34	1.866E+00	8.435E-05	9	91	5.730E+00	1.906E-01	3
35	3.623E+00	2.242E-01	9	92	1.000E+01	3.557E-02	3
36	8.951E-01	3.321E-04	9	93	3.080E+00	2.581E-03	3
37	2.235E+00	3.121E-01	7	94	1.337E+00	7.896E-02	5
38	3.188E-01	6.373E-01	7	95	1.023E+00	4.626E-02	5
39	1.528E+00	8.569E-03	7	96	1.551E+00	7.499E-02	5
40	3.060E-01	6.688E-01	7	97	4.267E-01	4.326E-02	5
41	6.862E-02	1.385E-01	7	98	1.339E+00	1.296E-01	4
42	6.591E-02	8.601E-01	7	99	1.205E+00	1.995E-02	4
43	1.000E+01	4.120E-02	7	100	7.518E-01	4.930E-03	4
44	9.768E-01	5.046E-01	7	101	6.759E-01	5.000E+00	4
45	3.469E+00	4.401E-01	7	102	5.655E+00	5.000E+00	4
46	1.000E+01	8.647E-03	7	103	1.878E+00	8.861E-02	3
47	7.614E+00	2.935E-01	7	104	4.795E-02	1.997E-02	3
48	5.926E-01	3.938E-01	5	105	1.766E+00	1.296E-01	3
49	7.737E-01	4.954E-01	5	106	4.457E-01	5.864E-04	3
50	6.111E-01	8.257E-06	5	107	1.000E+01	5.000E+00	3
51	3.035E+00	2.099E+00	5	108	7.779E+00	4.011E-01	3
52	7.662E-01	9.502E-02	5	109	5.187E+00	5.000E+00	3
53	4.516E-01	3.012E-01	5	110	1.436E-03	1.076E-03	3
54	8.406E-01	1.298E-05	5	111	8.573E-01	7.291E-02	3
55	2.863E-02	1.552E+00	5	112	5.891E-03	9.993E-04	3
56	6.826E-01	7.327E-04	5	113	2.639E+00	9.912E-04	3
57	3.458E+00	5.834E-02	5				

ft/d - feet/day

Kx - horizontal hydraulic conductivity

Kz - vertical hydraulic conductivity

Table 4. Specific Storage Coefficient Zones, KM Horizon Model, Lost Creek Uranium ISR Project

Zone Number	Specific Storage	Model Layer
1	5.10E-05	11
2	1.10E-06	10
3	4.80E-06	1
4	1.00E-08	3, 4, 5
5	3.90E-06	5
6	8.40E-07	2
7	3.80E-08	7
8	1.30E-06	6
9	1.00E-07	8
10	1.00E-08	3
11	1.00E-08	4
12	1.00E-08	5
13	2.50E-06	3

Specific storage units are in ft^{-1}

Table 5. Calibration Targets and Statistics, Steady State Simulation, Lost Creek Uranium ISR Project

Name	X-coordinate	Y-coordinate	Model Layer	Observed	Computed	Residual
	(ft)	(ft)		(ft amsl)	(ft amsl)	(ft)
5S-N1	2213940	595615	11	6737.69	6737.88	-0.19
M-N1	2213777	595217	11	6737.50	6737.09	0.41
M-M1	2213989	595526	9	6742.87	6745.52	-2.65
M-M2	2213830	595194	9	6742.64	6743.81	-1.17
M-M3	2214552	595550	9	6748.25	6747.74	0.51
M-M4	2214044	594453	9	6742.63	6742.92	-0.29
M-M5	2215196	595540	9	6748.64	6748.24	0.40
M-M6A	2214200	596525	9	6755.38	6754.75	0.63
M-M7	2212691	595346	9	6738.60	6740.60	-2.00
M-M8	2211634	596001	9	6744.79	6745.70	-0.91
M-WC9	2211051	595488	9	6737.84	6741.92	-4.08
M-KM1	2215130	595555	4	6757.24	6757.35	-0.11
M-KM2	2213993	594514	4	6753.59	6750.48	3.11
M-KM3A	2214543	595505	4	6756.07	6753.19	2.88
KPW-2	2210879	595477	4	6742.73	6743.47	-0.74
KPW-3	2213891	595227	4	6753.10	6750.87	2.23
LC20M	2211684	596034	4	6748.35	6747.11	1.24
MU-103	2212706	595380	4	6750.70	6750.05	0.65
M-UKM1	2214017	595516	4	6754.93	6751.09	3.84
KMP-3A	2214149	596543	4	6759.88	6759.67	0.21
HJMU-109	2212225	595540	4	6749.33	6749.46	-0.13
HJMU-110	2212005	595900	4	6749.03	6748.19	0.84
KMP-1	2216968	594503	4	6765.66	6766.68	-1.02
KMP-2	2216654	599180	4	6787.08	6788.28	-1.20
KMP-4	2211256	597607	4	6749.56	6750.57	-1.01
KMP-5	2210070	594057	4	6730.78	6734.09	-3.31
KPW-1A	2213927	595550	4	6752.98	6750.90	2.08
LC17M	2212869	595542	4	6751.13	6750.33	0.80
LC24M	2212886	595906	4	6753.36	6752.70	0.66
MU-101	2213855	595183	4	6753.38	6750.88	2.50
MU-102	2213286	595382	4	6752.06	6750.65	1.41
MU-104	2212006	595493	4	6746.82	6747.96	-1.14
MU-106	2211479	595964	4	6747.39	6746.25	1.14
MU-107	2210977	595802	4	6744.31	6744.14	0.17
MU-109	2210941	595221	4	6741.65	6742.29	-0.64
MU-110	2210162	595639	4	6739.73	6740.89	-1.16
MU-112	2209564	595529	4	6738.56	6739.03	-0.47
MU-113	2209839	594942	4	6737.56	6735.73	1.83
UKMP-101	2212410	595633	4	6750.03	6751.62	-1.59
UKMP-103	2212808	596263	4	6754.60	6752.52	2.08
UKMU-103	2212808	596251	4	6752.65	6752.50	0.15
KMU-1	2214011	595543	7	6751.35	6750.59	0.76
KMU-2	2215179	595572	7	6754.95	6756.58	-1.63
KMU-3	2214220	596506	7	6757.56	6757.56	0.00
KMU-4	2211051	595488	7	6742.96	6742.12	0.84
M-L1	2213855	595210	7	6749.94	6749.63	0.31
M-L2	2214551	595530	7	6752.31	6752.65	-0.34
M-L3	2212651	595362	7	6745.71	6746.74	-1.03

Table 5. Calibration Targets and Statistics, Steady State Simulation, Lost Creek Uranium ISR Project

Name	X-coordinate	Y-coordinate	Model Layer	Observed	Computed	Residual
	(ft)	(ft)		(ft amsl)	(ft amsl)	(ft)
M-L4	2213937	594454	7	6748.19	6748.46	-0.27
M-L5	2211589	595995	7	6744.77	6745.62	-0.85
HJMP-105	2211252	595778	1	6768.03	6767.73	0.30
HJMP-109	2212215	595535	1	6764.13	6761.32	2.81
HJT-101	2210880	595314	1	6764.76	6764.42	0.34
HJT-103	2211500	595374	1	6748.52	6749.24	-0.72
HJT-104	2211973	595596	1	6769.57	6767.62	1.95
M-104	2213540	594556	1	6759.46	6763.27	-3.81
M-109	2211177	594662	1	6745.07	6743.92	1.15
M-111	2210267	594443	1	6737.85	6739.20	-1.35
M-113	2209307	594502	1	6735.82	6734.82	1.00
M-114	2208939	594825	1	6742.37	6746.34	-3.97
M-115	2208876	595312	1	6753.40	6753.05	0.35
M-117	2209305	596139	1	6758.59	6759.57	-0.98
M-119	2210263	596294	1	6764.25	6765.12	-0.87
M-121	2211196	596586	1	6770.29	6770.15	0.14
M-123	2212163	596638	1	6772.47	6774.31	-1.84
M-125	2212967	596102	1	6773.88	6774.82	-0.94
M-127	2213929	595946	1	6772.48	6773.28	-0.80
MP-102	2213296	595391	1	6761.40	6765.59	-4.19
MP-104	2212004	595507	1	6755.20	6757.01	-1.81
MP-111	2209948	595352	1	6759.37	6760.43	-1.06
MP-113	2209858	594941	1	6737.58	6737.75	-0.17
UKMO-101	2212406	595647	1	6763.88	6763.37	0.51
UKMO-103	2212820	596261	1	6775.56	6774.86	0.70
LC26M	2216523	595537	1	6784.57	6783.62	0.95
5S-HJ1	2214013	595593	1	6772.89	6771.03	1.86
MP-101	2213872	595185	1	6771.00	6767.23	3.77
M-103A	2214017	594642	1	6769.24	6766.41	2.83
M-128	2214350	595698	1	6775.45	6773.36	2.09
HJMP-108	2211786	596015	1	6770.83	6770.84	-0.01
HJT-102	2211206	595401	1	6767.45	6764.95	2.50
MP-108	2210879	595460	1	6767.39	6765.04	2.35
HJ-WC1	2214149	596542	1	6777.58	6778.49	-0.91
HJ-WC2	2215129	595554	1	6774.95	6776.27	-1.32

Residual Mean	0.055
Absolute Residual Mean	1.33
Residual Std. Deviation	1.71
Sum of Squares	242.6
Min. Residual	-4.19
Max. Residual	3.84
Number of Observations	83.0
Range in Observations	56.3
Scaled Residual Std. Deviation	0.030
Scaled Absolute Residual Mean	0.024
Scaled Residual Mean	0.001

Table 6. Calibration Targets and Statistics, 2011 KM Regional Test, Lost Creek Uranium ISR Project

Well ID	X-coordinate	Y-coordinate	Model Layer	Observed Drawdown	Simulated Drawdown	Residual
	(ft)	(ft)		(ft)	(ft)	(ft)
5S-HJ1	2214013	595593	1	0.70	1.12	-0.42
HJMP-105	2211252	595778	1	0.00	0.22	-0.22
HJMP-109	2212215	595535	1	0.10	0.98	-0.88
HJT-101	2210880	595314	1	0.10	0.29	-0.19
HJT-102	2211206	595401	1	0.00	0.42	-0.42
HJT-103	2211500	595374	1	1.10	1.15	-0.05
HJT-104	2211973	595596	1	0.20	0.82	-0.62
M-103A	2214017	594642	1	0.80	0.35	0.45
M-104	2213540	594556	1	1.70	0.38	1.32
M-109	2211177	594662	1	1.00	0.13	0.87
M-111t	2210267	594443	1	0.60	0.06	0.54
M-113	2209307	594502	1	0.40	0.04	0.36
M-114	2208939	594825	1	0.10	0.25	-0.15
M-115	2208876	595312	1	0.00	0.11	-0.11
M-117	2209305	596139	1	0.00	0.07	-0.07
M-119	2210263	596294	1	0.00	0.08	-0.08
M-121	2211196	596586	1	0.00	0.12	-0.12
M-123	2212163	596638	1	0.10	0.20	-0.10
M-125	2212967	596102	1	0.10	0.30	-0.20
M-127	2213929	595946	1	0.40	0.91	-0.51
MP-101	2213872	595185	1	0.80	0.79	0.01
MP-102	2213296	595391	1	1.40	0.94	0.46
MP-103	2212706	595372	1	1.50	0.94	0.56
MP-104	2212004	595507	1	1.60	0.79	0.81
MP-108	2210879	595460	1	0.10	0.23	-0.13
MP-111	2209948	595352	1	0.00	0.11	-0.11
MP-113	2209858	594941	1	0.60	0.07	0.53
UKMO-101	2212406	595647	1	0.20	1.01	-0.81
UKMO-103	2212820	596261	1	0.10	0.27	-0.17
HJMU-109	2212225	595540	4	23.00	22.18	0.82
HJMU-110	2212005	595900	4	2.60	3.31	-0.71
KMP-1	2216968	594503	4	8.20	6.78	1.42
KMP-2	2216654	599180	4	0.30	0.54	-0.24
KMP-3	2214149	596543	4	3.50	4.28	-0.78
KMP-4	2211256	597607	4	0.70	1.24	-0.54
KMP-5	2210070	594057	4	3.30	3.15	0.15
KPW-1A	2213927	595550	4	33.80	35.97	-2.17
KPW-2	2210879	595477	4	1.80	2.06	-0.26
KPW-3	2213891	595227	4	112.30	114.35	-2.05
LC17M	2212869	595542	4	34.00	32.61	1.39
LC20M	2211684	596034	4	2.30	2.65	-0.35
LC24M	2212886	595906	4	3.60	3.48	0.12
M-KM1	2215130	595555	4	21.20	19.45	1.75
M-KM2	2213993	594514	4	33.90	33.34	0.56
M-KM3A	2214543	595505	4	26.90	26.99	-0.09
MU-101	2213855	595183	4	50.20	48.83	1.37
MU-102	2213289	595391	4	40.30	37.36	2.94
MU-103	2212706	595380	4	29.30	30.45	-1.15

Table 6. Calibration Targets and Statistics, 2011 KM Regional Test, Lost Creek Uranium ISR Project

Well ID	X-coordinate	Y-coordinate	Model Layer	Observed Drawdown	Simulated Drawdown	Residual
	(ft)	(ft)		(ft)	(ft)	(ft)
MU-104	2212006	595493	4	7.10	9.66	-2.56
MU-106	2211479	595964	4	2.20	2.48	-0.28
MU-107	2210977	595802	4	1.90	1.97	-0.07
MU-109	2210941	595221	4	3.50	3.31	0.19
MU-110	2210162	595639	4	0.80	1.28	-0.48
MU-112	2209564	595529	4	0.90	1.00	-0.10
MU-113	2209839	594942	4	3.00	2.30	0.70
M-UKM1	2214017	595516	4	33.20	32.41	0.79
UKMP-101	2212410	595633	4	4.50	4.51	-0.01
UKMP-103	2212808	596263	4	3.20	3.01	0.19
UKMU-103	2212801	596244	4	3.20	3.03	0.17
KMU-1	2214011	595543	7	18.40	18.26	0.14
KMU-2	2215179	595572	7	16.40	12.05	4.35
KMU-3	2214220	596506	7	4.00	4.40	-0.40
KMU-4t	2211051	595488	7	2.10	1.99	0.11
M-L1	2213855	595210	7	15.30	17.06	-1.76
M-L2	2214551	595530	7	14.80	14.55	0.25
M-L3	2212651	595362	7	14.20	12.83	1.37
M-L4	2213937	594454	7	11.80	13.37	-1.57
M-L5	2211589	595995	7	2.30	2.02	0.28
M-M1	2213989	595526	9	5.10	6.10	-1.00
M-M2	2213830	595194	9	5.80	4.98	0.82
M-M3	2214552	595550	9	8.40	7.73	0.67
M-M4	2214044	594453	9	4.10	4.14	-0.04
M-M5	2215196	595540	9	7.20	5.09	2.11
M-M6A	2214200	596525	9	2.40	2.32	0.08
M-M7	2212691	595346	9	2.90	2.55	0.35
M-M8	2211634	596001	9	2.20	1.92	0.28
5S-N1	2213940	595615	11	0.40	0.17	0.23
M-N1	2213777	595217	11	0.40	0.15	0.25

Residual Mean	0.100
Absolute Residual Mean	0.663
Residual Std. Deviation	1.00
Sum of Squares	79.33
Min. Residual	-2.56
Max. Residual	4.35
Number of Observations	78
Range in Observations	112.3
Scaled Residual Std. Deviation	0.0089
Scaled Absolute Residual Mean	0.0059
Scaled Residual Mean	0.0009

Table 7. Calibration Targets and Statistics, 2012 5-Spot Test, Lost Creek Uranium ISR Project

Well ID	X-coordinate	Y-coordinate	Model	Observed Drawdown	Simulated Drawdown	Target Weight	Weighted Residual
	(ft)	(ft)		(ft)	(ft)		(ft)
5S-KM3	2213986	595577	3	116.20	115.36	1	0.84
5S-KM1	2213950	595640	3	29.40	26.00	1	3.40
5S-KM2	2214046	595610	3	37.20	36.79	1	0.41
M-UKM-1	2214017	595516	3	61.20	59.21	0.1	1.99
5S-KM4	2213955	595563	3	30.30	30.71	1	-0.41
KMU-1	2214011	595543	7	6.10	7.67	1	-1.57
M-M1	2213989	595526	9	1.10	2.10	1	-1.00
5S-N1	2213940	595615	11	0.00	0.03	1	-0.03
5S-HJ1	2214013	595593	1	0.00	0.47	1	-0.47
KPW-1A	2213927	595550	3	23.20	25.95	1	-2.75

Residual Mean	0.040
Absolute Residual Mean	1.29
Residual Std. Deviation	1.67
Sum of Squares	27.82
Min. Residual	-2.75
Max. Residual	3.40
Number of Observations	10
Range in Observations	116.2
Scaled Residual Std. Deviation	0.0143
Scaled Absolute Residual Mean	0.0111
Scaled Residual Mean	0.0003

Petrotek

Petrotek Engineering Corporation 5935 South Zang Street, Suite 200 Littleton, Colorado 80127 USA (303) 290-9414 FAX (303) 290-9580

January 27, 2016

Ur-Energy USA, Inc.
5880 Independence Dr. Suite 200
Casper, WY 82609

Attention: Mr. John Cash and Mr. Kevin Shelburne

Subject: Submittal of Technical Memorandum-Lost Creek KM Horizon Model

Dear John and Kevin:

Per your request, Petrotek Engineering Corporation (PEC) has developed a numerical groundwater flow model to assist Ur-Energy USA, Inc. (URE) in estimating the potential hydraulic impacts resulting from ISR uranium mining of the KM Horizon of the Lost Creek Project in Wyoming. The attached Technical Memorandum summarizes the development, simulation and results of that modeling effort.

In addition to the Technical Memorandum, the input and output files to the models are included in electronic format on external usb (flash) drives. Two external drives are included, each one containing a complete set of the model files.

If additional information is needed regarding this assessment of potential hydraulic impacts from mining of the KM Horizon, please call Errol Lawrence at 303-880-9175 or Hal Demuth at 303-290-9414.

Sincerely,
Petrotek Engineering Corporation

Errol Lawrence

CC: Ken Cooper – Petrotek

Hal Demuth – Petrotek