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ISR

LOST CREEK ISR, LLC

February 2, 2015

ATTN: Document Control Desk
Director, Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Re: Submittal of Documents Pertaining to the KM and LC East Amendments
Lost Creek ISR Project License SUA-1598, Docket 040-09068

To Whom It May Concern:

Pursuant to a November 3, 2014 email request from NRC staff, Lost Creek ISR LLC hereby provides the following documents to NRC for review:

1. Revisions to the **LC East** Amendment Technical Report. References to the Wyoming Department of Environmental Quality Permit to Mine documents have been removed and replaced with references to documents submitted to the NRC.
2. An original submittal of the **LC East** Environmental Report.
3. Revisions to the **KM Amendment** Technical Report. References to the Wyoming Department of Environmental Quality Permit to Mine documents have been removed and replaced with references to documents submitted to the NRC.
4. An original submittal of the **KM Amendment** Environmental Report

<u>Instructions for page replacement for the KM Amendment Technical Report</u>
Remove the text portions of the "Overview of Application" and replace with the provided text

Remove the table of contents and text from sections D5 and D6 and replace them with the pages provided herein.

<u>Instructions for page replacement for the LC East Amendment Technical Report</u>
Remove the table of contents and text from sections D4, D5, D6, OP, and RP and replace them with the pages provided herein.

Please note that the figures, plates, tables, and attachments are not being replaced. The pink dividers inserted into the replacement pages were placed to make it easier to find the section breaks should not be placed into the Technical Reports.

NMSS01

Both of the KM Amendment and LC East Amendment Environmental Reports are complete documents and as such have been provided in binders for permanent retention.

Please feel free to contact me if you have any questions.

Sincerely,

John W. Cash
Vice President

Attachments: As Stated

Cc: Theresa Horne, Ur-Energy, Littleton (via e-mail, w/o attachments)

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D-4 Meteorology

Please see **Section 2.5** of the Lost Creek Technical Report for a discussion of local meteorological conditions. The meteorological station in Section 18 of Lost Creek is less than five miles from all known resource areas at LC East and with no significant terrain to alter weather is considered representative of both areas.

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D5 GEOLOGY

D5.1 Regional Geology

The Lost Creek Property is situated in the northeastern part of the Great Divide Basin (Basin) which is underlain by up to 25,000 feet of Paleozoic to Quaternary sediments. The Basin is an oval-shaped structural depression, encompassing some 3,500 square miles in south-central Wyoming. It represents the northeastern portions of the greater Green River Basin, which occupies much of southwestern Wyoming. The Basin lies within a unique divergence of the Continental Divide and is bounded by structural uplifts or fault displaced Precambrian rocks, resulting in internal drainage and an independent hydrogeologic system. It is bounded on the north by the Wind River Range and Granite Mountains, on the east by the Rawlins Uplift, on the south by the Wamsutter Arch and on the west by the Rock Springs Uplift. Geologic development of the Basin began in the Late Cretaceous and continued through much of the Early Eocene.

Rock outcrops in the Basin are dominated by the Battle Spring Formation of Eocene age. Due to the soft nature of the formation, this occurs largely as sub-crop beneath the soil. The dominant lithology in the Battle Spring Formation is coarse arkosic sandstone, separated by abundant but intermittent beds of mudstone, claystone and siltstone. Deposition occurred as alluvial-fluvial fan deposits within a south-southwest flowing paleo-drainage. The sedimentary source is considered to be the Granite Mountains, approximately 20 to 30 miles to the north. Maximum thickness of the Battle Spring Formation sediments within the Basin is 6,200 feet.

Uranium deposits in the Great Divide Basin, including the Lost Creek deposit, are found principally in the Battle Spring Formation.

D5.1.1 Regional Stratigraphy

The earliest sedimentation during development of the Basin was the Paleocene (Early Tertiary) Fort Union Formation, which was unconformably deposited upon the Lance Formation of Late Cretaceous age. The Fort Union Formation consists mostly of lacustrine shales, siltstones, and thin sandstones, which locally contain lignite and coal beds. The thickness of the Fort Union Formation varies from place to place in the Basin.

The Fort Union Formation is unconformably overlain by sediments of Eocene age, which consist of about 6,200 feet of basin fill. In the northern and northeastern portions of the Basin the Eocene is represented by thick, medium to coarse-grained arkosic sandstones and conglomerates of the Battle Spring Formation. The Battle Spring Formation represents a large alluvial fan complex relatively close to the sediment source in the ancestral Granite Mountains to the north. In the southern and southwestern portions of the Basin the Battle Spring Formation undergoes a facies transition into intertonguing units of the Wasatch and Green River Formations which represent distal fluvial and lacustrine depositional environments, respectively. The lithology of these units is predominately sandstone, claystone, siltstone, limestone, conglomerate and include thin lignite beds. Pliocene pediment deposits and recent alluvium cover large areas of the surface in the Basin.

The LC East Amendment area is located near the north-central part of the Basin. Here the Basin fill consists of the Eocene Battle Spring and Wasatch Formations plus the Paleocene Fort Union Formation. The upper portions of the stratigraphic section consist of Battle Spring Formation underlain by a tongue of the Wasatch Formation. The combined thickness of the Battle Spring and Wasatch formations under the Permit Area is approximately 6,200 feet. The Battle Spring/Wasatch formations are unconformably underlain by the Fort Union Formation which is approximately 4,650 feet thick beneath the Permit Area. The Fort Union Formation, in turn, is unconformably underlain by numerous Cretaceous, Jurassic, Triassic, Paleozoic, and Precambrian basement lithologic units.

Approximately six to eight miles southwest of the LC East Amendment area, the Battle Spring Formation interfingers with the Wasatch and Green River Formations of equivalent age (Eocene) within a belt roughly 15 miles wide. The Wasatch and Green River Formations collectively represent low-energy fluvial, lacustrine and paludal depositional environments which are time-equivalents of the alluvial fan deposits of the Battle Spring Formation. **Figure D5-1** schematically illustrates the stratigraphic relationships of Tertiary sediments within the Great Divide Basin, and the specific Lost Creek Project stratigraphy.

D5.1.2 Regional Structure

The present geomorphological features of the Basin were generated by geologic events of the Laramide Orogeny. During this upheaval, in the Late Cretaceous and Early Tertiary, bounding structures surrounding the Basin were formed or rejuvenated. The Wind River Mountains and Granite Mountains were thrust upward on the north side of the Basin. The Rawlins Uplift formed to the east; the Wamsutter Arch formed to the south; and the Rock Springs Uplift formed to the west. All of these highs formed a ring around the Basin, transforming the Basin into a bowl-shaped geological structure with internal drainage only.

The Great Divide Basin is asymmetrical in shape, with its major axis trending west-northwest. Strata in some locations along the basin margin may dip as much as 25 degrees. Dips gradually become gentler toward the center of the Basin, and in the LC East Amendment area they are approximately one to three degrees westerly and southwesterly.

Gentle folding during late Eocene accompanied late-stage regional thrusting resulting in several broad anticlinal and synclinal folds within the Basin. A few anticlines are oil-bearing (at levels much deeper than the uranium-bearing formations). Noteworthy among these is the Lost Soldier anticline at the northeastern edge of the Basin, approximately 15 miles northeast of the LC East Amendment area. The Battle Spring and Fort Union formations, as well as older units, crop out on the southwest flank of the anticline with dips of 20 to 25 degrees.

Deep-seated regional thrust faulting associated with the Wind River uplift occurred at depth in the north-central portions of the Great Divide Basin. The horizontal component of displacement is possibly greater than nine miles. However, displacement along these faults did not extend to the surface, such that the upper portions of the Battle Spring Formation are largely undisturbed. Shallow normal faulting is also common throughout the central Great Divide Basin, having a preferential orientation that is generally east-west. These are relatively local and appear to be the result of late stage events in the structural history of the Basin. They are believed to be the result of a regional extension event and possibly also of isostatic unloading within the basin due to regional erosion. They may be associated with the Chicken Springs fault system as shown on published geological maps but are not considered to be currently active. Displacements are generally less than 100 feet and most commonly are less than 50 feet. More details about the faulting and structure are discussed in Section D5.2.2 and illustrated on **Plates D5-4.1** and **D5-4.2**.

D5.2 Site Geology

Outcrop within the entire LC East Amendment area is represented solely by the upper portions of the Battle Spring Formation, which is the host to uranium mineralization. The depositional environment of the Battle Spring Formation is that of a major alluvial fan system extending from the ancestral Granite Mountains to the north. The Formation consists of abundant thin to thick beds of medium to coarse sandstones separated by a multitude of thin to medium thick layers of mudstone, claystone and siltstone. The sandstone facies represent fluvial channel fill depositional environments, whereas the shaley units represent channel margin and overbank depositional environments. The anastomosing nature of the fluvial channels has resulted in complex stratigraphy which tends to be erratic and lacking long range continuity. Detailed geological correlation has partitioned the stratigraphy into multiple named "Horizons" dominated by sandstone and separated by named shale intervals. Stratigraphic nomenclature is described in more detail in the following Section (Section D5.2.1) and illustrated in **Figure D5-1.**

The lithology of the Battle Spring Formation within the LC East Amendment area consists of approximately 60% to 80% weakly consolidated, medium to coarse, commonly conglomeratic, clean arkosic sands in units from five to 50 feet thick; separated by 20% to 40% interbedded mudstone, claystone, siltstone, and fine sandstone, generally less than 25 feet thick (**Figure D5-2**). This lithological assemblage remains relatively consistent throughout the entire vertical section of interest within the Battle Spring Formation, such that the lithology of the shallowest units is virtually identical to that of the deepest units of interest. Economic uranium mineralization is mainly associated with medium to coarse-grained sand facies.

Like at Lost Creek, the most significant mineral resources in the LC East Amendment occur within two major stratigraphic horizons: the HJ and the KM Horizons (**Figures D5-1** and **2**). The HJ Horizon is currently being developed under the Lost Creek Permit. The KM Horizon underlies the HJ Horizon and contains additional economic mineralization which will be targeted for production in both the Lost Creek and LC East areas. To date, a total of over 18 individual roll fronts have been identified in the HJ and KM Horizons within a composite stratigraphic interval of approximately 225 feet.

Mineralization also occurs within the FG Horizon. It is secondary to that of the HJ and KM and remains to be investigated for economic viability. Mineral discoveries have also been made in the L, M, and N Horizons which are collectively referred to as the Deep Horizons. Economic assessment of the FG and Deep Horizons will require additional exploration efforts and they are not the focus of current permitting activity.

The combined HJ and KM mineral trend within the LC East Amendment area is referred to as the East Mineral Trend (EMT). It extends in a general southwest to northeast orientation for approximately five miles (**Plate D5-1**). The composite width of the EMT varies considerably from 200 to 1,500 feet. The EMT represents a separate mineral trend from the MMT which is currently being mined in the Lost Creek Permit area. However, it is considered to be the product of the same regional mineralizing event and therefore virtually contemporaneous and similar in most respects.

Mineralization within the LC East Amendment area occurs as roll front type uranium deposits. It is similar in character to that in the Lost Creek Permit area in virtually all respects. The geometry of mineralization is dominated by the classic roll front "C" shape or crescent configuration at the alteration interface. Thickness of mineralization within each roll front may vary from 5 to 25 feet thick. Typical thickness is from 10 to 15 feet. Mineral intercepts of over 25 feet in total thickness are common where multiple roll fronts occur stacked on top of each other. Average grade is approximately 0.055% eU_3O_8. Mineralization on individual roll fronts within the deposit is typically 25 to 75 feet wide and is very sinuous. Roll fronts in both the HJ and KM Horizons are stacked vertically and commonly overlie each other in a complex, erratic, anastomosing pattern in plan-view.

Depth to the top of any given unit can vary from one end of the EMT to the other by up to 400 feet due to regional dip of one to three degrees, and to displacement by normal faulting. Within the LC East Amendment area the depth to the top of the HJ Horizon ranges from 375 feet in the south to outcropping in the northern limits of the project. Likewise, the depths to the top of the KM Horizon vary from 500 feet to 100 feet, respectively.

D5.2.1 Site Stratigraphy

The upper portion of the Battle Spring Formation is host to the uranium mineralization in the LC East Amendment area. Being the product of an alluvial fan depositional environment, the Battle Spring Formation can be described as a very thick sequence composed predominantly of numerous channel sands typically from five to 50 feet thick interfingered with innumerable shales typically two to 25 feet thick which represent channel margin and overbank environments. Lateral extent of both of these lithologies can range from 100 feet to miles. Where multiple sand channels are stacked on top of each other, the cumulative sand thickness and width can be considerable. The erratic nature of these narrow channels results in stratigraphy which can be highly variable. The outcome can be very complex, where interfingering or abrupt facies changes may result in drastic changes in shale or sand thickness over short distances. This is well illustrated in the thickness isopach maps of the various units of interest (**Plates D5-3a to D5-3e**) where discernable patterns of deposition are virtually absent; and also in the Geologic Cross-sections (**Plates D5-2a** to **D5-2j**).

Sedimentary and depositional conditions throughout the entire Battle Spring interval of interest remained quite consistent and uniform. Consequently, from a lithological and stratigraphic perspective there is little difference between deeper units and those near the surface. Distinctive characteristics of given stratigraphic intervals are subtle and generally are not consistent regionally, consequently partitioning into meaningful stratigraphic units remains largely arbitrary. Vertical boundaries have been defined at shale units showing the greatest regional continuity, or lacking that, at pre-established thickness intervals.

In the LC East Amendment area, the top 1,200 feet of the Battle Spring Formation represents the interval of interest. Within this interval the stratigraphy has been sub-divided into several thick stratigraphic "Horizons" (e.g. HJ or KM). Horizons are dominated by sands and separated from each other by **"Named Shales"** of regional extent. Each horizon, however, is in actuality the composite of numerous "sands" which are in turn separated by numerous **"Unnamed Shales"** within the horizon. Unnamed shales may be quite areally extensive, or may be only of local extent. Note also that the term "shale" is used herein rather loosely, as it commonly may include considerable amounts of siltstone or fine grained sand in addition to the typical mudstone and claystone.

Horizons of primary interest are further subdivided into "Sub-Horizons" (e.g., LFG, UHJ, and UKM). Criteria for establishing sub-horizons are based largely on a combination of continuity of sand packages and continuity of associated mineral horizons. Vertical boundaries between sub-horizons are established somewhat arbitrarily and may or may not coincide with the presence of an intervening shale.

The resulting system of stratigraphic nomenclature is illustrated in the Stratigraphic Column within **Figure D5-1**. This nomenclature is internal to Ur-Energy and is not recognized officially by the geological community. The foundation for this system has been carried over, with some modification, from that established by Conoco Minerals during its early exploration activities in the region and subsequently adopted by Texasgulf during its tenure with the property. Nomenclature terms from surface downward to the KM Horizon were inherited from previous operators; below that the terms were derived by Ur-Energy. Note that in the last few years Ur-Energy has abandoned the use of the term "Sand" in favor of the term "Horizon" to describe the major stratigraphic units. It is believed that the term "Sand" can be misleading in recognition of the fact that any substantial stratigraphic interval consists not only of sand facies but also contains a considerable number of interbedded shales which yields hydrogeological characteristics significantly different than an interval consisting only of sand. Also note that the boundaries between horizons (i.e. Named Shales) have been established on a relatively arbitrary basis and don't necessarily reflect patterns or breaks in sedimentary or depositional characteristics. As a result, the system of nomenclature as illustrated on **Figure D5-1** should be viewed essentially and simply as a cataloguing tool for stratigraphic organization.

Named Shales represent the shaley interval nearest the stratigraphic level established as the break between Horizons. Strictly defined they represent the shaley interval between the lowest sand assigned to the overlying Horizon and the uppermost sand assigned to the underlying Horizon. The Battle Spring interval of interest contains many more shales (unnamed) than just the Named Shales (see Type Log LCE149, **Figure D5-2** and Geological Cross-Sections **Plates D5-2a to D5-2j**). As such, Named Shales may not be the dominant shale in any given area nor represent the only shale occurring between production sands. Named Shales may not be regionally continuous; or they may represent a series of shales which can be overlapping en-echelon or complexly interwoven with vertically adjacent sands. Because of this complexity, thickness values selected for shale isopach mapping (**Plates D5-3a**, **D5-3c and D5-3e**) may not represent all shales in such a series, but rather only the one that best correlates to the stratigraphic nomenclature boundary. Shale complexity is well illustrated in the Cross-Sections (**Plates D5-2a to D5-2j**)

The most notable shales are the LCS and SBS Shales which exhibit a high degree of regional continuity and confinement, although locally may display considerably complexity.

Provided below is a brief description of each named stratigraphic unit within the Lost Creek Project. The general lithologic character of the units remains relatively consistent throughout the entire property, however depths below ground surface (bgs) may vary significantly locally due to regional stratigraphic dip and displacement due to normal faulting.

A Horizon –The A Horizon is not present in the LC East Amendment area, having been removed by erosion.

BC Horizon – The BC Horizon is the horizon occurring at the surface within the majority of the Lost Creek Project; however, similar to the A Horizon, the BC Horizon has been removed by erosion over the vast majority of the LC East Amendment area. Thin remnants remain only in the northern portions of Sections 20 and 21 in areas that had been down-dropped by faulting. Maximum depth is approximately 50 to 75 feet. When present, lithologic data is often missing in drill logs because it occurs above the fluid level in the drill hole while logging. Fluid in the hole is required to generate the single point resistance and spontaneous potential (SP) curves used for lithological characterization. In general it appears to be similar in character to the adjacent underlying DE Horizon. The upper and lower boundaries are arbitrary and poorly defined. Thickness is approximately 80 to 100 feet. The BC Horizon is dry and hosts no significant mineralization.

DE Horizon – This Horizon occurs at the surface in the southern and central portions of LC East Amendment area, but has been removed by erosion in the northern portions. In the LC East Amendment area, the top of the unit ranges in depth from surface to approximately 70 feet and is approximately 80 feet thick where the entire section is present. The DE Horizon is dry everywhere within the LC East Amendment area and carries no significant mineralization.

EF Shale (formerly the Upper No Name Shale) – The EF Shale represents the boundary between the overlying DE Horizon and the underlying FG Horizon. Hydrogeological continuity and confinement by the EF Shale is uncertain as lithologic data in drill logs is often missing, as mentioned above. It crops-out in a northwesterly strike near the common corner between Sections 10, 11, 14 and 15 and is absent to the north. Thickness varies considerably from a few feet to 30 feet. Where present, depths to the top of the EF Shale vary: from surface to 150 feet in the down-dropped northwestern portions of Section 20.

FG Horizon – The FG Horizon crops-out in the northern one-third of the LC East Amendment area. It reaches its deepest in the northern portions of Section 20 where depth to its top is approximately 150 feet. The total thickness of the FG Horizon ranges between 160 to 180 feet. Stratigraphically, the FG Horizon is subdivided into three sub-horizons: the Upper FG (UFG), Middle FG (MFG) and the Lower FG (LFG), all roughly of equal thickness. The breaks between these are not rigidly defined. Generally they are selected based on significant shales (if present) which separate channel-fill sequences. The FG commonly consists of sands and intervening shaley units which are thinner, more erratic than what is characteristic of the underlying HJ and lower horizons; and as a whole the FG has a lower SS/Sh ratio. Locally the FG contains significant mineralization in the LC East Amendment area. However, no recovery from the FG is planned.

Lost Creek Shale (LCS) – The Lost Creek Shale separates the FG and HJ Horizons. It is a dominant shaley horizon which has been observed to be continuous throughout the LC East Amendment area. For this reason it has been used as the datum for stratigraphic and structural correlation. Thickness ranges from 5 to 40 feet, typically being from 10 to 20 feet. Depth ranges from approximately 350 feet in the northern portions of Section 20 to outcropping in the far northern portions of the Amendment area. Its lithology is dominated by silty mudstone and dense claystone. It commonly includes siltstone, and may locally be sandy or contain thin lenticular sands. Segments of the LCS commonly interfinger with lower sands of the FG Horizon and upper sands of the HJ Horizon. This can complicate correlation and often results in dramatic changes in the thickness of the LCS within short horizontal distances. A thickness isopach map for the LCS Shale is presented as **Plate D5-3a**.

HJ Horizon – The HJ Horizon is a major host for mineralization in the East Mineral Trend (EMT) and is the host to current production at Lost Creek. The HJ Horizon has been subdivided into four sub-horizons: Upper HJ (UHJ), Middle HJ1 (MHJ1), Middle HJ2 (MHJ2) and the Lower HJ (LHJ). The boundaries between the sub-horizons are somewhat arbitrary but selection is guided by sand channel and roll front mineral horizon continuity. Boundaries may be accompanied by a shale break. The bulk of the uranium mineralization is present in the two MHJ sub-horizons. The HJ Horizon characteristically includes noticeably thicker sands and a high SS/Sh ratio compared to most of the other horizons. The total thickness of the HJ Horizon ranges from approximately 120 to 130 feet, thinning northerly slightly to about 110 feet. Depth to the top of the HJ Horizon within the LC East Amendment area ranges from a maximum of approximately 360 feet in the northern parts of Section 20 to outcropping in the northernmost portions of the Amendment area. **Plate D5-3b** is a thickness isopach map for the HJ Horizon.

Sagebrush Shale (SBS) – The Sagebrush Shale forms the boundary between the HJ Horizon and the underlying KM Horizon. The SBS is laterally extensive and virtually continuous throughout the LC East Amendment area. Depth to the top of the SBS within the LC East Amendment area ranges from a maximum of 510 feet in the northern parts of Section 20 to 100 feet in northernmost portions of the Amendment area. Thickness varies from 2 to 30 feet. Similar to the LCS, segments of the SBS commonly interfinger with and undergo rapid facies exchanges with lower sands of the HJ Horizon and upper sands of the KM Horizon. This can complicate correlation and often results in dramatic changes in the thickness of the SBS within short horizontal distances, as is evident in the thickness isopach map for the SBS (**Plate D5-3c**).

KM Horizon – The KM Horizon is also a primary host to the mineralization in the EMT. Nomenclature for the KM was modified in recent years. Initially, and at the time of the original Lost Creek Mine Permit, the KM Horizon was assigned three sub-horizons: the Upper KM (UKM), the Middle KM (MKM) and the Lower KM (LKM). As additional drilling results became available over time it became apparent that the KM is better described as having only two sub-horizons, underlain by the K Shale. Consequently the MKM designation was abandoned and replaced by the LKM such that the current nomenclature employs only the UKM and LKM.

Its general the character and lithology of the KM is similar to that of the HJ Horizon. Both the UKM and the LKM sub-horizons host mineralization. A shale unit referred to as the No Name Shale (NNS) commonly divides the two sub-horizons of the KM, but it is not always present. Depth to the top of the KM Horizon ranges from approximately 510 feet in the northern parts of Section 20 to about 100 feet in the far northern portions of the Amendment area. Thickness ranges from approximately 100 feet to 130 feet. A thickness isopach map for the KM Horizon is presented as **Plate D5-3d**.

K Shale – The K-Shale represents the lower boundary of the KM horizon. It occurs throughout the LC East Amendment area, and generally exhibits continuity and adequate confinement. However, it may locally be absent or be represented by multiple overlapping shales. Where this occurs, confinement may not be seamless. Average thickness is 10 feet, ranging from 2 feet to 30 feet. A thickness isopach map for the K Shale is presented as **Plate D5-3e**. Depth to the K Shale varies from approximately 610 feet in the northern portions of Section 20 to approximately 200 feet at the northern limits of the LC East Amendment area.

L, M, N, and P Horizons – These horizons are collectively referred to as the "Deep Horizons" and occur within a 300 to 350 feet interval below the K Shale. Currently they are the targets of exploration activities. Available drill data for these horizons is much sparser than for the shallower horizons. Individually, each horizon is approximately 100 feet thick. They consist of lithologies identical to that of overlying horizons. In general, like the remainder of the Battle Spring Formation, they are composed of multiple, stacked, coarse sands separated by numerous shale intervals. Stratigraphically, shales within these horizons are often relatively thick and more continuous than seen in the shallower horizons, contributing to an overall lower SS/Sh ratio. At the same time, individual sands tend to be thicker and show more regional continuity. This character becomes more dominant with depth.

> *L Horizon*: Depth to the L Horizon varies from approximately 640 feet in Section 20 to approximately 200 feet in the far north. Commonly the L Horizon exhibits a much more shaley character with more shale interbeds, thinner sands and a much lower SS/Sh ratio than the vertically adjacent horizons.
>
> *M Horizon*: The M Horizon typically exhibits thick shales with thick well developed sands. Depth to the top of the M Horizon ranges from approximately 720 feet in Section 20 to approximately 300 feet in the far north.
>
> *N and P Horizons*: The character of these horizons is similar to that of the M Horizon, commonly exhibiting thick shales with well developed sands. Data is relatively limited, particularly in the southern portions of the project, as drilling generally has not penetrated these units. Depth to the top of the N Horizon ranges from 830 to 410 feet and from 930 to 520 feet for the P Horizon.

LM, MN, and NP Shales – These shales represent the lower boundaries of the L, M and N Horizons respectively. Designation of these shales as horizon boundaries was arbitrarily established on roughly 100 foot intervals below the K Shale. As such they do not present unique characteristics compared to any other shales within this stratigraphic interval. Thickness of the shales varies considerably, reaching up to 30 feet with an average of approximately 10 feet. Although these shales have regional extent, continuity is unconfirmed. In many areas drill data spacing is insufficient to confirm correlation.

D5.2.2 Site Structure

Bedding within the Battle Spring Formation in the LC Amendment area is nearly flat-lying, dipping gently to the west and southwest at approximately one to three degrees. This regional pattern of strike and dip is modified locally due to horst and graben features resulting from normal faulting, as discussed below.

The dominant geologic structural features in the LC East Amendment area are a complex series of normal faults. The locations of these faults are illustrated in the Structural Contour Map (**Plates D5-4.1 and D5-4.2**); in the Geological Cross-Sections (**Plates D5-2a** to **D5-2j**) and in the Isopach Maps; (**Plates D5-3a** to **D5-3e**). They are believed to be the result of late stage events in the structural history of the Basin resulting from regional extension and possibly also of isostatic unloading within the basin due to regional erosion. Displacement typically exhibits maximum movement of up to 70 feet which tapers in both directions, commonly quite abruptly. Faulting occurred post-deposition and post-mineralization, therefore depositional patterns were not influenced by the fault movements and the mineral horizons are offset by faulting. The fault planes are very close to vertical in orientation.

The most prominent faulting occurs in Sections 20 and 21 where a system of faults with displacements of 50 to 70 feet created a series of horsts and grabens (**Plate D5-4.1**). Secondary to these are numerous minor faults which show displacements on the order of 10 feet and which appear to be fairly localized. Collectively the fault series results in a net down-dropping in the northern portions of Sections 20 and 21 resulting in a synclinal feature when viewed in a regional sense, with a northeast-southwest oriented axis.

Pump test results indicate that the faults serve as low-flow boundaries, but are not fully sealed (Section D6).

D5.2.3 Ore Mineralogy and Geochemistry

The nature of the uranium mineralization at the LC East Project is identical to that observed at the Lost Creek Project and therefore can be reasonably presumed to be identical in ore mineralogy and leaching amenability. No site-specific petrographic or leaching tests have been conducted for the LC East Project. Please refer to the Lost Creek Project, WDEQ-LQD Permit to Mine Application; December 2007 and subsequent revisions for a more complete description.

D5.2.4 Exploration and Production Activities

The ground currently designated as the LC East Amendment area has been extensively drilled in the past and can be considered to be in the mid to late exploration phase in the northern portions and pre-development phase in the southern portions. The earliest drilling was started in 1967 by Wolf Land and Exploration who was later joined in a joint venture by Conoco in 1969. Also, in 1967 Hecla Mining drilled one exploration hole on what is currently the LC East Project. Conoco took full control of the Red Desert venture in 1970 and continued to drill the property through 1977 as part of its Project A. By that time approximately 916 exploration holes had been drilled, including 13 core holes. Abundant significant mineralization had been found and a well-defined mineral trend identified, which is currently referred to as the EMT. Much of the drilling was on 200 foot spacing and in several localities has a spacing of 100 feet or less.

In 1978, Texasgulf joint-ventured with Conoco as the operator on Project A. They continued defining the trend by drilling an additional 126 exploration holes through 1981, including three core holes of very shallow targets (less than 150 feet). Texasgulf discontinued their operations in the Great Divide Basin in 1983. Portions of the current LC East Project were later acquired by PNC Exploration in 1987. In 1990 they drilled 21 holes within the current LC East Project in conjunction with their activities on the MMT in the Lost Creek Project. PNC released their property in 2000. Since then, no additional exploration drilling activity had been conducted in LC East until activities by URE in 2012. Prior to acquisition by URE, a total of 1,064 historical exploration holes for a total of 474,582 feet of drilling had been drilled within the currently defined LC East Project, including one water well which has since been abandoned. Drilled depths average 446 feet, ranging from 40 feet to 2,257 feet. Exploration by URE has been limited to 16 widely spaced stratigraphic test holes.

Since acquisition, URE has conducted pre-development drilling activities consisting of 179 delineation holes for a total of 114,600 feet of drilling, plus the installation of 28 baseline monitors and pump test wells totalling 11,945 feet. Baseline environmental studies have also been conducted and concluded.

No uranium production has been conducted in the past within the LC East Amendment area.

D5.3 Seismology

Please refer to the Lost Creek Project, WDEQ-LQD Permit to Mine Application; December 2007 and subsequent revisions.

D5.3.1 Historic Seismicity

Please refer to the Lost Creek Project, WDEQ-LQD Permit to Mine Application; December 2007 and subsequent revisions.

D5.3.2 Uniform Building Code

Please refer to the Lost Creek Project, WDEQ-LQD Permit to Mine Application; December 2007 and subsequent revisions.

D5.3.3 Deterministic Analysis of Active Fault Systems

Please refer to the Lost Creek Project, WDEQ-LQD Permit to Mine Application; December 2007 and subsequent revisions.

D5.3.4 Maximum Tectonic Province Earthquake "Floating Earthquake" Seismogenic Source

Please refer to the Lost Creek Project, WDEQ-LQD Permit to Mine Application; December 2007 and subsequent revisions.

D5.3.5 Short-Term Probabilistic Seismic Hazard Analysis

Please refer to the Lost Creek Project, WDEQ-LQD Permit to Mine Application; December 2007 and subsequent revisions.

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D6 HYDROLOGY

This appendix addresses surface water drainage characteristics and use (**Sections D6.1.1 and D6.1.2**), surface water quality (**Section D6.1.3**), regional and site hydrogeology (**Sections D6.2.1** and **D6.2.2**), groundwater use (**Section D6.3**), regional and site groundwater quality (**Sections D6.4.1** and **D6.4.2**), and the regional and site hydrologic conceptual models (**Sections D6.5.1** and **D6.5.2**). Potential hydrologic impacts, mitigation, and monitoring are presented in the **Operations Plan** and **Reclamation Plan**.

D6.1 Surface Water

D6.1.1 Drainage Characteristics

The Permit Amendment Area is located in the Great Divide Basin, a topographically closed system which drains internally due to a divergence in the Continental Divide. Most of the surface water is runoff from precipitation or snowmelt, and most runoff quickly infiltrates, recharging shallow groundwater, evaporates, or is consumed by plants through evapotranspiration. Based on the loam and sandy-loam soils found at the site, the steady-state saturated infiltration rate under laboratory conditions is estimated at 0.2 to 0.8 in/hr (Hillel, 1980). However, the practical infiltration rate is likely much higher because saturated conditions are rare, and more macropores are present under field conditions and at large scales. Infiltration-excess (Hortonian) overland flow has not been observed at the site, except on the compacted soils found in existing 2-track roads.

Alluvial deposits, if any, along drainages are not extensive, and the shallow Battle Spring aquifer is typically under confined conditions, although locally unconfined conditions exist. The variation from unconfined to confined conditions is due to the interfingering of sands and shales throughout the Battle Spring Formation (see, e.g., **Section D5.2.1 Site Stratigraphy**). The shallow water table is typically 100 to 200 feet below ground surface (ft bgs). There are no perennial or intermittent streams within the Permit Amendment Area or on adjacent lands. The only officially named drainages within the Permit Amendment Area are the Battle Spring Draw and Stratton Draw, which are dry for the majority of the year (**Figure D6.1-1**).

A 1:24,000 USGS topographic map was imported into GIS, and used to conduct the drainage network analyses described in this section. Two primary watersheds, Battle Spring Draw and Stratton Draw, drain ninety-seven percent of the Permit Amendment Area. The Battle Spring Draw watershed is divided into east and west tributaries as shown on **Figure D6.1-1**. Likewise, the Stratton Draw watershed is also divided into east and west tributaries within the Permit Amendment Area. The entire Permit and

Amendment Areas drain into the Battle Spring Flat, located approximately nine miles southwest of the Permit Amendment Area. Much of the water conveyed through the ephemeral channels does not reach Battle Spring Flat. Instead, it infiltrates into the alluvium and recharges the Battle Spring aquifer.

The existing drainages are incised, and have u-shaped trapezoidal cross-sectional morphologies. Vertical and slumping banks exist where active erosion is occurring. The channels near the downstream boundary of the Permit Amendment Area are incised three to 12 feet and are 10 to 15 feet wide. The channel side-slopes range in slope from 1:1 to approximately 2.5:1. The bed material in the larger draws is sandy textured and non-cohesive. Draws around the Permit Amendment Area are typically vegetated with sagebrush.

Annual runoff in the Permit Amendment Area is very low due to the high infiltration capacity and low annual precipitation. The channels are dry for the majority of the year. Drainages in the Permit Amendment Area are naturally ephemeral and primarily flow during spring snowmelt as saturated overland flow when soil moisture is at a maximum. The quantity of spring runoff is variable, depending on the amount of winter snowfall accumulation. Peak runoff from high intensity rain events can be significant; but surface flow is generally short-lived. Storm-water runoff after high intensity rain events is very rare because surface water infiltrates very rapidly or evaporates. Some intermittent and localized flow can occur near a small number of springs; but no surface runoff has been observed from springs within the Permit Amendment Area.

Runoff data are limited for the ephemeral and intermittent streams in the Great Divide Basin. There are two USGS streamflow gaging stations within 40 miles of the Permit Amendment Area, but they are on perennial streams and are not representative of drainages in the Permit Amendment Area. On April 6, 1976, the USGS measured the instantaneous discharge of Lost Soldier Creek, approximately 14.5 miles northeast of the Permit Amendment Area. The measurement of 0.2 cubic feet per second was taken during spring runoff so the source of water was predominantly snowmelt (USGS, 2006).

D6.1.2 Surface Water Use

Surface-water permits with legal descriptions inside and within three miles of the Permit Area were queried using the Wyoming State Engineers Office (WSEO) Water Rights Database (WSEO, 2014). **Table D6.1-1** lists the three surface water permits that exist within three miles of the Permit Amendment Area, and **Figure D6.1-2** shows their location relative to the Project area. The stated uses include irrigation, stock, and industrial.

As noted in **Section D6.3**, there are three BLM wells in or within three miles of the Permit Amendment Area. These wells have stock ponds associated with them. The water-use permits for these ponds are associated with the wells that supply the ponds, i.e., they are not associated with any surface-water-use permits.

D6.1.3 Surface Water Quality

Under the WDEQ Water Quality Division (WQD) Classification, Battle Spring Draw and Stratton Draw are listed as Class 3B water bodies. Beneficial uses for Class 3B waters can include recreation, wildlife, "other aquatic life," agriculture, industry, and scenic value, but do not include drinking water, game fish, non-game fish, and fish consumption.

Historic surface water quality within the study area was characterized using water quality data from the adjacent Lost Creek Project. The historic data set is small as surface water sample analysis commenced in 2007, and there were not many events to sample. The water-quality data for the historic sampling locations are summarized in **Table D6.1-2.** Due to the limited runoff volume very few analyses could be performed. Priority was given to analyzing radionuclides at the expense of other Guideline 8 parameters.

In 2012, Nalgene Storm Water Samplers were installed to collect 0.26 gallon (1 L) grab samples of first flush stream flow during runoff events. These samplers were installed at eight locations in the Permit Amendment Area shown on **Figure D6.1-3.** Four samplers were installed to capture runoff as it enters the Permit Amendment Area from the upstream side, and the others four samplers capture runoff at the downstream permit boundary. The water samples were collected to characterize the quality of ephemeral surface runoff. The sampling locations were selected based on their topographic potential to concentrate ephemeral surface flow.

The water quality data for six of the eight surface water samplers are summarized in **Table D6.1-3**; **Attachment D6-1** presents the laboratory raw water quality data. Dissolved uranium was present in only one sample at a very low concentration; slightly greater than the 0.0003 mg/L detection limit. Suspended uranium was detected in six of the eight samples tested at concentrations ranging from 0.024 to 0.106 mg/L.

There was only enough sample to analyze for radium-226 and thorium-230. **Table D6.1-3** results show that: 1) dissolved radium-226 was detected in all samples at levels ranging from 0.11 to 5.1 pCi/L, 2) dissolved thorium-230 was also detected in all samples at levels ranging from 0.08 to 0.4 pCi/L, 3) suspended radium-226 was present in all samples at levels ranging from 0.001 to 105 pCi/L, and 4) suspended thorium-230 was also present in all samples at levels ranging from 0.006 to 47.8 pCi/L.

D6.2 Groundwater Occurrence

This section describes the regional and local groundwater hydrology including hydrostratigraphy, groundwater flow patterns, hydraulic gradient and aquifer parameters. The discussion is based on information from investigations performed within the Great Divide Basin, data presented in previous applications/reports for the Permit and Amendment areas, and the geologic information presented in **Appendix D5** of this report. Regional and site hydrogeology are discussed in **Sections D6.2.1** and **D6.2.2**; groundwater use in **Section D6.3**; regional and site groundwater quality in **Sections D6.4.1** and **D6.4.2**; and the regional and site hydrologic conceptual models in **Sections D6.5.1** and **D6.5.2**.

D6.2.1 Regional Hydrogeology

See Section 2.7 of the Lost Creek Technical Report.

D6.2.2 Site Hydrogeology

LC ISR, LLC has been collecting lithologic, water level, water quality, and pump test data as part of its ongoing evaluation of hydrologic conditions at the Project. Drilling and installation of borings and monitor wells is ongoing to provide additional data to further refine the site hydrologic conceptual model. Recent water level measurements provide data to assess potentiometric surfaces, hydraulic gradients and inferred groundwater flow directions for the aquifers of interest at the Project. Five recently completed long-term pump tests (**Attachment D6-4**) were used to evaluate hydrologic properties of the aquifers of interest, to assess hydraulic characteristics of the confining units, and to preliminarily evaluate impacts to the hydrologic system of faults located in Sections 20 and 21 of the Permit Amendment Area. Results of Permit Amendment Area water quality sampling and analysis are presented in **Section D6.4.2**.

Figure D6.2-1 shows the locations of all the existing monitor and pump test wells in the Permit Amendment vicinity. **Table D6.2-1** provides completion information for the wells currently in use, and **Attachment D6-3** provides well completion logs for those specific wells.

D6.2.2.1 Hydrostratigraphic Units

LC ISR, LLC has employed the following nomenclature for the hydrostratigraphic units of interest within the Project. The primary LCE uranium production zones are identified as the HJ and KM Horizons. The HJ Horizon is subdivided into the Upper (UHJ), Middle (MHJ) and Lower (LHJ) Sands. The HJ Horizon is bounded above and below by areally extensive confining units identified as the Lost Creek Shale and the Sage Brush Shale, respectively. Overlying the Lost Creek Shale is the FG Horizon. The deepest sand in the FG Horizon, the Lower FG (LFG) Sand, is the overlying aquifer to the HJ Horizon. Beneath the Sage Brush Shale is the KM Horizon. The uppermost sand within the KM Horizon, designated the Upper KM (UKM) Sand, is the underlying aquifer to the HJ Horizon.

Figure D6.2-2 depicts the stratigraphic relationship of these units. A brief description of each hydrostratigraphic unit follows, from shallowest to deepest.

DE Horizon

The DE Horizon outcrops in the southern two-thirds of the project site, but is absent in the northern one-third. In the southern part of the Permit Amendment Area, DE Horizon sands coalesce with sands of the underlying FG Horizon. The DE Horizon consists of a sequence of sands and discontinuous clay/shale units. The DE Horizon is the shallowest occurrence of groundwater within the Permit Amendment Area; although the horizon is not saturated in all portions of the Project area.

FG Horizon

Underlying the DE Horizon is the FG Horizon, which is continuous throughout the Lost Creek East Project. Due to the regional dip and trend length, the top of the FG Horizon outcrops over the eastern one-third of the Project Area deepening to 50 feet at the west property boundary. The total thickness is typically about 180 feet, but ranges between 160 and 180 feet. The FG Horizon transitions from confined to unconfined aquifer conditions moving southwest to northeast along Cross-Section B-B' (**Attachment D6-4, Figure 2-3**).

Lost Creek Shale

Underlying the FG Horizon is the Lost Creek Shale. The Lost Creek Shale appears continuous across the Permit Amendment Area, ranging from five to 40 feet in thickness. Typically, this unit has a thickness of 10 to 20 feet. The Lost Creek Shale is the confining unit between the overlying aquifer FG Horizon and the HJ Horizon. The confining characteristics of the Lost Creek Shale have been demonstrated with pump tests, as described later in this application.

HJ Horizon

The HJ Horizon is one of the primary target for uranium production at the Lost Creek East Project. The HJ Horizon sands are generally composed of coarse-grained arkosic sands with thin lenticular intervals of fine sand, mudstone and siltstone. The sands are generally separated by thin clayey units that are not laterally extensive and, based on pump test results, do not act as confining units to prevent groundwater movement vertically between the HJ sand units. The total thickness of the HJ Horizon ranges from 110 to 120 feet, averaging approximately 110 feet. The top of the HJ Horizon is approximately 95 feet below ground surface (bgs) in the eastern Permit Amendment Area deepening to 360 feet bgs in the western part of the Permit Amendment Area. The underlying aquifer to the HJ Horizon is the KM Horizon, which is also a likely uranium production zone. Therefore, the deepest sand within the HJ Horizon, is also designated as the overlying aquifer to the KM Horizon.

Sage Brush Shale

Underlying the HJ Horizon is the Sage Brush Shale. It occurs at depths ranging from 100 to 510 feet bgs. The Sage Brush Shale is laterally extensive and ranges from two to 30 feet thick. The Sage Brush Shale is the lower confining unit to the HJ Production Zone. The confining characteristics of this unit have been demonstrated through pumping tests, as described in later sections of this application.

KM Horizon

The KM Horizon underlies the Sage Brush Shale, and is generally a massive coarse sandstone with lenticular fine sandstone intervals. The KM Horizon is the underlying aquifer to the HJ Horizon, but is also a targeted production zone within the Permit Amendment Area. The KM Horizon is continuous throughout the Lost Creek East Project. The top of the KM Horizon occurs at depths of approximately 210 feet near the eastern Project boundary deepening to 390 feet at the west property boundary (Section 20). The total thickness is typically about 125 feet, but ranges from 100 to 130 feet. The KM Horizon is fully confined throughout the project area.

The KM Horizon is the uppermost component of the composite KLM Horizon which is continuous throughout the Lost Creek East Project. The total thickness ranging from approximately 260 to 330 feet; the average thickness is approximately 305 feet (**Attachment D6-4, Figure 2-3**). Within the composite KLM Horizon, the KM is the only Horizon which contains significant mineralization; and, thus is herein considered a Production Zone. Within the composite KLM Horizon, there is no confirmed areally extensive confining unit that isolates the KM, L and M Horizons from each other. Rather, there is a series of interfingered layers of mudstone, siltstone and shales. Some of these have historically been referred to as "No Name Shale", K-Shale, LM Shale and MN Shale. Previous Lost Creek pump tests have evaluated some of these as potential lower aquitards to the KM Production Zone. These bedding units may show continuity over large areas but regional continuity has not been demonstrated. Thus, they cannot be considered truly confining units on a regional scale. However, due to the interfingering nature and low permeability of these units, they do limit and/or restrict vertical flow in the proposed production area (Petrotek, 2011).

MN Shale and N Horizon

The MN Shale is a zone of interfingered layers of mudstone, siltstone, and shale that separates the M Horizon from the deeper N Horizon (**Figure D6.2-2**). Based on geologic data, the MN Shale is not considered a true regional confining unit, as continuity is not observed over a regional scale. The MN Shale does limit and/or restrict vertical flow due to the interfingering of finer grained and lower permeability units. It ranges from approximately 10 to 30 feet thick, with a typical thickness of about 10 feet. As mentioned above, regional continuity of the MN Shale is not certain. An isopach map of the MN Shale is presented in **Plate D5-3e.1 and D5-3e.2**. Beneath the MN Shale is the N Horizon and based on limited data, the total thickness of the N Horizon is approximately 100 feet. No isopach was constructed for this aquifer due to the limited number of borings that have penetrated through the entire N Horizon.

D6.2.2.2 Potentiometric Surface, Groundwater Flow Direction and Hydraulic Gradient

The LC ISR, LLC hydrologic evaluation of the Project included measurement of water levels in monitor wells completed in the HJ and KM Horizons, the overlying FG Horizon and the underlying N Horizon, to assess the potentiometric surface, groundwater flow direction and hydraulic gradient of those units.

Water level measurements collected three months post testing were used to construct preliminary potentiometric surface maps for the FG, HJ, KM and N Horizons (**Attachment D6-4**, **Figures 2-5 to 2-8**). The water level data are considered representative of static conditions because measurements were collected after an extended period of inactivity within the test area (e.g., step-rate testing, groundwater sampling, water supply pumping, pump testing, etc.).

Due to the relative few data points from which to construct the potentiometric surfaces, the known regional direction of groundwater flow was used as a guide to constructing the maps. In addition, due to the lack of control, the potentiometric surfaces were constructed as though the faults were not present. However, based on prior Mine Unit 1 experience, the faults are known to act as low-flow barriers to groundwater movement thus the potentiometric surfaces maps are considered preliminary/conceptual. The role that the faults in Sections 20 and 21 play in influencing the movement of groundwater will be further evaluated during subsequent hydrologic investigations.

The following initial observations are presented:

FG Horizon

Based on potentiometric surface elevations, the direction of groundwater flow within the FG Horizon is predominantly to the west-southwest. Calculated hydraulic gradients range from 0.008 ft/ft to 0.019 ft/ft (44 to 100 ft/mile) in the Project Area (**Attachment D6-4**, **Figure 2-5**).

HJ Horizon

Based on potentiometric surface elevations, the direction of groundwater flow within the HJ Horizon is predominantly to the west-southwest. Calculated hydraulic gradients range from 0.005 ft/ft to 0.015 ft/ft (29 to 79 ft/mile) in the Project Area (**Attachment D6-4**, **Figure 2-6**).

KM Horizon

Based on potentiometric surface elevations, the direction of groundwater flow within the KM Horizon is predominantly to the west-southwest. Calculated hydraulic gradients range from 0.009 ft/ft to 0.018 ft/ft (49 to 95 ft/mile) in the Project Area (**Attachment D6-4**, **Figure 2-7**).

N Horizon

There are five N Horizon monitoring wells located in LCE. During the compilation of this report, it was discovered that monitor wells M-N2 and M-N3 are completed in both the M and N Horizons (**Attachment D6-3, Well Completion Logs**). Therefore, the static water elevation in these two wells is not believed to be representative. However, the MN Shale that typically separates the two Horizons is not well defined at these well locations; thus, the M and N Horizons are likely in hydraulic communication. Nevertheless, the static water level in monitor well M-N3 does not fit the regional trend and was therefore not used in constructing the potentiometric surface map (**Attachment D6-4**, **Figure 2-8**). Subsequent hydrologic investigations will attempt to resolve the water level anomaly and better define the N Horizon potentiometric surface.

Vertical Hydraulic Gradients

Vertical hydraulic gradients were determined by measuring water levels in closely grouped wells completed in different hydrostratigraphic units. **Figure D6.2-1** shows the location of the well groups used for the assessment of vertical hydraulic gradients Vertical hydraulic gradient from the FG to the HJ Horizon were evaluated at four locations where there were FG Horizon well completions, gradients from the HJ to the KM Horizon were evaluated at eight locations and at five locations for the KM to N Horizon calculation. **Table 2-1, Attachment D6-4** summarizes the calculated vertical gradients between the FG, HJ, KM and N Horizons. The following bullets briefly summarize the general head differentials observed in all LCE monitored Horizons.

- Head in the FG Horizon is approximately 10 to 32 feet higher than in the underlying HJ Horizon;
- Head in the HJ Horizon is from 5 to 33 feet higher than the in underlying KM Horizon; and,
- Head in the KM Horizon is from 6 to 135 feet higher than in the underlying N Horizon.

The vertical gradients indicate the potential for groundwater flow is downward. A downward potential is indicative of an area of recharge, as opposed to an upward potential that is normally indicative of an area of groundwater discharge. A downward gradient is consistent with the structural and stratigraphic location of the Project within the Great Divide Basin. Results are consistent with the regional conceptual model of decreasing heads with depth indicating proximity to areas of recharge in this portion of the Battle Spring Formation.

D6.2.2.3 Aquifer Properties

Aquifer properties (transmissivity, storativity, and hydraulic conductivity), for the Battle Spring aquifers within the Permit Amendment Area, have been calculated from analysis of data from five long-term pump tests. A brief summary of the pump test results and analyses are provided below. The full hydrologic report is presented in **Attachment D-4**.

2013 Pump Tests

The Lost Creek East Project is located contiguous to and east of the Lost Creek ISR Project as shown on **Figure D6.2-1**. The LCE Project lies within all or parts of Sections 1, 2, 3, 10, 11, 12, 14, 15, 20, 21, 22, 23, 27, 28, and 29 of T25N, R92W.

The LCE ore of interest is contained in the HJ and KM Horizons. Due to the length of the mineralized trend, LQD granted approval to perform regional pump tests at three different locations along the trend as shown on **Figure D6.2-1**. At each location, it was proposed to independently pump test the HJ and KM Horizons while observing monitoring wells completed in the same horizon, as well as those completed in the overlying and underlying horizons.

Figure D6.2-1 shows the location of wells used in the regional pump tests. The three clusters of pumping/observation wells installed over the length of the property are denoted as the North Cluster, Central Cluster and South Cluster. In addition, four clusters of observation wells were installed adjacent to or between the pump test clusters.

Pump tests were performed at three KM Horizon locations and two HJ Horizon locations. Due to insufficient saturation of the North Cluster HJ Horizon, no pump test was performed.

Each of the five long-term pump tests were run from three to seven days at pumping rates that ranged from 39 to 61 gallons per minute. Sufficient drawdown was observed in the same-horizon monitor wells for the calculation of aquifer properties.

Table 7-1, Attachment D6-4 presents a compilation of the analytical results for the two HJ Horizon pump tests. HJ Horizon transmissivity values computed from the Theis analysis ranged from 74 to 384 ft^2/day. Analysis using the Theis recovery method yielded values ranging from 54 to 318 ft^2/day. The lower end of this transmissivity range is generally consistent with the results obtained from previous Lost Creek HJ Horizon pump tests. Based on site specific aquifer thicknesses, the calculated mean hydraulic conductivity (K) values ranged from 0.78 to 3.20 ft/day.
Using the Theis method, calculated S values ranged between 1.15×10^{-4} and 3.03×10^{-4}. Again, the calculated HJ Horizon storativity values are similar to previously obtained Lost Creek test results.

Table 7-1, Attachment D6-4 presents a compilation of the analytical results for the three KM Horizon pump tests. KM Horizon transmissivity values computed from the Theis analysis ranged from 86 to 251 ft^2/day. Analysis using the Theis recovery method yielded values ranging from 113 to 359 ft^2/day. The lower end of this transmissivity range is generally consistent with the results obtained from previous Lost Creek KM Horizon pump tests. Based on site specific aquifer thicknesses, the calculated mean hydraulic conductivity (K) values ranged from 1.07 to 3.26 ft/day.

Using the Theis method, calculated S values ranged between 7.35×10^{-5} and 1.97×10^{-2}. Again, the calculated KM Horizon storativity values are similar to previously obtained Lost Creek test results.

The following paragraphs summarize the hydrologic investigation findings:

- The pump tests results demonstrated that: 1) there was hydrologic communication between the pumped well and one or more same-horizon observation wells, 2) there was no apparent hydraulic communication between the HJ and KM Horizons in any of the five pump test areas, and 3) there was no obvious hydraulic communication with the underlying N Horizon.

- The Central and South HJ Horizon tests, revealed only very minor hydrologic communication with the overlying FG Horizon. The water level drop in the FG Horizon was less than a barometrically corrected 7-inches in both tests.

- 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.

D6.3 Groundwater Use

Groundwater use permits with legal descriptions inside and within three miles of the Permit Amendment Area were queried using the WSEO Water Rights Database (WSEO, 2014). **Tables D6.3-1** and **D6.3-2** list the permits, including potentially active permits as well as abandoned and cancelled permits, which were issued by WSEO to parties other than LC ISR, LLC or its affiliates. The permit information includes, but is not limited to, location, uses, priority dates, status, yield, total depth, and static water depth. **Table D6.3-1** lists permits within one-half mile of the Permit Amendment Area; this table correlates with **Figure D6.3**-1 that shows the permit locations. **Table D6.3-2** lists permits within three miles of the Permit Amendment Area; these locations are shown on **Figure D6.3-2**. The majority of the groundwater use permits, filed in the vicinity of the Permit Amendment Area, are for stock watering, monitoring, miscellaneous and mining-related purposes.

Table D6.3-3 is a list of the permits issued by the WSEO to LC ISR, LLC or its affiliates (Ur-Energy and NFU Wyoming, LLC). At this time, there are 207 groundwater use permits of which 10 are designated water supply wells, 156 are monitor wells, two are disposal wells, 15 are test wells and 22 are industrial wells associated with ISR mining activities (four permits are for well re-work thus duplicates). Of the 207 permits only 24 are located within the Permit Amendment Area. Installation of supplemental wells is on-going, and locations of wells currently used for water quality sampling and pump tests are shown on **Figure D6.2-1**, which are discussed in other sections of **Appendix D6**. Currently, the Permit Amendment Area consumes a negligible amount of groundwater attributed to well development, monitoring, testing, and miscellaneous purposes related to uranium exploration.

The groundwater use permits within one-half mile unrelated to mining are those belonging to the BLM. In 1968 and 1980, the BLM Rawlins District was granted two permits by the WSEO (13834 and 55112, see below). Both permits, located inside the LCE Amendment Area, correspond to wells that supply water to a stock pond or storage tank (**permits #1 and #2 on Figure D6.3-1**).

SEO Permit 13834 - Battle Spring Draw Well No. 4451;
SEO Permit 55113 - Battle Spring Well No. 4777

Battle Spring Draw Well No. 4451 seasonally pumps water into a stock tank (Township 25 North, Range 92 West, Section 21, NW¼, NE¼, NE¼). In 1968, a uranium exploration hole was drilled at this location; when water was encountered, plastic casing was installed and the well was developed. According to the State Engineers Office records, the well depth is 900 feet, with a reported static water level of 104 feet, and a permitted yield of 19 gallons per minute. However, the screened interval is not specified. On October 1, 2013, LC ISR, LLC E-logged the well. The results indicate that there is 240 feet of casing in the hole with a static water level at 148 feet bgs. Apparently, the hole caved just beneath the casing (maximum probe depth). BLM well No. 4451 has been sampled by LC ISR, LLC numerous times since 2009 (analytical results are presented in the KM Amendment documents). The results indicate high levels of radionuclides.

The Battle Spring Well No. 4777 was drilled as a stock well in 1981 to a depth of approximately 220 feet. The well is shallower than the sands targeted by LC ISR, LLC under the current Permit. A water use of 25 gpm is permitted. Battle Spring Well No. 4777 is located in Township 25 North, Range 92 West, Section 30, SE¼, NW¼.

In March 2014, LC ISR, LLC contacted BLM staff to inquire about the current status of these groundwater use permits. The BLM stated that the groundwater use permits are active, and the wells are being used for stock watering from earthen impoundments. A trailer mounted solar pump is moved from one well to the other seasonally.

Throughout the phases of the Project, LC ISR, LLC will correspond with BLM to ensure that the stock reservoirs and wells are not impacted in a manner that restricts the intended use. LC ISR, LLC has committed to work with BLM to replace the water source if any wells are rendered unusable due to LC ISR's mining activities.

D6.4 Groundwater Quality

This section describes the regional and local groundwater quality based on information from investigations performed within the Great Divide Basin and recent data collected in the Permit Amendment Area.

D6.4.1 Regional Groundwater Quality

Water quality within the Great Divide Basin ranges from very poor to excellent. Groundwater in the near surface, more permeable aquifers, is generally of better quality than groundwater in deeper and less permeable aquifers. Groundwater with TDS less than 3,000 mg/L can generally be found at depths less than 1,500 feet within the Tertiary aquifer system, which includes the Battle Spring/Wasatch, Fort Union and Lance aquifers (Collentine et al., 1981).

Water quality for the Great Divide Basin is available from a large number of sources including the USGS National Water Information System (NWIS) database, the University of Wyoming Water Resources Data System (WRDS), and the USGS Produced Waters Database. Much of these data are tabulated in "Water Resources of Sweetwater County, Wyoming", a USGS Scientific Investigation Report by Mason and Miller (2005). However, the quality and accuracy of much of the data are difficult to assess. This section of the Permit Amendment describes general water quality of the Great Divide Basin, primarily by reference to these sources.

Mason and Miller (2005) noted that water quality in Sweetwater County is highly variable within even a single hydrogeologic unit, and that water quality tends to be better near outcrop areas where recharge occurs. They also noted that groundwater quality samples from the Quaternary and Tertiary aquifers are most likely biased toward better water quality and do not necessarily represent a random sampling for the following reasons: 1) Wells and springs that do not produce useable water usually are abandoned or not developed, 2) Deeper portions of the aquifers typically are not exploited as a groundwater resource because a shallower water supply may be available. As a result, these water sources do not become part of the sampled network of wells and springs that ultimately make up the available groundwater database. Groundwater quality samples from deeper Mesozoic and Paleozoic hydrostratigraphic units are often available where oil and gas production or exploration has occurred. Therefore, groundwater samples from older geologic units may have less bias in representing ambient groundwater quality than samples collected from Quaternary and Tertiary aquifers.

Water quality within the shallow Tertiary aquifers generally represents sodium-bicarbonate to sodium-sulfate water types. TDS levels within the Wasatch aquifer in the west and south parts of the Great Divide Basin tend to be high relative to the U.S. EPA's Secondary Drinking Water Standard (SDWS) of 500 mg/L; even within the shallow aquifers. TDS levels within the Battle Spring/Wasatch aquifers are generally less than 500 mg/L along the northern flank of the Great Divide Basin (which includes the Permit Amendment Area). Elevated TDS levels (greater than 3,000 mg/L) are present within the Wasatch aquifer along the eastern edge of the Washakie Basin and within the Fort Union and Lance aquifers along the east side of the Rock Springs uplift. Elsewhere within the Great Divide and Washakie Basins, TDS levels in the Tertiary aquifer system are typically between 1,000 and 3,000 mg/L (Collentine et al., 1981).

Low-TDS waters within the Battle Spring aquifer are predominately sodium-bicarbonate type waters. With increasing salinity, the water type tends to become more calcium-sulfate dominated. However, this trend is not exhibited in the Wasatch, Fort Union and Lance aquifers within the Great Divide and Washakie Basins. The Wasatch and Lance aquifers are characterized by predominately sodium-sulfate type waters, particularly near outcrop areas. The Fort Union is more variable in composition.

Water quality data for Tertiary aquifers away from the outcrop areas are sparse, but available data indicates that TDS levels increase rapidly away from the basin margins. Water samples collected from a Lance pump test in Section 14, Township 23 North, Range 99 West had reported TDS levels in excess of 35,000 mg/L. A Fort Union test in Section 25, Township 13 North, Range 95 West had TDS levels in excess of 60,000 mg/L, based on resistivity logs (Collentine et al., 1981). Water quality samples from produced water in the Wasatch and Fort Union Formations from an average depth of 3,500 feet had TDS values ranging from 1,050 to 153,000 mg/L with a median value of 13,900 mg/L (Mason and Miller, 2005). TDS from four wells completed in the Fort Union Formation located along the margins of the basin ranged from 800 to 3,400 mg/L (Welder and McGreevy, 1966).

A graph of TDS versus sampling depth for produced water samples from the Wasatch Formation in Sweetwater County prepared by Mason and Miller (2005) shows that at depths greater than 3,000 feet, TDS values are typically above 10,000 mg/L. It is noted that the Mason and Miller data set is small for a large area and may be biased by data from the southern part of the Great Divide Basin; few site-specific data directly applicable to the Permit Amendment Area are available.

Water quality within the Battle Spring aquifer is generally good in the northeast portion of the basin with TDS levels usually less than 1,000 mg/L and frequently less than 200 mg/L. Water type within the Battle Spring aquifer is typically sodium bicarbonate to sodium sulfate. Mason and Miller (2005) reviewed 18 groundwater samples collected from the Battle Spring aquifer and observed that those samples represented some of the best overall quality of those studied in Sweetwater County. Sulfate levels can be elevated in Tertiary aquifers, but are generally low in the shallow aquifers of the Battle Spring Formation. Out of 18 samples included in the Mason and Miller (2005) study, only one sample exceeded the WDEQ Class I Drinking Water Standard for sulfate of 250 mg/L. Most sample results were also less than the WDEQ TDS Class I Drinking Water Standard of 500 mg/L. Nitrate, fluoride and arsenic concentrations were less than WDEQ and EPA standards for all samples.

Notable exceptions to the relatively good water quality is the presence of elevated radionuclide constituents. Uranium and radium-226 (Ra-226) concentrations exceeded their respective EPA Maximum Contaminant Levels (MCLs) of 0.03 mg/L and 5 pCi/L in some of the samples; radon-222 (Rn-222) concentrations were also relatively high in some samples (Mason and Miller, 2005). The presence of high levels of uranium in Tertiary sediments and groundwater of the Great Divide Basin has been well documented. The Lost Creek Shroeckingerite deposit, located northwest of the Permit Amendment Area, is noted for high uranium levels in groundwater. Uranium-bearing coals are also present in the Great Divide Basin. Sediments of the Battle Spring Formation were derived from the Granite Mountains and contain from 0.0005 to 0.001 percent uranium (Masursky, 1962). Based on historical exploration results, certain areas of the Battle Spring Formation (e.g., Lost Creek) contain much higher uranium concentrations.

Water quality for aquifer systems deeper than the Tertiary (such as the Mesaverde aquifer system) are not described in this report; because they are several thousands of feet deep in the vicinity of the Project and are separated from the Tertiary aquifer system by the Lewis Shale, a regional aquitard. The deeper aquifer systems of the Great Divide Basin will not impact nor be impacted by ISR activities at Lost Creek East.

D6.4.2 Site Groundwater Quality

Information regarding site water quality is primarily derived from background monitor wells installed by LC ISR, LLC in 2012 and 2013.

D6.4.2.1 Groundwater Monitoring Network and Parameters

In 2012, LC ISR, LLC installed 20 monitor wells in the FG, HJ, KM and N Horizons and initiated background sampling for WDEQ-LQD Guideline 8 parameters. Four quarters of water sampling have been completed for most background monitor wells. Four supplemental monitor wells were installed in 2013 at the request of LQD. Only two or three quarts of analyses have been collected to date; however, sampling activities are continuing. The location of LC ISR, LLC's background monitor wells are indicated on **Figure D6.2-1**.

D6.4.2.2 Groundwater Quality Sampling Results

Background Sampling

LC ISR, LLC began background sampling in December 2012 at the following 20 locations:

- FG Monitor Wells: M-FG1 and M-FG2;
- HJ Monitor Wells: M-HJ1, M-HJ2A, M-HJ3, M-HJ4, M-HJ5, M-HJ6, and M-HJ7D;
- KM Monitor Wells: M-KM4A, M-KM5A, M-KM6, M-KM-7, M-KM8, M-KM9 and M-KM10; and
- N Monitor Wells: M-N2, M-N3, M-N4 and M-N5A.

Following the 2013 monitor well installations, sampling commenced in December 2013 at these four wells:

- FG Monitor Well : M-FG5;
- HJ Monitor Well: M-HJ8;
- KM Monitor Well: M-KM11A; and
- N Monitor Well: M-N6.

Results of the LC ISR, LLC background monitoring program are summarized in **Table D6.4-1**. The raw laboratory data was downloaded to the CD disk found in **Attachment D6-3**. In **Table D6.4-1**, those parameters that exceed specific WDEQ-WQD standards or EPA MCL criteria are shown in bold and color coded to the specific WQD or EPA criteria they exceed. **Table D6.4-2** presents the state Class-of-Use and federal Drinking Water Criteria for specific groundwater parameters.

A summary of water quality analytical results for each hydrostratigraphic Horizon of interest (FG, HJ, KM and N Horizons) is presented below.

FG Horizon Water Quality

Three wells completed in the FG Horizon were included in the background sampling program (M-FG1, M-FG2 and M-FG5). Sample analytical results from background monitor wells are presented in **Table D6.4-1**.

Background sampling results indicate that the FG Horizon monitor wells are calcium-bicarbonate to calcium-sulfate type water. TDS, iron and sulfate levels exceeded the WDEQ Class I Standards (500 mg/L, 0.3 mg/L and 250 mg/L, respectively) in two of the three wells. Selenium also exceeded the WDEQ Class I and II Standards in one FG Horizon well.

The chloride and magnesium levels in all three wells are low; less than 10 mg/L. One pH measurement from one background water sample exceeded the WDEQ Class I Standard (6.5 to 8.5 standard units).

Gross Alpha results exceeded the WDEQ Class I Standard (15.0 pCi/L) in all samples at every FG Horizon well. Uranium levels exceeded the EPA MCL (0.03 mg/L) in all samples collected from two of the three FG monitor wells (M-FG2 being the exception). The average uranium concentration for the FG samples was 0.475 mg/L. All but one FG Horizon water sample exceeded the WDEQ Class I Standard (5.0 pCi/L) for radium 226+228.

HJ Horizon Water Quality

Seven wells completed in the HJ Horizon were included in the background sampling program (M-HJ1, M-HJ2A, M-HJ3, M-HJ4, M-HJ5, M-HJ6 and M-HJ8). Sample analytical results from all background monitor wells are included in **Table D6.4-1**.

Background sampling results indicate that the HJ monitor wells are calcium-bicarbonate to calcium-sulfate type water. With the exception of selenium and uranium, none of the remaining inorganic parameters exceeded the WDEQ Class-of-Use or EPA drinking water criteria. Selenium exceeded WDEQ Class I and II Standards in background well M-HJ6. Uranium levels exceeded the EPA MCL in monitor wells M-HJ3, M-HJ5 and M-HJ6.

Three quarterly water sample results from monitor well M-HJ8 indicated pH measurement that exceeded the WDEQ Class I and III Standards (6.5 to 8.5 standard units). Chloride levels in all wells are low (7 mg/L or less).

Gross Alpha results exceeded the WDEQ Class I Standard (15.0 pCi/L) in all samples at every HJ Horizon well. Uranium levels exceeded the EPA MCL (0.03 mg/L) in three of the seven wells. The average uranium concentration for the HJ samples was 0.475 mg/L. All water samples in every HJ Horizon monitor well exceeded the WDEQ Class I Standard (5.0 pCi/L) for radium 226+228.

KM Horizon Water Quality

Eight wells completed in the KM Horizon were included in the background sampling program (M-KM4A, M-KM5, M-KM6, M-KM7, M-KM8, M-KM9, M-KM10, and M-KM11A). Sample analytical results from background monitor wells are included in **Table D6.4-1**.

Background sampling results indicate that the KM monitor wells are calcium-bicarbonate to calcium-sulfate type water. With the exception of pH, iron, selenium and uranium, none of the remaining inorganic parameters exceeded the WDEQ or EPA criteria. Four monitor wells had pH results that exceeded the WDEQ Class I and III Standards (6.5 to 8.5 standard units). Two monitor well iron results exceeded WDEQ Class I Standards (0.3 mg/L) and EPA Secondary Drinking Water Criteria (0.03 mg/L). Selenium exceeded the WDEQ Class II Standard in background well M-KM10. Uranium levels exceeded the EPA MCL in five different monitor wells.

Radium 226+228 levels exceeded the WDEQ Class I Standard (5.0 pCi/L) in seven of eight monitor wells, while Gross Alpha results exceed the WDEQ and EPA Standards (15 pCi/L) in all KM monitor wells at least once.

N Horizon Water Quality

Five wells completed in the N Horizon were included in the background sampling program (M-N2, M-N3, M-N4, M-N5A and M-N6). Sample analytical results from background monitor wells are presented in **Table D6.4-1**. Analytical results from baseline monitor wells M-N3 and M-N5A are not considered representative due to inadequate well purging prior to sample collection. Accordingly, those results are excluded from the following discussion. In future sampling events, the submersible sampling pumps in these two wells will be lowered to increase submergence thus allowing for more purge time.

Background sampling results indicate that the N Horizon monitor wells are calcium-bicarbonate to calcium-sulfate type water. The chloride levels in all wells are low; less than 5 mg/L. With the exception of four pH sample results and one iron sample result, none of the remaining inorganic parameters exceeded the WDEQ or EPA criteria.

None of the background water sample results exceeded the Gross Alpha WDEQ Class I Standard or EPA MCL criteria of 15.0 pCi/L. Only one water sample from monitor well M-N6 exceeded the uranium EPA MCL criteria (0.03 mg/L). All three N Horizon monitor well water samples exceeded the WDEQ Class I Standard (5.0 pCi/L) for radium 226+228.

Summary of Site Groundwater Quality

A Piper diagram (**Figure D6.4-1**) presents the average background groundwater quality for all quarterly sampling events. The Piper diagram compares the average water quality between individual Horizons (FG, HJ KM and N). The plot shows that there isn't much difference in groundwater geochemistry between the various Horizons. Groundwater contained in the shallow Battle Springs aquifers that underlie the Permit Amendment Area is a calcium-sulfate to calcium-bicarbonate type water. There is some variability in water chemistry when the wells are compared individually, but those differences don't change the overall groundwater character type.

In summary, the concentration of trace constituents, boron, cadmium, chromium, copper, mercury, molybdenum, nickel, and vanadium were at or less than the detection limits for all samples analyzed. TDS, iron and sulfate values are relatively low, with occasional exceedances of WDEQ Class I Standards. Twenty out of 22 wells reported TDS and sulfate concentrations less than their respective Class I Standards. Iron exceeded the WDEQ Class I Standard and EPA MCL in two FG monitor wells (M-FG1 and M-FG5), two KM monitor wells (M-KM8 and M-KM9), and one N monitor well (M-N6). Selenium was elevated in excess of state and federal standards in three different Horizon monitor wells.

Every monitor well contained some dissolved uranium, but only 10 wells contained concentrations that exceeded the 0.03 mg/L uranium EPA MCL. Radium-226+228 results exceeded the WDEQ Class I Standard and EPA MCL (5.0 pCi/L) in all background wells with the exception of M-KM10; which is approximately 71 percent of the total samples analyzed. Gross Alpha results exceeded the WDEQ Class I Standard and EPA MCL in all FG, HJ and KM Horizon wells, and one N Horizon well during at least one sampling event.

General water quality in the shallow Battle Spring aquifers within the Permit and Amendment Area tends to be relatively good, with the exception of the presence of radionuclides. However, elevated concentrations of radionuclides is consistent with the presence of uranium orebodies.

D6.5 Hydrologic Conceptual Model

A hydrologic conceptual model of the Project and surrounding area has been developed to provide a framework that allows LC ISR, LLC to make decisions regarding optimal methods for extracting uranium from mineralized zones, and to minimize environmental and safety concerns caused by ISR operations.

LC ISR, LLC will use ISR technology at the Project to extract uranium from permeable uranium-bearing sandstones within the upper portion of the Battle Spring Formation, at depths ranging from 125 to 500 feet. A conceptual hydrologic model of the Project is summarized below.

D6.5.1 Regional Groundwater Conceptual Model

The Project is located within the northeastern portion of the Great Divide Basin. The Eocene Battle Spring Formation crops out over most of the northeastern portion of the Great Divide Basin, including the Permit Amendment Area. The total thickness of the Battle Spring Formation in the vicinity of the Permit Amendment Area is approximately 6,200 feet. The Battle Spring Formation contains multiple aquifers that are a part of the Tertiary aquifer system. Groundwater flow within the Battle Spring aquifers is primarily toward the interior of the basin, southwest of the Project. Recharge to the Battle Springs aquifers within the Project Area is mostly the result of infiltration of precipitation to the north and northeast in the Green Mountains and Ferris Mountains. Based on available information, discharge from the Battle Spring aquifers is predominately to a series of lakes, springs and playa lake beds near the center of the basin. Some groundwater from the Battle Spring aquifers is discharged through pumping for stock watering, irrigation, industrial and domestic use.

The Battle Spring Formation is described as an arkosic fine- to coarse-grained sandstone with claystone and conglomerates. Groundwater within the Battle Spring aquifers is typically under confined (artesian) conditions, although locally unconfined conditions exist. The potentiometric surface within the Battle Spring aquifers is usually within 200 feet of the ground surface. Most wells drilled for water supply in this unit are less than 1,000 feet deep. Wells completed in the Battle Spring aquifers typically yield 30 to 40 gpm but yields as high as 150 gpm are possible.

Water quality within the shallow Tertiary aquifers generally represents sodium-bicarbonate to sodium-sulfate water types. TDS levels within the Battle Spring aquifers are generally less than 500 mg/L along the northern flank of the Great Divide Basin near areas of outcrop. Low TDS waters within the Battle Springs aquifer are predominately sodium-bicarbonate type waters. With increasing salinity, the water type tends to become more calcium-sulfate dominated. Notable exceptions to the relatively good water quality include waters with elevated radionuclides (uranium, Ra-226 and Ra-228). High levels of uranium are common in Tertiary sediments and groundwater of the Great Divide Basin. The Lost Creek Shroeckingerite deposit located northwest of the Project is noted for high uranium levels in groundwater. Uranium-bearing coals are present in the Wasatch Formation in the central part of the Great Divide Basin.

As described previously, the Battle Spring Formation crops out over most of the Permit and Amendment Area. The Battle Spring is the shallowest occurrence of groundwater within the Amendment Area. Water-bearing Quaternary and Tertiary units younger than the Battle Spring Formation are present several miles to the north and east and are hydraulically up-gradient of the Permit Amendment Area. Therefore, ISR operations conducted at the Project will have no impact on those shallower hydrostratigraphic units.

D6.5.2 Site Groundwater Conceptual Model

D6.5.2.1 Hydrostratigraphic Units

The hydrostratigraphic units of interest within the Battle Spring Formation, with respect to the Project include, from shallowest to deepest:

- FG Horizon (includes overlying aquifer to HJ Horizon):
    - subdivided into UFG, MFG and LFG Sands;
    - total thickness of horizon is 180 feet;
    - top of unit outcrops on the east side of the Permit Amendment Area and is present at a depth of 50 feet bgs on the west side;
    - LFG Sand is the overlying aquifer to HJ Horizon;
    - LFG Sand is 20 to 50 feet thick;
    - the FG 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 level depths range from 110 feet bgs in the center of the Permit Amendment Area to 125 feet bgs on the west side.
- Lost Creek Shale (upper confining unit to the HJ Horizon):
    - laterally continuous across Permit Amendment Area;
    - five to 25 feet thick; and
    - confining properties demonstrated from water levels and pump tests.
- HJ Horizon (primary production zone):
    - subdivided into UHJ, MHJ and LHJ Sands, although sands are hydraulically connected;
    - coarse-grained arkosic sands with thin lenticular intervals of fine sand, mudstone and siltstone;

  - 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, but will require additional hydrologic characterization.

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 N Horizons indicate that confining units are present between the FG-HJ-KM hydrostratigraphic units.

Pump tests indicate the presence of confining units between the LFG and HJ aquifers and between the HJ and UKM Horizons, although some minor hydraulic communication exists between the FG and HJ Horizons. The hydraulic communication only becomes apparent when large stresses (head differences) are applied to the aquifers through pumping. Hydraulic communication between the HJ Horizon and overlying FG aquifer may be through historic boreholes that were improperly abandoned, leakage through the confining shale units, or contact of sands juxtaposed across a fault. Additional investigation will be completed prior to production of any mine units.

Vertical hydraulic gradients between the FG and HJ Horizons range from 0.10 to 0.34 ft/ft, between the HJ and KM Horizons 0.04 to 0.24 ft/ft, and between the KM and N Horizons 0.02 to 0.37 ft/ft (**Table 2-1, Attachment D-4**). These findings are consistent with the Lost Creek observations of decreasing hydraulic head with depth. The vertical gradients indicate the potential for groundwater flow is predominately downward. The vertical gradients also support the confining nature of the Lost Creek and Sage Brush Shale.

D6.5.2.3 Aquifer Properties

Transmissivity values for the HJ Horizon range from 74 to 384 ft^2/d (554 to 2,872 gpd/ft). Storativity values for the HJ Horizon range from 1.15×10^{-4} to 3.03×10^{-4}. The range of KM Horizon transmissivity values are similar to the HJ aquifer characteristics (86 to 251 ft^2/d or 643 to 1,877 gpd/ft). Storativity values for the KM Horizon range from 4.53×10^{-5} to 1.97×10^{-2}.

D6.5.2.4 Water Quality

Water quality within the hydrostratigraphic units of interest (the production zones and overlying and underlying aquifers) is generally good with respect to major chemistry. TDS and sulfate levels are typically less than their respective WDEQ Class I Standards and EPA SDWS, although occasionally, regulatory standards are exceeded. Chloride levels are low, (less than 10 mg/L) making this parameter a good indicator for excursion monitoring.

Trace metals are generally less than WDEQ Class I Standards and EPA MCLs in the production zone, overlying and underlying aquifers. Iron, pH, sulfate, and selenium occasionally exceed their respective standards.

Uranium is present in all 22 background wells, but only 10 wells had concentration levels that exceed the EPA MCL of 0.03 mg/L. Radium-226+228 results exceeded the WDEQ Class I Standard and EPA MCL (5.0 pCi/L) in all background wells with the exception of M-KM10. Radium-226+228 results exceeded the EPA MCL in approximately 71 percent of the samples collected. Dissolved radionuclide levels are commonly elevated in groundwater associated with uranium-bearing sandstones.

D6.5.2.5 Summary

The uranium bearing sandstones within the upper Battle Spring Formation are suitable targets for ISR operations as demonstrated by the successful operation at the adjacent Lost Creek mine where aquifer characteristics are comparable to LCE conditions. The primary upper production zone aquifer (HJ Horizon) is bounded by laterally extensive upper and lower confining units, as demonstrated by static water level differences and responses to pump tests. 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.

Water quality is generally consistent throughout the hydrostratigraphic units of interest. Elevated radionuclides are present in the groundwater, but this is consistent with the presence of uranium ore deposits.

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ABBREVIATIONS AND ACRONYMS

BLM	Bureau of Land Management
DOT	Department of Transportation
ft	feet
ft bgs	feet below ground surface
gpm	gallons per minute
ISR	In Situ Recovery
LC East	Lost Creek East
LC ISR, LLC	Lost Creek ISR, LLC
LQD	Land Quality Division
NEC	National Electric Code
NRC	Nuclear Regulatory Commission
OP	Operations Plan
Plant	Lost Creek Plant
PPE	personal protective equipment
Project	Refers to the combined LC East and Lost Creek Project unless otherwise defined
RO	reverse osmosis
RWP	Radiation Work Permit
SOP	standard operating procedure
SWPPP	Storm Water Pollution Prevention Plan
U_3O_8	uranium oxide
UIC	Underground Injection Control
US	United States
WDEQ	Wyoming Department of Environmental Quality
WYPDES	Wyoming Pollution Discharge Elimination System

OPERATIONS PLAN

Lost Creek ISR, LLC (LC ISR, LLC) has prepared this Operations Plan (OP) for the Wyoming Department of Environmental Quality (WDEQ), Bureau of Land Management (BLM) and Nuclear Regulatory Commission (NRC) in support of an amendment to the Lost Creek Permit to Mine permit to conduct In Situ Recovery (ISR) of uranium in the Lost Creek East (LC East) area and expand production within Lost Creek to the KM Horizon and additional HJ Horizon mine units. The Project will use existing ISR technology and best industry practices to extract uranium from permeable, uranium-bearing sandstones, located at depths ranging from 150 to 650 feet below surface, through a series of mine units. Each mine unit consists of a "pattern" of production and injection wells, ringed by monitor wells. Once extracted from a mine unit, the uranium will be recovered by means of ion exchange, using commercially available anionic resin, and prepared for shipment as uranium oxide (U_3O_8) "yellowcake" slurry to a facility licensed to process the slurry into dry yellowcake or processed on-site to generate dry yellowcake and then shipped to a conversion facility.

OP 1.0 OVERVIEW OF PROPOSED OPERATION

LC East contains approximately 5,750 acres and Lost Creek contains approximately 4,254 acres (**Plate OP-2a and Plate OP-2b**). Within that area, the surface to be affected by the ISR operation will total approximately 642 acres, following the ore trend which extends southwest–northeast in LC East and east-west through Lost Creek.

The Project requires the additional preparation, construction, and operation of the following:

- the secondary access roads/utility corridors, including pipelines connecting the mine units to the existing Plant and power lines;
- UIC Class I wells and associated pipe lines; and
- the mine units, which include the header houses, through which fluids are routed to/from the injection/production well patterns, and the monitor wells, including those which ring the pattern area and those in overlying and underlying aquifers.

Site preparation, construction, and operations of the Project will be conducted such that potential environmental effects will be minimized to the greatest extent possible. The measures that will be taken during initial site development and for general maintenance throughout the Project are described in **Sections 3, 4 and 5** of the Lost Creek Technical Report.

The details of the mine units, well construction, and instrumentation and control are provided in **Section 3.0** of the Lost Creek Permit Technical Report. The ISR process will be conducted using a carbonate lixiviant, which is pumped from the Plant through buried pipelines to the injection wells in the operational mine unit(s). After circulation through the production zone from the injection wells to the production wells, the lixiviant recovered from the production wells will be pumped from the mine unit(s) through buried pipelines to the ion exchange circuit in the Plant. There, the uranium will be removed by solid resin ion exchange. The carbonate lixiviant will then be regenerated and pumped back to the mine units to recover additional uranium.

Information on the Plant located within the current Lost Creek Permit is provided in **Section 3.3** of the Lost Creek Technical Report. The Plant houses three distinct process circuits: the ion exchange circuit (also called the resin-loading circuit), the elution circuit, and the precipitation/filtration circuit. The final product will be either yellowcake slurry as approved in the original application or dried yellowcake as approved in the original BLM ROD and NRC license amendment. The slurry will be transported from the site via United States (US) Department of Transportation (DOT) approved containers to a facility licensed by the US Nuclear Regulatory Commission (NRC) or an Agreement State for processing the slurry into dry yellowcake.

Effluent control measures that will be used during the Project are described in **Section 4.0** of the Lost Creek Technical Report. Surface reclamation and groundwater restoration are described in the Reclamation Plan (RP), which is a separate portion of this application.

OP 1.1 Site Facilities Layout

The approximate location of the LC East and Lost Creek areas within the general region is shown in **Figure OP-1**. The mine units will be along a southwest to northeast trend through the LC East area and west to east in the Lost Creek area (**Plates OP-2a** and **OP-2b**). The locations of the eight UIC Class I wells (5 previously approved wells at Lost Creek plus three wells proposed for LC East) are widely scattered to accommodate regulatory requirements and meet the necessary injection criteria.

The primary access road and associated culverts have already been constructed. The secondary access roads and associated culverts for each mine unit will be constructed prior to and during installation of that mine unit. Secondary access roads and associated culverts for the UIC Class I wells will be constructed prior to installation of those wells.

Electrical power has been brought into the Lost Creek site, through an overhead line, from the transmission line located directly west of the site. The overhead line will branch out to required areas or header houses throughout the mine units. Depending on the location of wells, roads and other infrastructure, transformers may be installed on poles or on the ground near the service point.

Overhead power lines will be built in compliance with regional raptor specifications. Buried lines, either before or after transform, will be installed per the National Electrical Code 2008 Handbook (Earley et al., 2008). Specifically, Table 300.5 in the Handbook details the depth of burial and Article 340, Section II, 340.10, (1) specifies the use of Type UF (Underground Feed) cable for direct burial.

LC ISR, LLC plans to use direct burial cable as allowed in the NEC 2008 Handbook to deliver power to the header house and to the production wells as needed. From the header houses to the production wells, power will be transmitted through underground lines that will be located along the same corridors as the piping to and from the wells.

Five mine units are currently planned for the LC East area and six mine units are planned for the Lost Creek area, as shown on **Figure OP-2a** and **Plate OP-2a**. The boundaries of each mine unit are considered conceptual until a more detailed 'mine unit package' is prepared for that mine unit and submitted to WDEQ-Land Quality Division (LQD). Each mine unit will consist of a reserve block covering about 20 to 100 acres, with about eighteen header houses currently planned for the entire LC East Project. Each header house will be designed to accommodate the well controls and distribution plumbing for approximately twenty-five production wells and the associated injection wells (usually about 50 injection wells). Typically, one or two mine units may be in production at any one time with additional mine units in various states of development and/or restoration.

OP 1.2 Ore Deposits

As described in **Appendix D5** of this application, the ore deposits in Lost Creek and LC East generally occur at depths of 150 to 650 feet below ground surface (ft bgs) in long narrow trends varying from a few hundred to several thousand feet long and 50 to 250 feet wide (**Figure 3.1-2** of the Lost Creek Technical Report). The depth depends on the local topography, the dip of the formation, and the stratigraphic horizon. The available geologic and hydrologic data presented in **Appendices D5 and D6**, respectively, identify uranium mineralization in several sandstone layers (e.g., from shallow to deeper, the FG, HJ, and KM Horizons).

OP 2.0 PROJECT DEVELOPMENT, MAINTENANCE, AND MONITORING

Initial project development is generally limited to facilities such as secondary access roads, trunklines and powerlines. Development of the mine units is progressive, so some mine units may be in operation while others are being developed. This section describes activities that occur for both initial project development and mine unit development, and those maintenance and monitoring activities that are applicable throughout the Project. More detailed information on the mine unit operations is provided in **Section 3.0** of the Lost Creek Technical Report. The monitoring that will take place throughout the life of the Project is summarized in **Section 5.7** of the Lost Creek Technical Report.

OP 2.1 Project Schedule

At this time, LC ISR, LLC is planning to develop the mine units shown on **Figure OP-2a**. **Figure OP-4a** provides the current estimated schedule of operational activities at Lost Creek and LC East. The projected mining schedule is based on an annual production rate of up to 1,200,000 pounds of U_3O_8 from Lost Creek and/or LC East wellfields and up to an additional 1,000,000 pounds of U_3O_8 derived from slurry or ion exchange resin shipped to the Lost Creek Plant from other operations. This equates to a maximum annual production from the Lost Creek Plant of 2.2 million pounds of U_3O_8. The projected ISR operation schedule for each of the mine units, along with the anticipated groundwater restoration schedule, is also provided in **Figure OP-4a.** The basic assumptions for the major aspects of the Project (development, production, and restoration/reclamation) are outlined below.

Development

The schedule generally provides two years for development of a mine unit, including provisions for drilling restrictions to protect wildlife and for submittal of the Hydrologic Test Plan and Report for the mine unit to WDEQ-LQD for review and approval. The time requirement for mine unit development is a function of manpower and drill rigs dedicated to the task. The under-riding driver for the development timeline is the production schedule. Because production from LC East will be coordinated with production from Lost Creek, the development is expected to be expanded as drilling and construction occurs at both projects during the same time frame. Many aspects of the development time line can be adjusted as needed by increasing or decreasing the quantity of drilling rigs and people dedicated to the task. **Figure OP-4a** reflects the plan to complete the development work as follows:

A. Monitor Well Installation: Typically 50 to 140 wells, plan two drill rigs for up to seven months.
B. Pump Test and Sampling: Allow for three months.
C. Mine Unit Application Preparation: Allow for two months.
D. Injection/Production Well Installation: Typically 4 to 13 header houses per unit, 75 wells per header house. Requires 10 drill rigs to complete one header house in approximately one month. Work will occur intermittently in conjunction with monitor well installation and other operational activities.
E. Construction – Allow one month per header house.

Production

The schedule also provides for one to just over two years for uranium production from each mine unit. All the necessary processing and disposal facilities, including ion exchange columns, and storage ponds, have already been installed. Up to three additional UIC Class I wells may be installed at the LC East Project if additional waste water disposal capacity is required. The schedule on **Figure OP-4a** includes five UIC Class I wells at Lost Creek and three UIC Class I wells at LC East.

Mine units are generally developed and activated in stages. Commonly, new production is staged in on the level of header houses, rather than staging in complete new mine units. Depending on available pipeline and plant capacity, an operator may initiate new production in areas as discrete as individual patterns. Production begins once injection of lixiviant begins. The total time for production of a pattern is dependent on: the efficiency of the areal sweep of the lixiviant; the effectiveness of the oxidation of the uranium in place; and the injectivity and productivity of the formation (well flow rates). The factors below were incorporated into the estimation of the average time for economic production from a pattern at the Lost Creek Project.

A. Production Rate: 32 gallons per minute per production well, based on hydrologic results of several formation characterization tests.
B. Pore Volumes (PV): The estimated number of PVs processed to achieve economic depletion of the pattern is approximately 60.
C. Recovery Percentage: The percentage rate, based on laboratory tests, is 84 to 93% recovery rate. An 80% recovery rate was used for calculations despite early production from Lost Creek showing recovery rates approaching 100%.
D. Production Grade: The grade at which a pattern is expected to be turned off because the lixiviant grade has diminished to an uneconomic level was selected to be 10 milligrams per liter U_3O_8 for the purpose of the production model. The criteria for determining when the transition from production to restoration should occur in a given mine unit are discussed in **Section RP 1.0**.

Using the above information, the required time for economic depletion of a single pattern is calculated to be 12 months. Therefore, production in a mine unit is modeled to be completed 12 months after the initiation of production in the last developed header house in the unit. There is commonly a delay between the completion of development and the commencement of production at a given header house as determined by the availability of flow capacity within the process facility, specifically the ion exchange section. **Figure OP-4a** was developed on the premise that the header houses within a mine unit will be activated in stages and that the final header house will generally be activated approximately one to two years after the first.

Restoration/Reclamation

Restoration and Reclamation will follow the approved plan described in the original Permit to Mine Application. However, since additional mine units will be utilized, the production and restoration schedules have been updated in this application.

Schedule Adjustments

The production and restoration schedules will be adjusted in the same manner as described in the original Lost Creek Permit to Mine Application.

OP 2.2 Additional Regulatory Requirements

Many of the Permits and Licenses obtained for the Lost Creek Project will need to be amended to add the LC East Project. Specifically, this application is being supplied to the WDEQ-LQD, BLM and NRC simultaneously so the existing Permit to Mine, Plan of Operations, and Source and Byproduct Materials License, respectively, can be amended.

Additionally, LC ISR LLC will be required to seek an aquifer exemption prior to initiating mining from Class III UIC Wells in areas that have not been exempted. An aquifer exemption for the three Class I UIC wells may also be necessary depending on the water quality of the receiving zone. The existing Air Quality Permit will need to be revised to incorporate the additional activity. The existing Wyoming Pollution Discharge Elimination System (WYPDES) Permit and associated Storm Water Pollution Prevention Plan (SWPPP) already incorporates activities at both Lost Creek and Lost Creek East and therefore will not need to be revised. Finally, LC ISR, LLC will apply to Sweetwater County to rezone LC East from Agriculture to Mining.

A list of the necessary permits and licenses for the Project at the federal, state, and local levels is provided in the Adjudication File in **Table ADJ-1.**

OP 2.3 Land Use

During the life of the Project, a total of approximately 642 acres of the land surface could potentially be disturbed; approximately six percent of the combined area of Lost Creek and LC East. While the southwest to northeast secondary access road is long-term (through the life of the Project), most other disturbances are temporary, and will be reclaimed within months or years of disturbance. It should be noted that this disturbance acreage is for maximum vegetation disturbance and does not equate with acreage of topsoil removal, which will be less than the vegetation disturbance as discussed in more detail in **Sections OP 2.5** and **OP 2.7**. Ultimately, all disturbed areas will be reclaimed to support the post-operational land uses of the area, as discussed in the Reclamation Plan.

OP 2.4 Cultural Resources Mitigation Program

Extensive cultural resource surveys have been performed over the proposed amendment area with the findings submitted to the Rawlins BLM Office. See **Section 2.4** of the Lost Creek Technical Report for information on how cultural resources will be protected.

OP 2.5 Topsoil Management

See **Section 2.6.4.5** of the Lost Creek Technical Report for a description of how topsoil will be managed. Also see **Appendix D-7** of this application for a description of the soils at LC East. **Table OP-2** of this application shows the total acreage of expected disturbance associated with the various facilities at the Lost Creek Project. The table also includes the projected topsoil salvage. As discussed below, vegetation and topsoil disturbance are not considered to be equal.

OP 2.5.1 Short-Term Topsoil Protection

See **Section 2.6.4** of the Lost Creek Technical Report.

OP 2.5.2 Long-Term Topsoil Protection

See **Section 2.6.4** of the Lost Creek Technical Report. Locations of the long-term stockpiles are noted in **Table OP-2**.

OP 2.5.2.1 Facility Siting Criteria

See **Section 3.1.1** of the original Lost Creek Technical Report.

OP 2.6 Roads

LC East will be accessed using the pre-existing roads established for the Lost Creek Project. The planned network of on-site primary and secondary roads is portrayed in **Figure OP-2a** and **Plates OP-2a and 2b.** The mine units will be accessed using existing primary roads with extensions of secondary roads as shown in **Plate OP-2b**.

The NRC Supplemental Environmental Impact Statement (NUREG 1910 Supplement 3) and BLM Environmental Impact Statement completed for the initial Lost Creek License, analyzed the environmental impact of the expected quantity of traffic. The actual amount of light vehicle traffic (SUVs, vans, pickups) at the site is averaging 22 vehicles per day while the predicted amount in Table 4.3-1 of the BLM EIS is 18 to 21 light vehicles per day. LC ISR LLC expects the number of light vehicles travelling to and from the site to remain about the same or decrease slightly in the future since fewer contractors will be used as the facility moves out of construction and into routine operations.

The actual number of tractor trailers travelling to and from the site averages 0.61 per day. Table 4.3-1 in the BLM EIS predicted the number of tractor trailers to be 3 to 5 per week or 0.42 to 0.71 per day. LC ISR expects the average number of tractor trailers to increase to up to 1.15 per day when the facility is at maximum production (1.2 million pounds of U_3O_8 from site wellfields plus 1.0 million pounds of U_3O_8 per year delivered in the form of ion exchange resin from an off-site facility such as Shirley Basin. This analysis assumes that each load of ion exchange resin contains 6,500 pounds of U_3O_8 and each shipment of dried yellowcake contains 36,000 pounds of U_3O_8.

OP 2.7 Vegetation Protection and Weed Control

Vegetation will be temporarily impacted during the construction and operation of the Project. During construction, vegetation will be removed at some areas of the mine units, supporting facilities, and roads, although vegetation removal will be minimized whenever possible to protect topsoil, preserve wildlife habitat, and improve re-vegetation success. To stabilize soils and support the ecosystem, vegetation will be established at disturbed areas as soon as conditions allow.

During operations, mine units and supporting facilities will be accessed using a defined road network. Employees will be trained to minimize the impact to vegetation by staying on defined roadways and reducing the amount of vehicle traffic to the extent possible.

SWPPP inspections will include a check of active work areas to insure employees are minimizing impacts to vegetation, and any problems noted during inspections will be brought to the attention of the area supervisor for correction.

Drilling and construction activities will be limited or halted when field conditions are muddy in order to minimize damage to vegetation and topsoil. Alternatively, activities may be shifted to areas where they will not impact soil and vegetation. Critical facility monitoring and inspections generally occur in areas with all weather roads and will therefore continue during muddy conditions.

Weed prevention measures following BLM guidelines and recommendations will be implemented.

OP 2.8 Wildlife Protection and Monitoring

See **Section 2.8.3** of the Lost Creek Technical Report for details on wildlife . Also see **Appendix D-9** of this application for baseline characterization of wildlife at LC East.

OP 2.9 Prevention and Remediation of Accidental Releases

OP 2.9.1 Wells

See **Section 4.2.5.5** of the Lost Creek Technical Report.

OP 2.9.2 Buildings

The only buildings that will be utilized at LC East are header houses in the mine units and pump houses at the Class I UIC wells. See **Section 4.2.5.5** of the Lost Creek Technical Report.

OP 2.9.3 Storage Ponds

No additional storage ponds are planned. See Section 5.3.2 of the Lost Creek Technical Report for a description of the storage ponds constructed at Lost Creek.

OP 2.9.4 Fuel Storage Areas

No additional fuel storage is planned.

OP 2.10 Air Monitoring

Climate data collection from the on-site air monitoring station will continue until approval is granted by the NRC to halt data collection. A separate application to the WDEQ-Air Quality Division will submitted seeking a revision to the current Air Quality Permit. Once approved, a copy of the AQD permit will be included in **Attachment AJD-1** of this document.

OP 2.11 Surface Water and Groundwater

OP 2.11.1 Surface Water

See **Section 2.7.1** of the Lost Creek Technical Report.

OP 2.11.2 Groundwater

See **Sections 2.7.2 and 2.7.3** of the Lost Creek Permit Technical Report.

OP 2.11.2.1 On-Site Wells

The monitor wells installed at LC East will be used exclusively for monitoring groundwater quality and for aquifer testing. There are currently no acceptable water supply wells located within the LC East Area. Therefore, LC ISR LLC proposes to install up to three water supply wells on the margins of the Class I well pads shown in **Plate OP-2a**. The water supply wells will be used for drill water and dust suppression with an estimated maximum annual usage of 20 million gallons per well. Installation of these wells will reduce truck traffic by providing local sources of water. The wells will be completed in Horizons below the KM (L horizon or deeper) in order to eliminate the potential for hydrologic interference with mining.

In addition to the 27 Lost Creek monitor wells described in the original permit to mine application and the 24 new monitor wells at LC East (see **Figure D6.2-1** of the LC East Amendment), an additional 4 monitor wells in the L Horizon (MB-11, MB-12A, MB-14 and ML-5); two wells in M Horizon (M-M5 and M-M8) and one well in the N Horizon (M-N1) will be monitored for water level on a quarterly basis within the existing Lost Creek Permit Area (see **Appendix D6** of the KM Amendment). Upon approval of the KM and LC East amendments, these wells will be added to the list of monitor wells in **Attachment OP-8**. This will bring the total number of non-wellfield related monitor wells up to 58.

OP 2.11.2.2 Off-Site Wells

A review of the State Engineer's web page as well as a ground search did not reveal any additional public wells that will be within 2 kilometers of any active or proposed mine unit.

OP 2.12 Exploration and Delineation Drilling

Exploration drilling will be carried out to locate additional mineral reserves throughout the property. A systematic effort to locate all mineable mineralization will optimize the mining process and prevent resources from being stranded at the end of mining. Approximately 300 exploration holes will be drilled throughout LC East over the life of the mine and approximately 470 exploration holes will be drilled at Lost Creek as described in the original Lost Creek Permit to Mine Application. Delineation drilling is generally on closer spacing than exploration drilling) and finds economic portions of the ore zone mine unit delineation drilling.

OP 2.12.1 Exploration Drilling

See **Attachment OP-1** for information regarding historic exploration drilling at LC East including a table listing each known hole and a series of maps showing their locations.

OP 2.12.2 Delineation Drilling

See **Section 3.2.2** of the Lost Creek Technical Report. Each mine unit will require approximately 300 delineation drill holes within the pattern area.

OP 2.13 Aquifer Injection Testing

See **Section 3.2.2** of the Lost Creek Technical Report.

OP 3.0 MINE UNIT PROCESSES, INSTRUMENTATION AND CONTROL

The uranium mineralization, that is economic to recover, has been divided into mine units for scheduling purposes and for establishing baseline data, monitoring requirements, and restoration criteria. Each mine unit will consist of a reserve block covering about 20 to 100 acres and represents an area LC ISR, LLC expects to develop, produce, and restore as a unit. Five mine units are currently planned in LC East area and 6 mine units in the Lost Creek area. Typically, one or two mine units may be in production at any one time with additional mine units in various states of development and/or restoration.

The mine units will be subdivided into operational areas referred to as header houses; and each mine unit may include as many as thirteen header houses. Each header house will be designed to accommodate the well controls and distribution plumbing for approximately twenty-five production wells and the associated injection wells (usually about 50 injection wells). With the Plant operating at a nominal flow rate of 6,000 gpm, approximately 180 production wells and 360 injection wells will be in operation. However, the number of wells in use at any given time will vary depending on production needs, head grades, and actual flows.

OP 3.1 Mine Unit Chemistry

See **Section 3.2.1** of the Technical Report.

OP 3.2 Mine Unit Design

Continued delineation drilling will better define ore resources for design of mine units. A mine unit will consist of patterns of production and injection wells (e.g., the pattern area) within a ring of monitor wells to detect horizontal excursions of lixiviant away from the mineralized zone. Monitor wells will also be completed in overlying and underlying aquifers as necessary to detect vertical excursions. Inside the pattern area, monitor wells (which may double as production or injection wells) will also be completed in the mineralized zone to provide information on the mining process. The term "Resource Area" has nearly the same meaning as "Mine Unit." However, a Mine Unit is in the process of being developed while a Resource Area isn't.

LC East and Lost Creek will have moderate sized mine unit areas, each containing approximately 0.4 to 2.0 million pounds of resources, within the HJ or KM Horizon. Mining is planned in the KM prior to attempting to mine any immediately overlying mineral in the HJ Horizon.

With regard to mining within a particular horizon, in the simplest scenario, where only one ore quality sand is present in a Horizon, the production, injection, and monitor wells will be installed in that sand. Where more than one ore quality sand is present in the Horizon, e.g., the MHJ and LHJ Sands, the sands will be produced concurrently, with each Sand having its own set of production and injection wells.

See **Section 3.2.2** of the Lost Creek Technical Report for additional details.

OP 3.2.1 Injection and Production Well Patterns

The injection and production well pattern design will be generally based on conventional five-spot patterns, modified as necessary to fit the characteristics of the orebody. The conventional five-spot pattern is four injection wells surrounding a central production well. The cell dimensions will vary depending on the characteristics of the formation and the orebody; but the injection wells are expected to be between 75 and 150 feet apart. Line drive patterns may also be used on occasions when a five-spot pattern is too large to efficiently sweep the mineralization. Line drive patterns will consist of alternating injection and production wells about 60 to 100 feet apart. Contrary to the name, these patterns are not necessarily in a straight line but instead conform to the shape of the ore body.

OP 3.2.2 Monitor Well Locations

Monitor wells will be completed within the Horizon containing the ore-bearing Sands to be mined (e.g., the HJ Horizon) and in overlying and underlying Horizons, if aquifers occur in those Horizons. The monitor wells in the Horizon containing the ore-bearing Sands will include perimeter monitor wells around each mine unit and monitor wells within the production zone of each mine unit.

OP 3.2.2.1 Perimeter Monitor Wells

See **Section 3.2.2.2** of the Lost Creek Technical Report.

OP 3.2.2.2 Observation Wells

See **Section 3.2.2.2** of the Lost Creek Technical Report.

OP 3.2.2.3 Production Zone Monitor Wells

See **Section 3.2.2.2** of the Lost Creek Technical Report.

OP 3.2.2.4 Overlying and Underlying Monitor Wells

As mentioned above, when mineralization in the HJ and KM Horizons overlap, the KM horizon is planned to be mined prior to mining in the HJ Horizon. Regardless of the order of mining, when mining within the KM Horizon the overlying monitor wells will be installed in the lower HJ Horizon. The underlying monitor wells will be placed in an appropriate underlying aquifer based on the results of aquifer testing for that specific mine unit and as approved by the WDEQ-LQD.

When mining in the HJ Horizon the underlying monitor wells will be placed in the upper KM Horizon and the overlying monitor wells will be placed in the lower FG Horizon.

See **Section 3.2.2.2** of the Lost Creek Technical Report for additional details.

OP 3.3 Well Completion

See **Section 3.2.4** of the Lost Creek Technical Report.

OP 3.4 Well Integrity Testing

See **Section 3.2.5** of the Lost Creek Technical Report.

OP 3.5 Mine Unit Piping and Instrumentation

See **Section 3.2.6** of the Lost Creek Technical Report.

OP 3.6 Mine Unit Control

See **Section 3.2.7** of the Lost Creek Technical Report.

OP 3.6.1 Header House Control

See **Section 3.2.7.1** of the Lost Creek Technical Report.

OP 3.6.1.1 Plant Control Room

There will be no plant at LC East. See **Section 3.3** of the Lost Creek Technical Report.

OP 3.6.2 Pattern Control

See **Section 3.2.7.2** of the Lost Creek Technical Report.

OP 3.6.3 Projected Water Balance and Water Level Changes

See **Section 3.2.7.3** of the Lost Creek Technical Report.

OP 3.6.3.1 Water Balance

See **Section 3.2.7.3** of the Lost Creek Technical Report.

OP 3.6.3.2 Mine Unit Interference

Decisions about the order in which mine units will be brought on line and the rates at which they will be developed and restored will depend, in part, on the potential for interference among the mine units. Any particular concerns about interference will be addressed in the Hydrologic Test Proposal and Report.

OP 3.6.3.3 Cumulative Drawdown - Mine Unit Operations

As discussed in **Appendix D6**, a regional pump test has been conducted to assess the hydraulic characteristics of the HJ and KM Horizon and overlying and underlying confining units. Pump tests also will be performed for each successive mine unit in order to assess hydraulic containment above and below the production zone, demonstrate communication between the pattern area and perimeter monitor wells, and to further evaluate the hydraulic properties of the HJ or KM Horizon.

Based on a bleed of 0.5 to 1.5 percent, the potential impact from consumptive use of groundwater is expected to be minimal. In this regard, the vast majority (e.g., on the order of 98 percent) of groundwater used in the ISR production and restoration process will be treated and re-injected.

During ISR operations, extraction of groundwater will result in drawdown within the production zone aquifer, and potentially, in the overlying and underlying aquifers. Additional drawdown will occur in aquifers that are pumped to the water supply requirements for dust suppression, drilling, plant process and wash water, and potable water. Drawdown estimates for the mine units are described below, and **Section 3.6.3.4** addresses drawdown related to water supply requirements.

Drawdown will be greatest in the immediate vicinity of the mine units. A numerical model was used to assess drawdown impacts from Lost Creek ISR operations. The model was developed using site-specific data based on geologic and hydrologic information collected from site characterization activities. The model development, calibration and simulations are described in the report "Numerical Modeling of Hydrologic Conditions at the Lost Creek In-Situ Recovery Uranium Project, Wyoming" found in Addendum 5-1 of the MU1 Volume. Simulations were run representing the full production-restoration sequence for Mine Unit 1. The simulation included a production phase at a maximum rate of 5,838 gpm (with a net bleed of 38 gpm or 0.65%) for a period of 26 months (791 days), groundwater sweep at 30 gpm for 12 months (365 days), and treatment with RO at 541 gpm for 18 months (548 days). The total simulation period was 56 months (4.75 years). During RO, the simulated consumptive use (reject brine) was 67.6 gpm. Simulated drawdown during the maximum production rate is estimated to be on the order of 1 foot at four miles from the mine unit. Drawdown during the RO phase is expected to be on the order of 5 feet at 3.3 miles (17,250 feet) beyond the Lost Creek Permit Area boundary. The maximum drawdown outside the Lost Creek Permit Area boundary is slightly greater than 25 feet. This occurs where Mine Unit 1 is closest to the Lost Creek Permit Area boundary. Although this simulation only represents production and restoration from Mine Unit 1, the production and RO rates are maximized. During a portion of the Lost Creek ISR operations, full production and restoration could occur simultaneously; thus, the cumulative effect is represented by combining the predictions and accounting for some shift in mine unit location.

The nearest surface water body to the Lost Creek Permit Area is the Sweetwater Mill Pit Lake which is about 4 miles from the closest production planed at Lost Creek. It is unknown if the Sweetwater Mill Pit intercepts strata that are the stratigraphic equivalent of the HJ Horizon. The effects of the Sweetwater Mill Pit Lake on the hydrology of the HJ Horizon, or vice versa, are unknown. Regardless, performing the Cumulative Effect Analysis described in the previous paragraph of projected Lost Creek ISR operations, approximately two feet or less of drawdown is projected at distances as far as the Sweetwater Mill Pit Lake. The Sweetwater Mill operation (Permit 481) has collected water level data from the Pit Lake for approximately 20 years. Based on a review of the Permit 481 Annual Report, it appears that Pit Lake water levels have remained relatively constant over 12 years. Water elevation records for the Pit Lake are believed to be of sufficient length to provide a reasonable baseline of expected fluctuations. In conjunction with the data collected from regional monitor wells, LC ISR, LLC will utilize the data available in the Permit 481 Annual Report to perform an ongoing assessment of impacts. In the event that the Sweetwater Mill Pit Lake experiences unacceptable drawdown (greater than two feet), LC ISR, LLC will cooperate with the owner of the Sweetwater Mill to determine the cause of the drawdown. If the Lost Creek ISR operations are determined to be the cause of the drawdown, LC ISR, LLC will work with the Sweetwater Mill Pit Lake owner to develop and implement a mutually agreeable solution.

The estimated drawdown from production and restoration will not result in loss of use of wells outside of the Lost Creek Permit Area.

OP 3.6.3.4 Cumulative Drawdown - Water Supply Wells

Drawdown will occur in the aquifer that is pumped to meet water supply requirements for dust suppression and drilling. The LCE water supply is anticipated to be derived from one to three wells completed in the N Horizon. Water supply demand is projected to be temporary averaging 38 gallons per minute (approximately 55,000 gallons per day) during the peak drilling period; first four years. For purposes of estimating N Horizon drawdown resulting from pumping 38 gpm at LC East, it is assumed that all supply for Lost Creek is derived from water supply well LC229W located immediately northwest of the plant. The interference between the LC East water supply well and the Lost Creek Plant water supply well, both completed in the N Horizon, should provide a worst case drawdown scenario. The drawdown impact on the overlying FG, HJ and KM Horizon aquifers resulting from water supply procurement should remain unchanged from the original permit assessment since there is no projected change in the number of water supply wells or rates of water use from these Horizons.

Aquifer properties for the HJ and KM aquifers in LC East and Lost Creek area are presented in Appendix D6 of this application, the KM Amendment, and the original Permit to Mine Application. Because no data are available for the N Horizon aquifer, it is assumed that the Horizon has similar aquifer properties to the overlying KM Horizon for which there is data. Transmissivity values for the KM Horizon in the LCE area range between 86 and 251 ft^2/d (644 and 1,878 gpd/ft). A representative value of 184 ft^2/d is used for calculation purposes. Computed storativity (S) values range between 7.35×10^{-5} and 1.97×10^{-2}. A representative S value of 1.15×10^{-4} is used for calculation purposes.

An eight-year use of the water supply well is assumed, but the first four years will be the largest consumptive use period. The computed drawdown at distances from a pumping well, at the end of four years, is estimated using the Cooper-Jacob modified non-equilibrium solution and the above-referenced aquifer parameters:

Calculated Drawdown (ft.) at Specified Distance After Four Years

No. of LC East Wells	Pumping Rate (gpm)	2 miles	3 miles	5 miles
1	38	12.2	9.6	6.4

The drawdown caused by simultaneously pumping both the Lost Creek Plant wells (LC1148W and LC229W; which are completed in the N Horizon) and the closest LCE water supply well are additive. To compute the maximum interference drawdown, it was assumed that the LCE water supply well pumped at 38 gpm and the LC Plant wells pumped at 25 gpm (actual). The two pumping sites are approximately 15,800 feet apart. Using the Cooper-Jacob modified non-equilibrium solution and the above-referenced aquifer parameters, the composite drawdown computed half way between the two pumping sites, after four years of continuous pumping, was 23.2 feet.

Use of the Cooper-Jacob solution implies numerous assumptions that are not fully applicable. In particular, because the Cooper-Jacob solution does not account for recharge to the aquifers, the predicted drawdown is overestimated. Therefore, the drawdown resulting from pumping water supply wells will most likely be less than the calculated values shown above.

OP 3.6.4 Excursion Monitoring and Control

In general, the HJ Horizon will be mined prior to the underlying KM Horizon. In such cases, the water quality of the restored HJ Horizon will be determined and will serve as the monitored overlying aquifer during recovery of KM Horizon mineral.

If the KM Horizon is mined prior to the overlying HJ Horizon, restoration of the KM Horizon may or may not be finalized prior to mining the HJ. If the KM is not restored, then the aquifer underlying the KM will be monitored for excursions until such time the KM is restored at which point the KM Horizon will serve as the monitored underlying aquifer for the HJ. If the KM Horizon is restored prior to mining the HJ Horizon, the restored baseline water quality of the KM Horizon will be determined and the KM Horizon will serve as the monitored underlying aquifer.

The specific method for determining baseline and the monitoring plan will be outlined in each respective Mine Unit application.

See **Section 3.2.7.4** of the Lost Creek Technical Report for additional detail.

OP 3.6.4.1 Mine Unit Baseline Water Quality and Upper Control Limits

The following language was cut and pasted from **Section OP 3.6.4.1** of the original Lost Creek Permit to Mine Application; only the date of the WDEQ-LQD Guideline No. 4 reference has been updated since the Guideline was recently revised. The language is included in this document in order to conform the UCL calculation method previously approved by the NRC to the method approved by the WDEQ-LQD and BLM. No changes to the UCL calculation method previously approved by the WDEQ-LQD and BLM are being proposed.

Excursion monitoring includes the monitor ring wells completed in the same sand as the pattern area and monitor wells in overlying or underlying water-bearing strata. Excursion detection is based on comparison of concentrations of specific parameters with the Upper Control Limits (UCLs) for those parameters, which are calculated from the baseline concentrations of those parameters.

After delineation of a pattern area, monitor wells will be installed around that area as described in **Section OP 3.2**. A pump test will be used to verify communication between monitor wells in the monitor ring and the pattern area and lack of communication between the pattern area and overlying and underlying monitor wells. Baseline groundwater samples will be collected in accordance with the protocols in LC ISR, LLC's Environmental Manual.

As a part of the baseline assessment, all the mine unit monitor wells will be sampled at least four times at intervals at least 14 days apart. Water levels will be measured at the same frequency as the monitor well sampling. One round of samples will be analyzed for the parameters listed in **Table OP-8** and three rounds will be analyzed for just the UCL parameters. As outlined below, the analytical results will be evaluated for outliers prior to the UCL calculations, and the information submitted in the mine unit package.

Outlier Evaluation

The water quality data of the monitor wells will be evaluated to identify and remove potential outliers (anomalously high or low values relative to other values) that may otherwise strongly influence the general characterization of the wells. The outliers will be identified according to Reference Document 4 of WDEQ-LQD Guideline No. 4 (2013). An outlier may result from one or more of the following conditions:

- transcription errors;
- sampling errors;
- analytical errors;
- incorrect units of measurement;
- natural water quality variability; and
- differences in geology within the sampled aquifer.

The inclusion of an outlier in a database may have a disproportionately large influence on statistical analyses of water quality data. Therefore, the following tolerance-limit formula (Loftis et al., 1987) was used to screen outliers from the baseline data:

$$\text{tolerance interval} = x \pm kS$$

where:

x = mean of observations in sample
k = tolerance limit factor
S = standard deviation of sample

and assuming:

alpha = 0.05
$p = 0.99$

The tolerance limit factor (k) is a function of sample size (n), confidence level (1 – alpha), and proportionality values (p). The assumed alpha value of 0.05 is based solely on its historical use for statistical evaluation of hydrologic data. The 99 percent proportionality value (p) is the highest value for which k values are available.

For a given sample size (n) of 100, only one value should be expected to be discarded as an outlier when it may actually be a representative value. If one or more wells have parameter values that contain a relatively large number of outliers, then these wells are treated separately as an additional baseline database.

Well outliers will be identified from the combined quarterly water quality sampling results of each type of monitor well. As noted in WDEQ-LQD Guideline No. 4, "there are no hard and fast rules regarding the initial selection of potential outliers." The water quality data will be visually screened for anomalous values or groups of values, which will then be subjectively evaluated as especially high or low relative to other values. Each potential outlier will be compared to its tolerance interval, which will be calculated excluding the potential outlier from the dataset. Each potential outlier will be considered an outlier if its value is not within the calculated tolerance limit, unless it only marginally differs from the tolerance interval, is one of only a few detected samples, or is similar to multiple samples.

Upper Control Limit (UCL) Selection and Calculation

UCLs will be set for parameters indicative of migration of lixiviant from the mine unit. These parameters will generally be chloride, conductivity, and total alkalinity. Chloride is a common UCL parameter in Wyoming due to its low natural levels in the native groundwater and because chloride is introduced into the lixiviant from the ion exchange process (uranium is exchanged for chloride on the ion exchange resin). Chloride is also a very mobile constituent in the groundwater and will show up quickly in the case of a lixiviant migration to a monitor well. The lixiviant TDS concentration generally differs than that of the baseline groundwater quality and does not appreciably change with sediment interaction; therefore, conductivity is an excellent indicator due to its direct correlation to TDS. Total alkalinity concentrations should be affected during a potential excursion, as bicarbonate is the major constituent added to the lixiviant during mining. If another parameter is determined to be more suitable for a given mine unit, it will be identified in the respective mine unit package, along with explanation of its suitability.

UCLs will established for each class of monitor well (M, MO, and MU) on a mine unit basis. In the event that baseline measurements exceed the calculated UCL value for a particular monitor well, a well specific set of UCLs will be calculated for the respective well(s). The baseline data for the outlier well will not be used in the dataset used to calculate the UCLs for the other wells. As recommended in WDEQ-LQD's Guideline No. 4 (2013), the alkalinity and specific conductance UCLs were calculated by adding five standard deviations to each UCL parameter baseline mean. Each chloride UCL was calculated by adding five standard deviations to each mean chloride concentration or by adding 15 mg/L to each mean chloride concentration, whichever was larger. Identified outliers will be excluded from the UCL calculations.

OP 3.6.4.2 Excursion Detection

See **Section 3.2.7.4** of the Lost Creek Technical Report.

OP 3.6.4.3 Excursion Verification and Corrective Action

See **Section 3.2.7.4** of the Lost Creek Technical Report.

OP 3.6.4.4 Ability to Control an Excursion

See **Section 3.2.7.4** of the Lost Creek Technical Report.

OP 4.0 PLANT PROCESSES, INSTRUMENTATION, AND CONTROL

See **Section 3.3** of the Lost Creek Technical Report.

OP 4.1 Ion Exchange (Resin-Loading) Circuit

See **Section 3.3.1** of the Lost Creek Technical Report.

OP 4.2 Elution Circuit

See **Section 3.3.2** of the Lost Creek Technical Report.

OP 4.3 Precipitation/Filtration Circuit

See **Section 3.3.3** of the Lost Creek Technical Report.

OP 4.4 Major Process Equipment and Instrumentation

See **Section 3.3.4** of the Lost Creek Technical Report.

OP 5.0 EFFLUENT CONTROL SYSTEMS

See **Section 4.0** of the Lost Creek Technical Report.

OP 5.1 Gaseous Emissions and Airborne Particulates

See **Section 4.1** of the Lost Creek Technical Report.

OP 5.1.1 Non-Radioactive Emissions and Particulates

See **Section 4.1.1** of the Lost Creek Technical Report.

OP 5.1.2 Radioactive Emissions

Radioactive airborne effluents will be minimal due to controls in place in the yellowcake drying and packaging circuit and because the Storage Ponds will be kept wet.

Radon will be the radioactive gaseous emission from the mining and ore processing, as it is present in the orebody and collected with the lixiviant solution. Radon will be released occasionally from the mine unit wells as gas is vented from the injection wells. Production wells will be open at the surface; however, water levels will typically be low and radon venting will be minimal. All of the well releases will be outside of buildings and are directly vented to the atmosphere. The header houses and the UIC Class I well pumphouses will also be vented. Potential radon exposure will be reduced or eliminated with ventilation to the outside of the buildings using high-volume exhaust fans, PPE, and limited exposure durations, in accordance with SOPs, or an RWP during non-routine work. Occupational and public exposures to radon emitted from the mine units and from the ore processing were analyzed using the MILDOS computer model to ensure the discharged amount will be within regulatory dose limits. See **Appendix D-10** of this application for the results of the updated MILDOS run that includes production from all Lost Creek and LC East mine units.

OP 5.2 Liquid Wastes

See **Section 4.2** of the Lost Creek Technical Report.

OP 5.2.1 Liquid Non-11(e)(2) Byproduct Materials

Appropriate storage, treatment, and disposal methods for these liquids differ, as outlined below.

OP 5.2.1.1 "Native" Groundwater Recovered during Well Development, Sample Collection, and Pump Testing

Please see **Section 4.2.1** of the Lost Creek Technical Report.

OP 5.2.1.2 Storm Water Runoff

Please see **Section 4.2.2** of the Lost Creek Technical Report.

OP 5.2.1.3 Waste Petroleum Products and Chemicals

Please see **Section 4.2.3** of the Lost Creek Technical Report.

OP 5.2.1.4 Domestic Liquid Waste

Please see **Section 4.2.4** of the Lost Creek Technical Report.

OP 5.2.2 Sources of Liquid 11(e)(2) Byproduct Material

Please see **Section 4.2.5** of the Lost Creek Technical Report.

OP 5.2.2.1 Liquid Process Wastes

Please see **Section 4.2.5.1** of the Lost Creek Technical Report.

OP 5.2.2.2 "Affected" Groundwater Generated during Well Development and Sample Collection

Please see **Section 4.2.5.2** of the Lost Creek Technical Report.

OP 5.2.2.3 Groundwater Generated during Aquifer Restoration

Please see **Section 4.2.5.3** of the Lost Creek Technical Report.

OP 5.2.3 Disposal of Liquid 11(e)(2) Byproduct Materials

Please see **Section 4.2.5.4** of the Lost Creek Technical Report.

OP 5.2.3.1 Storage Ponds

Please see **Section 4.2.5.4** of the Lost Creek Technical Report.

OP 5.2.3.2 UIC Class I Wells

Up to three UIC Class I wells may be installed in the LC East Permit Area for disposal of liquid 11(e)(2) byproduct materials. A permit for up to five UIC Class I wells within the Lost Creek Permit Area has already been approved and three of the five wells have been installed. If the UIC Class I wells at Lost Creek aren't capable of receiving the quantity of waste needed to maintain operations at an acceptable level, additional well(s) may be installed within the LC East Project (See **Plate OP-2a** for the location of the proposed UIC Class I Wells).

OP 5.3 Solid Wastes

Please see **Section 4.3** of the Lost Creek Technical Report.

OP 5.3.1 Solid Non-11(e)(2) Byproduct Materials

Please see **Section 4.3.1** of the Lost Creek Technical Report.

OP 5.3.2 Solid 11(e)(2) Byproduct Materials

Please see **Section 4.3.2** of the Lost Creek Technical Report.

REFERENCES

Earley, MW, Sarget, JS, Sheehan, JV, and Buss, EW. 2008. National Electrical Code Handbook.

Wyoming Department of Environmental Quality, Land Quality Division. 2013. Guideline No. 4 In Situ Mining Noncoal. Cheyenne, WY

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FIGURES

ABBREVIATIONS AND ACRONYMS

BLM	Bureau of Land Management
ISR	In Situ Recovery
LC ISR, LLC	Lost Creek ISR, LLC
LQD	Land Quality Division
NRC	Nuclear Regulatory Commission
Permit Area	Lost Creek Permit Area
Project	Lost Creek Project
RO	reverse osmosis
WDEQ	Wyoming Department of Environmental Quality

GROUNDWATER QUALITY RESTORATION AND SURFACE RECLAMATION

See **Section 6.0** in the Lost Creek Technical Report. **Figure OP-4a Lost Creek Project Development, Production and Restoration Schedule** has been updated and included in this application.

RP 1.0 COMPLETION OF PRODUCTION OPERATIONS

See **Section 6.1** of the Lost Creek Technical Report.

RP 2.0 PLANS AND SCHEDULE FOR GROUNDWATER QUALITY RESTORATION

The objective of restoration and reclamation is to return the affected groundwater and land surface to the uses for which they were suitable before commencement of the Project operations. The methods to achieve this objective for groundwater are described in this section.

The schedule for the Project activities, including groundwater restoration, is shown in **Figure OP-4a** and is discussed in detail in **Section OP 2.1**. **Plates OP-2a and 2b** show the location of the mine units and a schedule of mining and restoration for each mine unit is included in **Figure OP-4a**. See **Section 6.0** of the Lost Creek Technical Report for additional details.

RP 2.1 Conditions in the Mineralized Zone Before and After Operations

See **Section 6.2.1** of the Lost Creek Technical Report.

RP 2.2 Restoration Requirements

See **Section 6.2.2** of the Lost Creek Technical Report.

RP 2.3 Groundwater Restoration Methods

See **Section 6.2.3** of the Lost Creek Technical Report.

RP 2.3.1 Groundwater Transfer

Groundwater transfer (or exchange) involves moving groundwater between a mine unit in restoration and another mine unit where uranium production is beginning. (Alternately, it may be desirable to transfer water between different portions of the same mine unit, depending on the water quality and operational state of the different portions.) Both mine units will first have received approval for UIC Class III injection. The transferred groundwater may undergo treatment using one or more of the permit-approved processes (such as ion exchange, chemical pH adjustment, and/or reverse osmosis) prior to injection within the destination mine unit. This technique is generally used to replace operationally-affected waters in the restoration mine unit with baseline quality water from the production mine unit. The operationally-affected waters from the restoration mine unit are then used as the basis for the lixiviant in the production mine unit. Because water is transferred (or exchanged) between mine units at equal rates, the transfer typically does not generate liquid effluents.

The operations plan and project schedule for the Lost Creek Project do not represent the use of groundwater transfer techniques. However, should the opportunity arise and BPT dictates the use of the method, LC ISR, LLC will beneficially utilize groundwater transfer to enhance the project restoration effort. In such an event, it is projected that the transfer will involve between zero and two pore volumes. As two discreet mine units of differing volume are involved, the actual pore volume transferred will vary depending on the mine units involved. For the restoration mine unit, groundwater transfer has much of the benefit of groundwater sweep without the large consumptive use of water. This technique has been used successfully at ISR operations in Nebraska.

RP 2.3.2 Groundwater Sweep

See **Section 6.2.3.1** of the Lost Creek Technical Report.

RP 2.3.3 Reverse Osmosis Treatment with Permeate Injection

See **Section 6.2.3.2** of the Lost Creek Technical Report.

RP 2.3.4 Recirculation

See Section **6.2.3.3** of the Lost Creek Technical Report.

RP 2.4 Stabilization Phase

See **Section 6.2.3.3** of the Lost Creek Technical Report.

RP 2.5 Reporting

See **Section 6.2.5** of the Lost Creek Technical Report.

RP 3.0 MINE UNIT RECLAMATION

See **Section 6.3** of the Lost Creek Technical Report.

RP 3.1 Well Abandonment

See **Section 6.3.2** of the Lost Creek Technical Report.

RP 3.2 Facility and Road Reclamation

See **Section 6.3.3** of the Lost Creek Technical Report.

RP 4.0 RECLAMATION AND DECOMMISSIONING OF PROCESSING AND SUPPORT FACILITIES

See **Section 6.4** of the Lost Creek Technical Report.

RP 4.1 Removal and Disposal of Equipment and Structures

See **Section 6.4.2** of the Lost Creek Technical Report.

RP 4.2 Waste Storage, Treatment, and Disposal Facilities

See **Section 6.4.3** of the Lost Creek Technical Report.

RP 4.3 Buried Piping and Engineering Control Structures

See **Section 6.4.4** of the Lost Creek Technical Report.

RP 4.4 Roads

See **Section 6.4.5** of the Lost Creek Technical Report.

RP 4.5 Soil Replacement and Revegetation

See **Section 6.6** of the Lost Creek Technical Report.

RP 4.5.1 Post-Operational Land Use

See **Section 6.6.1** of the Lost Creek Technical Report.

RP 4.5.2 Surface Preparation

See **Section 6.6.2** of the Lost Creek Technical Report.

RP 4.5.3 Soil Replacement

See **Section 6.6.3** of the Lost Creek Technical Report.

RP 4.5.4 Seed Mix, Reseeding Methods, and Fencing

See **Section 6.6.4** of the Lost Creek Technical Report.

RP 4.5.5 Revegetation Success Criteria

See **Section 6.6.5** of the Lost Creek Technical Report.

RP 4.6 Recovery of Groundwater Levels

Once ISR operations cease, water levels will begin to recover to pre-ISR levels. An estimate of the time required for water levels to recover following completion of ISR operations at Mine Unit 1 (MU1) was performed using a numerical groundwater flow model. The model was developed using site-specific data based on geologic and hydrologic information collected from site characterization activities. The model development, calibration and simulations are described in the report "Numerical Modeling of Hydrologic Conditions at the Lost Creek In-Situ Recovery Uranium Project, Wyoming" (Petrotek 2010).

Simulations were run representing the full production-restoration sequence for MU1. The simulation included a production phase at a maximum rate of 5,838 gpm (with a net bleed of 38 gpm) for a period of 26 months (791 days), groundwater sweep at 30 gpm for 12 months (365 days), and treatment with RO at 541 gpm for 18 months (548 days). During RO, the simulated consumptive use (reject brine) was 67.6 gpm. The total operational period for MU1 was simulated as 56 months (4.75 years). The average rate of extraction for the 4.75-year model simulation is 45.8 gpm. A recovery period of 5 years (1,825 days) was also simulated. During the simulated recovery period, water levels returned to within one foot of pre-mining levels in less than one year.

Simulated recovery of water levels in the HJ Horizon aquifer after termination of ISR operations is illustrated by placing observation points on the northwest, southwest, northeast and south-central edges of the Lost Creek Permit Area. **Figure RP-5a** shows the location of the simulation monitoring points. **Figure RP-5b** illustrates the simulated drawdown that occurs during ISR operations at MU1 and the recovery following termination of operations.

Although the model simulation only represents production and restoration from a single mine unit, the production rates and RO rates are maximized. During various stages of the Lost Creek ISR operations, multiple mine units are projected to be simultaneously in production and/or restoration. This may result in greater drawdown than simulated in the single mine unit model. However, the magnitude of drawdown and the duration of recovery are anticipated to be similar. Even if the drawdown is increased by twofold during ISR operations, recovery of HJ Horizon aquifer water levels to pre-mining conditions should occur within a few years after the end of the Lost Creek ISR Project.

In the event that draw dawn induced by mining activities affects the functionality of any local BLM wells, Lost Creek ISR, LLC will work with the BLM to replace or deepen the affected well in such a way that the water supply is not affected.

RP 5.0 FINANCIAL ASSURANCE

LC ISR, LLC will establish and maintain appropriate surety arrangements with NRC and WDEQ to cover the costs of groundwater restoration, radiological decontamination, facility decommissioning, and surface reclamation. The surety will be reviewed annually and adjusted to reflect changes in cost and in the Project.

Restoration costs for additional mine units and header houses will be added to the surety as the mine units are brought online. The anticipated schedule and approximate amounts for the bond increases associated with the additional mine units are shown on **Figure RP-3**.

A detailed description of this surety estimate is provided in **Table 6.8-1** of the Lost Creek Technical Report, and the schedule on which the estimate is based is detailed in **Table RP-5** (attached to end of Table 6.8-1) of the Lost Creek Technical Report. The surety amount is updated annually with the most recent surety approved by WDEQ-LQD on March 25, 2014 with concurrence from BLM and NRC.

REFERENCES

Petrotek. 2010. Numerical Modeling of Hydrologic Conditions at the Lost Creek In-Situ Recovery Uranium Project, Wyoming.

OVERVIEW OF APPLICATION

With this application, Lost Creek ISR, LLC proposes to add mine units and associated infrastructure and disturbance to the existing Permit to Mine. Specifically, this application adjusts the aerial extent of previously approved mine units based on the results of post permit drilling and proposes three additional mine units in the existing Lost Creek Permit boundary; Resource Area (RA) 3 and RA12 in the KM Horizon and RA4 in the HJ Horizon. The term resource area is interchangeable with mine unit.

Since each of the proposed mine units are within the existing Lost Creek boundary, the majority of environmental baseline work had already been completed and reviewed and approved by appropriate regulatory agencies. The following Sections of the existing Technical Report do not require amendment to incorporate the proposed mine units and the reader should refer back to the approved Technical Report for baseline information:

Land Use, Section 2.2 of approved Technical Report

Brief History, Section 2.4 of approved Technical Report

Archeology, Section 2.4 of approved Technical Report

Meteorology, Section 2.5 of approved Technical Report

Soil, Section 2.6 of approved Technical Report

Vegetation, Section 2.8 of approved Technical Report

Wildlife, Section 2.8 of approved Technical Report

Background Radiation (A new MILDOS run which models all production from the HJ and KM mine units is included in the LC East Application.), Section 2.9 of approved Technical Report

Wetlands Section 2.8.2 of approved Technical Report

Operations Plan (Minor changes are incorporated into the LC East Application.), Sections 3-5 of approved Technical Report

Reclamation Plan (Minor changes are incorporated into the LC East Application.), Section 6 of approved Technical Report

Appendices D5-Geology and D6-Hydrology have been included in this application since considerable new baseline information relevant to mining in the KM Horizon has been collected.

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D5 GEOLOGY

D5.1 Regional Geology

The Lost Creek Property (Property) is currently comprised of six individual and contiguous Projects: the Lost Creek, LC East, LC North, LC South, LC West and EN Projects. The Lost Creek Project is effectively contained within the Lost Creek Permit Area (Permit Area) and is situated in the northeastern part of the Great Divide Basin (GDB) which is underlain by up to 25,000 feet of Paleozoic to Quaternary sediments. The GDB is an oval-shaped structural depression, encompassing some 3,500 square miles in south-central Wyoming. It represents the northeastern portions of the greater Green River Basin, which occupies much of southwestern Wyoming. The GDB lies within a unique divergence of the Continental Divide and is bounded by structural uplifts or fault displaced Precambrian rocks, resulting in internal drainage and an independent hydrogeologic system. It is bounded on the north by the Wind River Range and Granite Mountains, on the east by the Rawlins Uplift, on the south by the Wamsutter Arch and on the west by the Rock Springs Uplift. Geologic development of the GDB began in the Late Cretaceous and continued through much of the Early Eocene.

Rock outcrops in the GDB are dominated by the Battle Spring Formation of Eocene age. Due to the soft nature of the formation, this occurs largely as sub-crop beneath the soil. Regional and local surficial geology is shown on **Figure D5-1**. Maximum thickness of the Battle Spring Formation sediments within the GDB is 6,200 feet. Uranium deposits in the GDB, including the Permit Area, are found principally in the Battle Spring Formation.

D5.1.1 Regional Stratigraphy

The earliest sedimentation in the GDB was the Paleocene (Early Tertiary) Fort Union Formation, which was unconformably deposited upon the Lance Formation of Late Cretaceous age. The Fort Union Formation consists mostly of lacustrine shales, siltstones, and thin sandstones, which locally contain lignite and coal beds. The thickness of the Fort Union Formation varies from place to place in the GDB, and it is approximately 4,650 feet thick in the Permit Area.

The Fort Union Formation is unconformably overlain by sediments of Eocene age, making up about 6,200 feet of basin fill. The northern and northeastern portions of the GDB are dominated by thick, medium to coarse-grained arkosic sandstones and conglomerates, separated by intermittent mudstone, claystone and siltstone of the Battle Spring Formation. The Battle Spring Formation represents a large alluvial fan complex relatively close to the sediment source in the ancestral Granite Mountains, approximately 20 to 30 miles to the north. In the southern and southwestern portions of the GDB the

Battle Spring Formation undergoes a facies transition into intertonguing units of the Wasatch and Green River Formations which represent distal fluvial and lacustrine depositional environments, respectively. Lithology of these units is predominately sandstone, claystone, siltstone, limestone, conglomerate and include thin lignite beds. Pliocene pediment deposits and recent alluvium cover large areas of the surface in the GDB.

The Lost Creek Permit Area is located near the north-central part of the Basin. Here the GDB fill consists of the Eocene Battle Spring and Wasatch Formations plus the Paleocene Fort Union Formation. The upper portions of the stratigraphic section consist of Battle Spring Formation underlain by a tongue of the Wasatch Formation. The combined thickness of the Battle Spring and Wasatch Formations is approximately 6,200 feet. The Battle Spring/Wasatch Formations are unconformably underlain by the Fort Union Formation which is approximately 4,650 feet thick. The Fort Union Formation, in turn, is unconformably underlain by numerous Cretaceous, Jurassic, Triassic, Paleozoic, and Precambrian basement lithologic units.

Approximately six miles southwest of the Permit Area, the Battle Spring Formation interfingers with the Wasatch and Green River Formations of equivalent age (Eocene) within a belt roughly 15 miles wide (as illustrated on **Figure D5-1**). The Wasatch and Green River collectively represent low-energy fluvial, lacustrine and paludal depositional environments which are time-equivalents of the alluvial fan deposits of the Battle Spring Formation. **Figure D5-1** schematically illustrates the stratigraphic relationships of Tertiary sediments within the GDB, and the specific Permit Area stratigraphy.

D5.1.2 Regional Structure

The present geomorphological features of the GDB were generated by the Laramide Orogeny. During the Late Cretaceous and Early Tertiary, the structures surrounding the GDB were either rejuvenated or were formed, transforming the area into a bowl-shaped geological structure, the Basin. During this upheaval, the Wind River Mountains and Granite Mountains were thrusted upward on the north side of the GDB. The Rawlins Uplift formed to the east; the Wamsutter Arch formed to the south; and the Rock Spring Uplift formed to the west.

The GDB is asymmetrical, with its major axis trending west-northwest. Several anticlines and synclines have been mapped within the GDB, and some of these features are oil-bearing (at much deeper levels than the uranium-bearing formations). Noteworthy among these structures is the Lost Soldier anticline in the northeastern part of the GDB, approximately 15 miles northeast of the Permit Area. The Battle Spring and Fort Union Formations, as well as older rocks crop out in the anticline; and the formations on the southwestern flank of the anticline dip 20 to 25 degrees to the southwest. The dip gradually becomes gentler and, at the Permit Area, it is merely three degrees westerly.

Deep-seated regional thrust faulting associated with the Wind River uplift occurred at depth in the north-central portions of the GDB. The horizontal component of displacement is possibly greater than nine miles. However, displacement along these faults did not extend to the surface, such that the upper portions of the Battle Spring Formation are largely undisturbed.

Shallow normal faulting is also common throughout the central GDB, having a preferential orientation that is generally east-west. These are relatively local and appear to be the result of late stage events in the structural history of the GDB. They are believed to be the result of a regional extension event and possibly also isostatic unloading within the GDB due to regional erosion. They are not considered to be currently active. Displacements are generally less than 100 feet and most commonly less than 50 feet. For example, the maximum displacement within the Lost Creek Fault System, which traverses the mineralized area from west-southwest to east-northeast, is about 80 feet. More details about the Lost Creek Fault are discussed in Section D5.2.2.

Strata within the GDB generally exhibit gentle dips of one to three degrees, increasing to as much as 20 degrees in some locations along the GDB margin. Gentle folding during late Eocene accompanied late-stage regional thrusting; therefore broad anticlinal and synclinal folds are present within the Battle Spring Formation. Similar to the shallow normal faulting discussed above, the fold axes generally are oriented east-west.

D5.2 Site Geology

Outcrop within the entire Permit Area is represented solely by the upper portions of the Battle Spring Formation, which is the host to uranium mineralization. The Battle Spring Formation in the vicinity of the Lost Creek Property is part of a major alluvial fan system, consisting of a multitude of thin to thick beds of sandstones separated by numerous thin to medium thick layers of mudstone, claystone and siltstone. The sandstone facies represent fluvial channel fill depositional environments. The shaly units represent channel margin and overbank depositional environments. The anastomosing nature of the fluvial channels has resulted in stratigraphy which tends to be erratic and lacking long range continuity. Various stratigraphic intervals, some dominated by sandstone and others by mudstone, have been correlated and named across the Property and Permit Area. These named "Horizons" are described in more depth in the following Section (Section D5.2.1).

Lithology of the Battle Spring Formation within the Permit Area consists of approximately 60% to 80% weakly consolidated, medium to coarse, commonly conglomeratic, clean arkosic sands in units from five to 50 feet thick; separated by 20% to 40% interbedded mudstone, claystone, siltstone, and fine sandstone, generally less than 25 feet thick (**Figure D5-1**). This lithological assemblage remains relatively consistent throughout the entire vertical section of interest within the Battle Spring Formation, such that the lithology of the shallowest units is virtually identical to that of the deepest units of interest. Economic uranium mineralization is generally associated with medium to coarse-grained sand facies.

Uranium deposits within the Lost Creek Property occur as roll front type deposits. The most significant mineral resources in the Lost Creek Property and the Permit Area occur within two major stratigraphic Horizons within the Battle Spring Formation: the HJ and the KM Horizons (**Figure D5-1**). The HJ Horizon carries the majority of the currently defined mineral resource and is currently permitted and being developed. The KM Horizon, the subject of this application, underlies the HJ Horizon and contains additional economic mineralization, which is the focus of this document.

Depth to the top of any given unit can vary from one end of the mineral trend to the other by up to 220 feet due to the regional dip of one to three degrees, and to displacement by normal faulting. Within the Permit Area the depth to KM Horizon mineralization ranges from 425 to 685 feet, averaging 515 feet.

Mineralization also occurs above the HJ within the DE and FG Horizons. The DE hosts only minor occurrences which are virtually always above the water table. Consequently it is of little economic interest. Mineralization within the FG is secondary to that of the HJ and KM, but is none the less significant, and remains to be investigated for economic viability. Mineral discoveries have also been made in the L, M, and N sands which are collectively referred to as the Deep Horizons and underlie the KM. Economic assessment of these Horizons will require additional exploration activity.

The combined HJ and KM mineral trend within the Permit Area is referred to as the Main Mineral Trend (MMT) and extends in an east-northeast to west-southwest orientation for nearly three miles (**Plate D5-1a and 1b**). The composite width of the MMT varies from 500 to 2,000 feet. Individual roll fronts within the deposit are typically 25 to 75 feet wide and are very sinuous. Mineralization in both the HJ and KM Horizons are stacked vertically and commonly overlie each other in a complex, erratic, anastomosing pattern in plan-view. Both the HJ and KM mineralization are considered to be the product of the same regional mineralizing event and therefore virtually contemporaneous and similar in most respects. The location of currently identified KM mineralization is illustrated in **Plate D5-1a.**

The geometry of the uranium mineralization is dominated by the classic roll front "C" shape or crescent configuration at the alteration interface. Thickness of mineralization within each roll front may vary from 5 to 25 feet thick. Typical thickness is from 10 to 15 feet. Mineral intercepts of over 25 feet in total thickness are common where multiple roll fronts occur stacked on top of each other. To date, a total of nine individual roll fronts have been identified in the KM Horizon within a stratigraphic interval of approximately 100 feet. Average grade within the Lost Creek MMT is approximately

0.057% eU_3O_8. East-west oriented normal faulting is common in the Lost Creek Property. As discussed above, these appear to be the product of relatively late-stage structural adjustments. They appear to be genetically associated with the Chicken Springs Fault system identified on published geological maps approximately five to ten miles to the east. The latest displacement of these faults was post-mineralization and therefore has offset mineralization. They are no longer considered active. The fault planes are close to vertical, being less than 3 degrees from vertical in locations where dip of the fault plane can be determined. Faulting is discussed in greater detail in Section D5.2.2.

D5.2.1 Site Stratigraphy

The upper portion of the Battle Spring Formation is host to the uranium mineralization in the Permit Area. Being the product of an alluvial fan depositional environment, the Battle Spring Formation can be described as a very thick sequence composed of innumerable individual channel sands typically from five to 50 feet thick interfingered with shales typically two to 25 feet thick which represent channel margin and overbank environments. Lateral extent of both of these lithologies can range from 100 feet to miles. Where multiple sand channels are stacked on top of each other, the cumulative sand thickness and width can be considerable. The erratic nature of these narrow channels results in stratigraphy which can be highly variable. The outcome can be very complex, where interfingering or abrupt facies changes may result in drastic changes in shale or sand thickness over short distances. This is well illustrated in the thickness isopach maps of the SBS and K Shales (**Plates D5-3a** and **D5-3b**) where discernible patterns of deposition are virtually absent; and also in the Geologic Cross-Sections (**Plates D5-2a** to **D5-2h and the Well Completion Reports in Attachment D5-1**).

Sedimentary and depositional patterns throughout the entire Battle Spring interval of interest remained quite consistent and uniform. Consequently, from a lithological and stratigraphic perspective there is little difference between deeper units and those near the surface. Distinctive characteristics of given stratigraphic intervals are subtle and generally are not consistent regionally, consequently partitioning into meaningful stratigraphic units remains largely arbitrary. Vertical boundaries have been defined at shale units showing the greatest regional continuity, or lacking that, at pre-established thickness intervals.

In the Permit Area, the top 1,200 feet of the Battle Spring Formation represents the interval of interest. Within this interval the stratigraphy has been sub-divided into several thick stratigraphic "Horizons" (e.g. HJ or KM). Horizons are dominated by sands and separated from each other by **"Named Shales"** of regional extent. Each horizon, however, is in actuality the composite of numerous "sands" which are in turn separated by numerous **"Unnamed Shales"** within the horizon. Unnamed shales may be quite extensive, or may be only of local extent. Note also that the term "shale" is used herein rather loosely, as it commonly may include considerable amounts of siltstone or fine grained sand as well as mudstone and claystone.

Horizons of primary interest are further subdivided into "Sub-Horizons" (e.g., LFG, UHJ, UKM). Criteria for establishing sub-horizons are based largely on a combination of continuity of sand packages and continuity of associated mineral horizons. Vertical boundaries between sub-horizons are established somewhat arbitrarily and may or may not coincide with the presence of an intervening shale.

The resulting system of stratigraphic nomenclature is illustrated in the Stratigraphic Column within **Figure D5-1**. This nomenclature is internal to Ur-Energy and is not recognized officially by the geological community. The foundation for this system has been carried over, with some modification, from that established by Conoco Minerals during its early exploration activities in the region and subsequently adopted by Texasgulf during its tenure with the property. Nomenclature terms from surface downward to the KM Horizon were inherited from previous operators; below that the terms were derived by Ur-Energy.

Note that in the last few years Ur-Energy has abandoned the use of the term "Sand" in favor of the term "Horizon" to describe the major stratigraphic units. It is believed that the term "Sand" can be misleading in recognition of the fact that any substantial stratigraphic interval consists not only of sand facies but also contains a considerable number of interbedded shales which yields hydrogeological characteristics significantly different than an interval consisting only of sand.

Also note that the boundaries between horizons (i.e. Named Shales) have been established on a relatively arbitrary basis and don't necessarily reflect patterns or breaks in sedimentary or depositional characteristics. As a result, the system of nomenclature as illustrated on **Figure D5-1** should be viewed essentially and simply as a cataloguing tool for stratigraphic organization.

Named Shales represent the shaly interval nearest the stratigraphic level established as the break between Horizons. Strictly defined, they represent the shaly interval between the lowest sand assigned to the overlying Horizon and the uppermost sand assigned to the underlying Horizon. The Battle Spring interval of interest contains many more shales (unnamed) than just the Named Shales (see Type Log #2, **Figure D5-2** and Geological Cross-Sections **Plates D5-2a to D5-2h**). As such, Named Shales may not be the dominant shale in any given area nor represent the only shale occurring between production sands. Named Shales may not be regionally continuous; or they may represent a series of shales which can be overlapping, en-echelon, or complexly interwoven with vertically adjacent sands. Because of this complexity, thickness values selected for shale isopach mapping (**Plates D5-3a** and **D5-3b**) may not represent all shales in such a series, but rather only the one that best correlates to the stratigraphic nomenclature boundary. An example of shale complexity is well illustrated in the central portions of Cross-Section I-I' (**Plate D5-2h**).

The most notable exceptions to the above statements are the LCS and SBS Shales which locally may display considerable complexity but do exhibit a high degree of regional continuity and confinement.

Provided below is a brief description of each named stratigraphic unit within the Permit Area. The general lithologic character of the units remains relatively consistent throughout the entire Property, however depths below ground surface (bgs) may vary significantly locally due to regional stratigraphic dip and displacement due to normal faulting.

A Horizon –The A Horizon is poorly characterized largely because it is commonly not present, having been removed by erosion; except in the western down-dip portions of the property and where it has been down-thrown by faulting. When present, lithologic data is often missing in drill logs because it is dry and occurs above the fluid level in the drill hole while logging. Fluid in the hole is required to generate the single point resistance and spontaneous potential (SP) curves used for lithological characterization. The lower boundary of the A Horizon is arbitrary and poorly defined. Significant mineralization is rare.

BC Horizon – The BC Horizon is the horizon occurring at the surface within the majority of the Permit Area. Like the A Horizon, it is often completely or partially above the drilling fluid level while logging, consequently detailed characterization of the BC Horizon is sporadic. In general it appears to be similar in character to the adjacent underlying DE Horizon. The upper and lower boundaries are arbitrary and poorly defined. Thickness is approximately 80 to 100 feet. The BC Horizon is dry, except possibly for some local perched water tables. Significant mineralization is rare.

DE Horizon – This Horizon occurs at the surface in the eastern portions of the Project. It commonly consists of a sequence of relatively thick sands with thick intervening shaly units. In portions of the Permit Area, the lower shale boundary is absent such that the sands of the DE Horizon coalesce vertically with sands of the underlying FG Horizon. In the Lost Creek Project, the top of the unit ranges in depth from surface to 200 feet and is approximately 80 feet thick where the entire section is present. The DE Horizon is the shallowest horizon which carries groundwater (i.e., the shallowest aquifer). When present, standing water levels occur at the very basal portions of the DE Horizon. Significant mineralization is uncommon.

EF Shale (formerly the Upper No Name Shale) – The EF Shale represents the boundary between the overlying DE Horizon and the underlying FG Horizon. Hydrogeological confinement by the EF Shale is not complete. It is not everywhere present and commonly does not consist of one regionally continuous shale but rather multiple shales which overlap in en-echelon manner (for example, see the east half of Cross-Section D-E, **Plate D5-2c**). Thickness varies considerably from two to 45 feet. Depths to the EF Shale vary from 125 feet in the eastern portions of the Project to 300 feet in the western portions.

FG Horizon – In the Permit Area the top of the FG Horizon occurs at depths of approximately 125 feet in the east to 300 feet in the western regions of the Project. The total thickness of the FG Horizon is typically about 160 feet, ranging between 140 to 175 feet. Stratigraphically, the FG Horizon is subdivided into three sub-horizons: the Upper FG (UFG), Middle FG (MFG) and the Lower FG (LFG), all roughly of equal thickness. The breaks between these are not rigidly defined. Generally they are selected based on significant shales (if present) which separate channel-fill sequences. The character of individual FG sand units tends to be thinner, more erratic and shaly than what is characteristic of lower horizons; and as a whole the FG has a lower Sandstone to Shale (SS/Sh) ratio. The FG contains significant mineralization in the Permit Area.

Lost Creek Shale (LCS) – The Lost Creek Shale separates the FG and HJ Horizons. It is a dominant shaly horizon which has been found to be continuous throughout the Lost Creek Permit area. For this reason it has been used as the datum for stratigraphic correlation. Thickness ranges from 5 to 45 feet, typically being from 10 to 25 feet. Depth ranges from approximately 280 feet in the east portions of the project to 475 feet in the west. Its lithology is dominated by silty mudstone and dense claystone. It commonly includes siltstone, and may locally be sandy or contain thin lenticular sands. Segments of the LCS commonly interfinger with and undergo rapid facies exchanges with lower sands of the FG Horizon and upper sands of the HJ Horizon. This can complicate correlation and often results in dramatic changes in the thickness of the LCS within short horizontal distances.

HJ Horizon – The HJ Horizon is the dominant host for mineralization in the MMT and is the host to current production development. The HJ Horizon has been subdivided into four sub-horizons: Upper HJ (UHJ), Middle HJ1 (MHJ1), Middle HJ2 (MHJ2) and the Lower HJ (LHJ). The boundaries between the sub-horizons are somewhat arbitrary but selection is guided by sand channel and roll front mineral horizon continuity. Boundaries may be accompanied by a shale break. The bulk of the uranium mineralization is present in the two MHJ sub-horizons. The HJ Horizon characteristically includes noticeably thicker sands and a high SS/Sh ratio compared to most of the other horizons. The total thickness of the HJ Horizon ranges from 120 to 160 feet, averaging approximately 130 feet. Depth to the top of the HJ Horizon within the Permit Area ranges from approximately 280 feet in the east to 475 feet in the west.

Sagebrush Shale (SBS) – The Sagebrush Shale forms the boundary between the HJ Horizon and the underlying KM Horizon. As such it represents the aquitard between the HJ production horizon and the proposed KM production horizon. The SBS is laterally extensive and virtually continuous throughout the Permit Area. Within the Permit Area depth to this shale ranges from 425 feet in the eastern portions of the Project to approximately 625 feet in the west. Thickness varies from 2 to 50 feet. Similar to the LCS, segments of the SBS commonly interfinger with and undergo rapid facies exchanges with lower sands of the HJ Horizon and upper sands of the KM Horizon. This can complicate correlation and often results in dramatic changes in the thickness of the SBS within short horizontal distances, as is evident in the thickness isopach map for the SBS (**Plate D5-3a**)

KM Horizon – The KM Horizon is the secondary host to the mineralization in the MMT. Proposed production from the KM is the focus of this document. Nomenclature for the KM was modified in recent years. Initially, and at the time of the original Technical Report, the KM Horizon was assigned three sub-horizons: the Upper KM (UKM), the Middle KM (MKM) and the Lower KM (LKM). As additional drilling results became available over time it became apparent that the KM is better described as having only two sub-horizons, underlain by the K Shale. Consequently the MKM designation was abandoned and replaced by the LKM such that the current nomenclature employs only the UKM and LKM.

In general the character and lithology of the KM is similar to that of the HJ Horizon. Both the UKM and the LKM sub-horizons host mineralization. A shale unit referred to as the No Name Shale (NNS) commonly divides the two sub-horizons of the KM, but it is not present everywhere within the Project. Depth to the top of the KM Horizon ranges from 430 feet in the eastern portions of the Project to 650 feet in the far western portions. Thickness ranges from 80 feet to 110 feet.

K Shale – The K-Shale represents the lower boundary of the proposed KM production horizon. It occurs throughout the Lost Creek area, but may be sporadically absent locally. Where present, continuity and confinement is not seamless as it may locally be represented by multiple overlapping shales. Average thickness is 10 feet, ranging from 2 feet to 40 feet. A thickness isopach map for the K Shale is presented as **Plate D5-3b**. Depth to the K Shale varies from 525 feet in the eastern margins of the Project to 750 feet in the west.

L, M, and N Horizons – These horizons are collectively referred to as the "Deep Horizons" and occur within a 300 to 350 feet interval below the K Shale. Currently they are the targets of exploration activities. Available drill data for these horizons is much sparser than for the shallower horizons. Individually, each horizon is approximately 100 feet thick. They consist of lithologies identical to that of shallower horizons. In general, like the remainder of the Battle Spring Formation, they are composed of multiple, stacked, coarse sands separated by numerous shale intervals. Stratigraphically, shales within these horizons are often relatively thick and more continuous than seen in the shallower horizons, contributing to an overall lower SS/Sh ratio. At the same time, individual sands tend to be thicker and show more regional continuity. This character becomes more dominant with depth.

L Horizon: Depth to the L Horizon varies from 525 feet in the east to approximately 750 feet in the west. Thickness of the L Horizon is locally diminished significantly due to substantial thickening of the underlying LM Shale.

M Horizon: Locally the M Horizon exhibits a much more shaly character with more shale interbeds, thinner sands and a much lower SS/Sh ratio than the vertically adjacent horizons. Depth to the top of the M Horizon ranges from 610 feet in the east to 825 feet in the western portions of the Project.

N Horizon: The character of the N Horizon is similar to that of the L and M, commonly exhibiting thick shales with well-developed sands. Depth to the top of the N Horizon ranges from 725 feet in the east to approximately 940 feet in the west.

LM, MN, and NP Shales – These shales represent the lower boundaries of the L, M and N Horizons respectively. Designation of these shales as horizon boundaries were arbitrarily established on roughly 100 foot intervals below the K Shale. As such they do not present unique characteristics compared to any other shales within this stratigraphic interval. Thickness of the shales varies considerably, reaching up to 50 feet with an average of approximately 13 feet. Although these shales have regional extent, continuity is unconfirmed. In many areas drill data spacing is insufficient to confirm correlation. Breaks in these shales have locally been identified.

D5.2.2 Site Structure

The dominant geologic structural features in the Permit Area are a series of normal faults. The locations of these faults are illustrated in the General Location Map (**Plate D5-1a and 1b**); in the Geological Cross-Sections (**Plates D5-2a** to **D5-2h**) and in the Isopach Maps; (**Plates D5-3a** to **D5-3b**). Bedding within the Battle Spring Formation in the Permit Area is nearly flat-lying, dipping gently to the northwest at roughly three degrees. This regional pattern of strike and dip is modified locally due to horst and graben features resulting from normal faulting in the Lost Creek area.

The MMT within the Permit Area is bisected by a normal fault system, which is collectively referred to as the Lost Creek Fault. This consists essentially of two faults, lying roughly parallel and en-echelon, trending from east-northeast to west-southwest (**Plate D5-1**).

The 'main' Lost Creek Fault trends east to west and dissects the eastern two-thirds of the Permit Area. Downward displacement occurs on the south block. Throw is approximately 70 to 80 feet in the eastern portion of the Permit Area, decreasing to the west, and eventually losing identity in the western one-third of the Permit Area. Easterly, displacement on the 'main' fault disappears near the eastern boundary of Section 17. In addition, a minor 'splay' fault has been identified close to the 'main' fault in the west-central portion of the Main Mineral Trend. Maximum throw on this fault is roughly 20 feet in the opposite direction than the 'main' fault, creating a localized graben structure between.

A second or 'subsidiary' fault to the 'main' fault is positioned sub-parallel and approximately 800 to 1,000 feet south. Throw is opposite that of the 'main' fault with a maximum down to the north displacement of approximately 50 feet. The 'subsidiary' fault also has a minor splay fault associated with it which splits off to the north between the 'subsidiary' and 'main' faults. Drilling conducted in recent years shows that the primary branch of the 'subsidiary' fault continues easterly out of the Permit Area. Portions of it were previously referred to as the South fault. Westerly, the 'subsidiary' fault appears to diminish before reaching the western Permit boundary.

Drilling has identified additional faults elsewhere within the Permit Area. The 'north' Fault is located roughly 3,800 feet north of the MMT and has displacement ranging from approximately 20 feet to 80 feet. Also a significant fault has been discovered in Section 25 in the southernmost portions of the Permit Area. Displacement on this fault is approximately 120 to 160 feet. Both of these faults are distant from the MMT and are well outside of anticipated production areas. Several other minor faults have also been identified (**Plate D5-1a**). Most of these are of limited extent and exhibit throws no more than 10 to 20 feet.

Finally, drilling has revealed three faults within Section 16 in the eastern portions of the Permit Area. Orientation of these faults closely parallels that of the Main Fault. Displacement varies from 15 to 50 feet. They are east of the anticipated areas of KM production and therefore will have minimal, if any, effect on that production.

Pump-testing and monitoring on both sides of the 'main' fault in the Mine Unit 1 area have demonstrated that the fault plane acts as a substantial barrier to flow within the HJ and KM Horizons (see Section D6).

D5.2.3 Ore Mineralogy and Geochemistry

Mineralogy has been studied in thin section and by x-ray diffraction analysis. These analyses were conducted in 2007 by Hazen Research (Hazen, 2007) which included samples from the KM Horizon derived from core (core-hole LC64C). Results indicate that the uranium in the KM is virtually identical to that in the HJ Horizon, occurring primarily as the mineral coffinite (uranium silicate) in the form of micron- to submicron-size inclusions disseminated in and on interstitial clay, possibly absorbed by cation exchange; also intimately interspersed through some of the pyrite and as partial coatings on quartz and biotite. Minor amounts of uraninite (uranium oxide) and brannerite (uranium-titanium oxide) have also been identified. Clay rich fractions are predominantly smectite (montmorillonite), with minor kaolinite.

The Hazen Research analysis concluded that uranium should be recoverable by an ISR operation because of the unconsolidated nature of the sandstone and expected diffusion of the lixiviant through the smectite minerals. Leach amenability tests as discussed in the original Permit Application included one set of core samples collected from the UKM Horizon (core-hole LC46C). Recoverability has been confirmed by these leach testing results, which revealed that the character of KM mineralization is virtually identical to that in the HJ Horizon.

D5.2.4 Exploration and Production Activities

This section is unchanged from Section 3.0 of the approved Technical Report.

D5.3 Seismology

This section is unchanged from Section 2.6.3 of the approved Technical Report.

D5.3.1 Historic Seismicity

This section is unchanged from Section 2.6.3.1 of the approved Technical Report.

D5.3.2 Uniform Building Code

This section is unchanged from Section 2.6.3.2 of the approved Technical Report.

D5.3.3 Deterministic Analysis of Active Fault Systems

This section is unchanged from Section 2.6.3.3 of the approved Technical Report.

D5.3.4 Maximum Tectonic Province Earthquake "Floating Earthquake" Seismogenic Source

This section is unchanged from Section 2.6.3.4 of the approved Technical Report.

D5.3.5 Short-Term Probabilistic Seismic Hazard Analysis

This section is unchanged from Section 2.6.3.5 of the approved Technical Report.

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FIGURES

TABLES

ATTACHMENT

Attachment D6-2c (CD-ROM)

- Petrotek Engineering Corporation, 2009. Lost Creek Hydrologic Test, Composite KLM Horizon Pump Tests, KPW-2 and KPW-1A, June-July 2009.
- Petrotek Engineering Corporation, 2011. Lost Creek Hydrologic Test, Composite KLM Horizon Regional Pump Test, October 2011.
- Petrotek Engineering Corporation, 2012. Lost Creek Hydrologic Test, Composite KLM Horizon 5-Spot Testing, October 2012.

D6 HYDROLOGY

This appendix addresses surface water drainage characteristics and use (**Sections D6.1.1 and D6.1.2**), surface water quality (**Section D6.1.3**), regional and site hydrogeology (**Sections D6.2.1** and **D6.2.2**), groundwater use (**Section D6.3**), regional and site groundwater quality (**Sections D6.4.1** and **D6.4.2**), and the regional and site hydrologic conceptual models (**Sections D6.5.1** and **D6.5.2**). Potential hydrologic impacts, mitigation, and monitoring are presented in the revised **Operations Plan (contained in this application)**.

D6.1 Surface Water

D6.1.1 Drainage Characteristics

This section is unchanged from Section 2.7.1.1 of the approved Technical Report.

D6.1.2 Surface Water Use

This section is unchanged from Section 2.7.1 of the approved Technical Report.

D6.1.3 Surface Water Quality

This section is unchanged from Section 2.7.1.2 of the approved Technical Report.

D6.2 Groundwater Occurrence

This section describes the regional and local groundwater hydrology including hydrostratigraphy, groundwater flow patterns, hydraulic gradient and aquifer parameters. The discussion is based on information from investigations performed within the Great Divide Basin, data presented in previous applications/reports for the Permit Area, and the geologic information presented in **Section 2.7** of the approved Technical Report. Regional and site hydrogeology are discussed in **Sections D6.2.1** and **D6.2.2**; groundwater use in **Section D6.3**; regional and site groundwater quality in **Sections D6.4.1** and **D6.4.2**; and the regional and site hydrologic conceptual models in **Sections D6.5.1** and **D6.5.2**.

D6.2.1 Regional Hydrogeology

This section is unchanged from Section 2.7 of the approved Technical Report.

D6.2.2 Site Hydrogeology

LC ISR, LLC has been collecting lithologic, water level, water quality, and pump test data as part of its ongoing evaluation of hydrologic conditions at the Project. Water level measurements, both historic and recent, provide data to assess potentiometric surface, hydraulic gradients and inferred groundwater flow directions for the aquifers of interest at the Project. Three long-term pump tests (**Attachment D6-2c**) were used to: 1) evaluate hydrologic properties of the aquifers of interest, 2) to assess hydraulic characteristics of the confining units, 3) to evaluate impacts to the hydrologic system of the Lost Creek Fault (Fault) through the Permit Area, and 4) to evaluate aquifer injectivity characteristics. Results of Permit Area water quality sampling and analysis are presented in **Section D6.4.2**.

Figure D6-11h shows the locations of all existing KM Horizon monitor wells in the Permit Area. **Table D6-5** provides completion data for the monitor wells currently in use.

D6.2.2.1 Hydrostratigraphic Units

Aquifers in the Battle Spring Formation are comprised of the sand facies components of the formation. Mapable sand units consist of clean, medium to coarse-grained, fluvial channel fill sands which may range from five to 50 feet in composite thickness. Aquifers, as applied herein, typically consist of multiple stacked sand units separated by numerous unnamed aquitards and aquicludes which can be local or laterally extensive.

For ease of geologic mapping, the Battle Spring Formation is segregated into vertical intervals called Horizons. The total composite thickness of each Horizon (for example: the HJ Horizon) is commonly in excess of 100 feet. (**Figure D5-2**). The vertical extent of Horizons may or may not be identified based on aquitards or aquicludes.

Aquicludes and aquitards consist of the intervening shaly units separating sand units. They represent quiescent floodplain and overbank sedimentary environments between channel-fill sequences. Generally referred to as 'shales', they are in essence, sedimentary sequences dominated by mudstone and claystone lithology, but also may include substantial amounts of siltstone and fine-grained sands. Hydrogeologically, they represent substantially lower permeabilities compared to the clean coarse sands of the aquifers. Shale lithologies are often transitional to the Horizons above or below or can exhibit rapid lateral facies changes and interfingering with adjacent lithology. As a result, dramatic thickening and thinning of the aquicludes can occur locally (see **Plates D5-3a and D5-3b**). Thicknesses of aquicludes and sand packages are commonly in excess of 25 feet, and may be as thin as one to five feet thick.

In a global sense, the entire Battle Spring Formation essentially represents a single aquifer. On the scale of the Lost Creek Project more definition and distinctions can be made. Vertical boundaries of aquifers are herein defined arbitrarily at the named shales, although in many cases the named shales show little distinction from unnamed shales. The notable exception to this is the HJ aquifer bounded by the Lost Creek Shale (LCS) and Sagebrush Shale (SBS) aquicludes, resulting in a clearly confined aquifer. Elsewhere within the Battle Spring stratigraphy, differentiation between aquifers is less distinct. Due to this lack of clearly defined boundaries, the term Horizon is commonly used instead of aquifer.

Nomenclature for the hydrostratigraphic units of interest within the Project follows the nomenclature for stratigraphic units (Refer to **Section D5.2.1** for a discussion of the stratigraphic units). A brief description of each hydrostratigraphic unit follows, from shallowest to deepest.

DE Horizon

The DE Horizon is the shallowest occurrence of groundwater within the Permit Area; however, the Horizon does not carry water in all portions of the Permit Area. Where it does the unit is not saturated, water levels being restricted to the basal portions of the Horizon. Locally, the lower bounding EF Shale is not present so that the sands of the DE Horizon coalesce with sands of the FG Horizon.

FG Horizon

The upper boundary of the FG Horizon, separating it from DE, is the EF Shale. The EF Shale is not everywhere present or may locally be represented by a composite of en-echelon overlapping shales. Overlying hydrogeological confinement is poor. The lower boundary is the Lost Creek Shale, which has been shown to be an affective aquiclude. The Lower FG (LFG) is the basal sub-horizon in the FG Horizon. It ranges from 20 to 50 feet thick within the Permit Area, and has been designated as the overlying aquifer for the HJ production orebody.

Lost Creek Shale

The Lost Creek Shale acts as the overlying confining aquiclude to the currently permitted HJ production zone. The LCS has shown continuity throughout the Lost Creek Permit area. The confining characteristics have been demonstrated by multiple pump tests, as discussed later in this application.

HJ Horizon

The primary production aquifer at Lost Creek is the HJ Horizon, which is currently permitted and in development for production. The HJ Horizon represents a confined aquifer, bounded above and below by the Lost Creek Shale and the Sagebrush Shale confining units, respectively. The dominant lithology of the HJ Horizon is clean, 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 Technical Report, 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. At this time, lower confinement of the KM aquifer remains under investigation.

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 remains under investigation. However, based on previous "Regional" and "Permit Area" scale pump test results, there is demonstrated hydrogeologic communication between the KM Horizon and the underlying horizons. The degree of communication diminishes with depth.

D6.2.2.2 Potentiometric Surface, Groundwater Flow Direction and Hydraulic Gradient

The LC ISR, LLC hydrologic evaluation of the Project included measurement of water levels in monitor wells completed in the KM Horizon and the underlying composite L, M, and N Horizons to assess the potentiometric surface, groundwater flow direction and hydraulic gradient of those units. **Table D6-6** lists static water level data recorded in 2010, 2011 and 2012.

The 2010, 2011 and 2012 data were used to construct potentiometric surface maps for the L, M, and N Horizons **Figures D6-11i** through **D6-11k**, respectively, and are also shown on cross sections in **Plates D5-2a to D5-2h**. 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. The Figures and Plates show that the hydraulic gradient and groundwater flow direction across the permit area are similar to that seen in the overlying KM and HJ Horizons.

The horizontal hydraulic gradient for the KM aquifer in the vicinity of the Lost Creek Fault, determined from 2010, 2011, and 2012 water level data, ranged from 0.0032 to 0.0139 ft/ft (16.9 to 73.4 ft/mi). **Table D6-7a** summarizes the hydraulic gradients determined from the most recent water level data. The horizontal hydraulic gradient across the permit area averages 0.0063 ft/ft north of the Lost Creek Fault and 0.0035 ft/ft on the south side.

Vertical hydraulic gradients were determined for the UKM Horizon by measuring water levels in closely grouped wells completed in different hydrostratigraphic units. **Figure D6-12b** shows the location of the UKM well groups used for the assessment of vertical hydraulic gradients. **Table D6-7b** is an updated table that presents the calculated vertical gradients between the HJ and UKM aquifers. Vertical hydraulic gradients range from 0.05 to 0.36 ft/ft between the HJ and UKM aquifers and typically indicate decreasing hydraulic head with depth. A downward gradient is consistent with the structural and stratigraphic location of the Project within the Great Divide Basin.

D6.2.2.3 Aquifer Properties

As part of the hydrologic characterization activities for the NRC License and LQD Permit to Mine applications, LC ISR and Petrotek previously performed several in-house pump tests that provided progressively more information related to the composite KLM Horizon hydraulics. The KM Horizon of the composite KLM Horizon is further subdivided into two sandy sub-horizons designated the UKM (upper KM) and the LKM (lower KM).

In 2007, a pump test was conducted in sub-horizon UKM. Based on the degree of drawdown response observed in the underlying sub-horizon LKM wells, it was determined that additional zones below the KM Horizon would need to be investigated and monitored during pump tests. In 2009, LC ISR and Petrotek conducted two additional in-house pump tests in the KM Horizon, at pumping wells KPW-2 (north side of the fault) and KPW-1A (south side). The drawdown results in the L Horizon indicated that the KM and L Horizons were in hydraulic communication. A re-test at pumping well KPW-1A was conducted in 2010 with additional deeper monitoring in the M Horizon to evaluate deeper responses. Based on the previous test results, the most recent composite KLM Horizon Permit Area Pump Test was conducted in October 2011. This test represents the most complete characterization of the composite KLM Horizon, with monitoring conducted in the KM, L, M and N Horizons. A brief summary of KM and KLM Horizon investigations is provided below with aquifer characteristics summarized in **Table D6-11**. **Figure D6-13b** shows the locations of all pump tests performed between 2007 and 2012 as compiled in the following table.

Summary of KM Horizon Hydrologic Investigations

Test	Pump Well	Location relative to fault	Rate (gpm)	Duration (days)
November 2007	UKMP-103	North	29 gpm	6 days
June 2009	KPW-2	North	68 gpm	0.33 days
June-July 2009	KPW-1A	South	63 gpm	7 days
April 2010	MU-101	South	50 gpm	1 day
November 2010	KPW-1A (re-test)	South	62 gpm	4 days
October 2011 Mine Unit Pump Test	KPW-3	South	70 gpm	4.9 days
October 2012 5-Spot Pump Test	5S-KM3	South	Various	Various

November 2007 – Internal Testing

The 2007 test was a long-term, multi-well test conducted on the north side of the Lost Creek Fault and designed to provide general hydrologic characterization of the Upper KM Horizon (sub-horizon UKM). **Table D6-9c** lists the wells monitored during the test. At that time it was believed that the No Name Shale represented a regionally contiguous aquitard between the UKM and LKM sub-horizons. However, responses observed during this test indicated that the two KM sub-horizons had a strong hydrologic connection. Subsequent drilling and logging performed in the summer of 2008 substantiated the lack of continuity of the No Name Shale.

The test was run for a period of approximately six days at an average rate of 29 gpm. Test results (**Table D6-10c**) indicated an average aquifer transmissivity of 138 ft^2/d and average storativity of 1.07×10^{-4}. Water level responses observed during the test indicated that the Lost Creek Fault acts as a partial hydrologic barrier to groundwater flow, or zone of lower permeability, within the upper UKM sub-horizon when pumped on the north side of the fault. A single KM Horizon well located between the main fault and the splay fault showed a similar scale of drawdown across the main fault compared to wells on the north side. Several KM Horizon wells south of the main fault and splay fault showed lower drawdowns compared to similarly spaced wells north of the fault. Distance versus drawdown observations across the fault and splay for these wells were reduced by approximately five times. Therefore, based on the responses observed during this test, the secondary fault splay, mentioned above, also appears to behave as a zone of lower permeability.

Although the pump test on the north side of the fault did not recognize the upper and lower KM sub-horizons as a single hydrostratigraphic unit, the data acquired from that test were valuable in determining aquifer properties for the KM Horizon on the north side of the fault.

Following the initial 2007 KM Horizon pump test and analysis by Petrotek, additional drilling and logging was conducted which allowed for better definition of deeper stratigraphic units underlying the KM Horizon. In 2009 and 2010, additional monitor wells were installed in the deeper L and M Horizons. Subsequent in-house pump tests (summarized below) were conducted by LC ISR to evaluate possible lower aquitards to the composite KLM Horizon and to characterize KM Horizon aquifer properties on both sides of the fault.

June 2009 – Internal Testing

In June 2009, a short-term multi-well pump test was conducted at KPW-2, which is completed in the KM Horizon and located north of the Lost Creek Fault. **Table D6-9d** lists the wells monitored during the test. KPW-2 was pumped for eight hours at an average rate of 68.3 gpm. Test results (**Table D6-10d**) indicated an average aquifer transmissivity of 139 ft^2/d and average storativity of 1.2×10^{-4}. No drawdown responses were observed in the overlying HJ Horizon during this relatively short test. However, hydrologic communication between the KM Horizon and underlying L Horizon was observed. An L Horizon well (KMU-4) approximately 170 feet away from KPW-2 exhibited greater than 11 feet of drawdown.

June-July 2009 – Internal Testing

During June and July 2009, a long-term multi-well pump test was conducted on the south side of the Lost Creek Fault at well KPW-1A by pumping at an average rate of 63 gpm for seven days. **Table D6-9d** lists the wells monitored during the test. Drawdown data from HJ Horizon wells indicated adequate overlying confinement (Sagebrush Shale) separating the composite KLM Horizon from the HJ Horizon. Observed drawdown in HJ Horizon wells, located on the south side of the fault, ranged between 0.5 to 1.8 feet, while no responses were observed in wells located north of the fault. Test results (**Table D6-10d**) indicated an average aquifer transmissivity of 156.2 ft^2/d and average storativity of 1.1×10^{-4}.

As seen in the KPW-2 test, hydrologic communication between the KM Horizon and the underlying L Horizon was observed. Drawdowns observed in two L Horizon wells located on the south side of the Lost Creek Fault were approximately 21 feet, compared to approximately 40 feet in the KM Horizon wells on the same side of the fault. Observed drawdowns in two L Horizon wells located north of the fault were between 2.7 to 5.1 feet and comparable with drawdown observed in nearby KM Horizon wells north of the fault.

Based on the drawdown responses observed across the fault during this test, the Lost Creek Fault appeared to act as a partial barrier to flow or zone of lower permeability when a well on the south side of the fault is pumped, and wells are monitored on the north side of the fault.

Following the pump testing in the summer of 2009, four historic exploration holes that penetrated the K Shale (mudstone interval at the base of the KM Horizon) were located, re-entered and re-abandoned. Also, additional monitor wells were installed in the deeper L and M Horizons during the first quarter of 2010. Following the activities mentioned above, LC ISR conducted a short-term pump test using MU-101 (UKM sub-horizon completion) as the pumping well on the south side of the fault to assess whether the re-abandonment activities decreased the observed response in the L Horizon and to assess response in the deeper M Horizon. MU-101 was pumped for 24 hours at approximately 50 gpm. Data suggested limited hydrologic separation between the KM Horizon and L Horizon with a maximum drawdown of 2.6 feet observed in the L Horizon versus 12 to 17 feet observed in KM Horizon wells. No drawdown response was observed in the deeper M Horizon. The lack of response in the M Horizon wells was likely due to: 1) the pumping well (MU-101) being completed in only the upper portion of the KM Horizon, 2) the vertical separation between the two horizons, and 3) the presence of numerous discontinuous siltstone, mudstone and shale beds that exist between the two horizons.

November 2010 – Internal Testing

In November 2010, LC ISR conducted a re-test of KPW-1A (located south of fault) in order to replicate the test performed in June 2009, while also monitoring newer wells installed in the lower L and M Horizons. KPW-1A was pumped for four days at an average rate of 62.2 gpm. Test results indicated that hydrologic isolation between the KM and L Horizons appeared to be limited based on a maximum drawdown of 16.0 feet observed in the L Horizon wells in contrast to a nearby KM Horizon well that showed 43 feet of drawdown. Hydrologic isolation between the L Horizon and the deeper M Horizon also appeared to be limited as evidenced by the 6.8 feet of drawdown response seen in M Horizon wells as compared to the 16.0 feet observed in overlying L Horizon wells. Based on the drawdown responses observed north and south of the fault during the test at

KPW-1A, the Lost Creek Fault appears to act as a partial hydrologic barrier (low permeability zone). The observed drawdown on the north side of the fault was lower by approximately 10 times relative to wells on the south side of the fault. Based on the results of testing, the responses observed in the KM, L and M Horizons indicate that the three layers comprising the composite KLM Horizon are in varying degrees of hydraulic communication.

October 2011 – Internal Testing

The 2011 Composite KLM Horizon Regional Pump Test was designed to evaluate the hydrologic characteristics as required for an amendment to include Resource Area 3 in current State and Federal permits at Lost Creek. Based on the results of internal testing conducted at four pumping well locations in the KM Horizon both north and south of the Lost Creek Fault, the regional pump test was conducted at pumping well KPW-3 on the south side of the Lost Creek Fault. Drawdown monitoring was conducted within the HJ, KM, L, M, and the lowermost N Horizon. The results support previous data that indicate the KLM Horizon acts as one hydrostratigraphic unit, albeit with locally occurring interfingered mudstone and siltstone beds and decreasing drawdown with depth. Based on drilling and logging data, the MN Shale is not considered a truly regional confining unit, but does restrict vertical flow between the M Horizon and the deeper N Horizon. The scale of hydraulic communication observed relative to the pumped KM Horizon and the overlying HJ Horizon is similar in scale to the communication observed relative to the KM and N Horizons.

For reference, the following table summarizes the in-house testing programs conducted between 2007 and 2012.

Summary of Pump Testing, 2007-2010

Date	Pump Well and Completion	Side of LC Fault	Obs. Wells by Horizon	Pump Rate (gpm)	Time (days)	Notes on Responses
Nov 2007	UKMP-103 (Upper KM)	North	33 total 3 FG 7 HJ 20 U. KM 3 L. KM	28.8	5.96	- Significant response observed in Lower KM Horizon, which was the monitored underlying zone. - Minimal (<1') response observed in overlying HJ.
June 2009	KPW-2 (Upper and Lower KM)	North	24 total 6 HJ 14 KM 4 L	68.3	0.33	- Demonstrated successful abandonment of MU-108; communication due to completion issues were indicated during 2008 MU1 testing. - Drawdown propagation dampened across the fault. - No response observed in overlying HJ Horizon. - L Horizon well on north side showed 11.6' of drawdown.
June July 2009	KPW-1A (Upper and Lower KM)	South	24 total 6 HJ 14 KM 4 L	63.0	6.91	- Minimal responses observed in overlying HJ Horizon. - Level of drawdown observed in L Horizon similar in scale to pumped KM Horizon.
April 2010	MU-101 (Upper KM)	South	27 total 6 HJ 13 KM 5 L 3 M	50.0	1.0	- Conducted to confirm whether abandonment of nearby historic drill holes affected drawdown in deeper L and M Horizons; results indicated communication between these horizons.
Nov 2010	KPW-1A (Upper and Lower KM)	South	48 total 6 HJ 33 KM 6 L 3 M	62.2	4.0	- Minimal response observed in overlying HJ Horizon. - Limited hydrologic separation between the KM Horizon and deeper L and M Horizons. - Drawdown propagation dampened across fault.
Oct 2011	KPW-3	South	79 total 30 HJ 30 KM 9 L 8 M 2 N	70	4.92	- Varying degrees of hydraulic communication between the two underlying L and M Horizons of the composite KLM Horizon, thus confirming that the entire KLM is hydraulically connected.
Oct 2012	5S-KM3	South	10 total 1 HJ 6 KM 1 L 1 M 1 N	28.5	3.1	5-Spot injection/extraction test - Drawdown response in HJ and N Horizons was minor.

October 2012 - Internal Testing

LC ISR plans to develop and extract uranium from mine units within the KM Horizon of the Battle Spring Formation via ISR. Initial production from the KM Horizon will occur within an area of the Lost Creek Project currently designated as Resource Area 3. This resource area lies to the east of Mine Unit 1, the first planned production well field, and partially underlies Mine Unit 1, which will produce from the HJ Horizon.

With reference to Resource Area 3, significant mineralization has been identified in the KM Horizon, occurring between depths of approximately 430 to 590 feet below ground surface (ft bgs). Average thickness of the KM Horizon is approximately 115 feet thick and total thickness of the composite KLM ranges from approximately 260 to 330 feet.

The purpose of the 5-Spot Hydrologic Testing was to assess the level of hydraulic communication between the KM Horizon (Production Zone), and the overlying HJ Horizon, the underlying L and M Horizons of the composite KLM Horizon, in addition to the deeper N Horizon in a typical commercial scale 5-Spot production pattern.

Prior to testing activities, LC ISR re-developed all wells utilized in the 5-Spot Hydrologic Testing. During development activities, bentonite grout was produced from well KPW-1A. LC ISR initiated remedial activities on KPW-1A. In addition, a completion assessment of all other KM Horizon wells in the 5-Spot area was performed prior to beginning testing activities.

Extraction testing conducted in the KM Horizon indicated varying degrees of hydraulic communication between the two underlying L and M Horizons of the composite KLM Horizon, confirming that the entire composite KLM Horizon is hydraulically connected.

Drawdown responses in the overlying HJ Horizon and deeper N Horizon during the extraction test were minor (an order of magnitude lower than responses observed in the composite KLM Horizon). LC ISR has aggressively pursued the re-plugging and abandonment of historic wells, and therefore cross-horizon communication through improperly abandoned wells is considered to be relatively unlikely.

Based on hydrologic testing results to date, it is anticipated that 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.

Based on the minimal responses observed in the underlying L and M Horizons and overlying HJ Horizon and deeper N Horizon during the Injection/Extraction portion of testing conducted with no bleed, it is anticipated that commercial scale production operations in Resource Area 3 *with typical bleed* will have little if any impact on the overlying and underlying horizons.

D6.3 Groundwater Use

Table D6-12c is an updated list (April 2014) of the permits issued by the WSEO to LC ISR, LLC or its affiliates (Ur-E and NFU Wyoming, LLC). At this time, there are 207 groundwater permits of which 10 are water supply wells, 156 are monitor wells, two are disposal wells, 15 are test wells and 22 are industrial wells associated with ISR mining activities (four permits are for well rework thus duplicates). Currently, the ISR milling operation consumes approximately 21 gallons per minute (gpm), and the well fields generate another 6 to 8 gpm.

A negligible amount of groundwater is used for seasonal drilling, well construction and development, monitoring, testing, and miscellaneous purposes related to uranium exploration.

D6.4 Groundwater Quality

This section describes the regional and local groundwater quality based on information from investigations performed within the Great Divide Basin, data presented in previous applications/reports for the Permit Area, and recent data collected in the Permit Area.

D6.4.1 Regional Groundwater Quality

This section is unchanged from **Section 2.7.3** of the approved Technical Report.

D6.4.2 Site Groundwater Quality

Water quality information for the KM and underlying horizons has been obtained from baseline and background monitoring wells since 2009.

D6.4.2.1 Groundwater Monitoring Network and Parameters

Within the Permit boundary, LC ISR, LLC installed 12 background monitoring wells in the L Horizon and sampled eight of the 12 wells for Guideline 8 parameters. The monitor well locations are shown on **Figure D6-24b** and the analytical results presented in **Table D6-15b**.

Within the Permit boundary, LC ISR, LLC installed nine background monitoring wells in the M Horizon and sampled five of the nine wells for Guideline 8 parameters. The monitor well locations are shown on **Figure D6-24b** and the analytical results presented in **Table D6-15b**.

Within the Permit boundary, LC ISR, LLC installed two new background monitoring wells in the N Horizon and sampled one well for Guideline 8 parameters. The monitor well locations are shown on **Figure D6-24b** and the Guideline 8 parameter results presented in **Table D6-15b**.

D6.4.2.2 Groundwater Quality Sampling Results

Historic Results

This section is unchanged from **Section 2.7.2** of the approved Technical Report.

Baseline Sampling

LC ISR, LLC began baseline sampling of the L, M and N Horizons in 2009. The baseline sampling round included the following locations:

- L Horizon Wells: KMU-1, KMU-2, KMU-3, KMU-4, MB-11, MB-12A, MB-14, M-L2;
- M Horizon Wells: M-M1, M-M2, M-M3, LC229W, LC606W; and
- N Horizon Well: LC33W.

Results of the LC ISR, LLC baseline monitoring program for Horizons L, M and N are compiled in **Table D6-15b**. In **Table D6-15b**, those analytical results which exceed specific WDEQ WQD or EPA criteria are bolded/highlighted, and the WQD and EPA criteria used for the comparison are included in **Table D6-15c**. The following bullets summarize the salient points gleaned from **Table D6-15b** analysis:

- The trace constituents: barium, boron, cadmium, chromium, copper, mercury, molybdenum, nickel, selenium, vanadium, and zinc were at or less than the detection limits for all samples tested.

- As with all prior monitoring results, chloride values are low; less than 10 mg/L and typically 5 mg/L or less.

- The pH laboratory measures exceeded the WDEQ Class I Standard and EPA MCL Secondary Standard (6.5 – 8.5) in seven of the eight L monitoring wells, and in two of the three M monitoring wells. Where the pH standard was exceed, the values ranged from 8.5 to 9.5.

- The distribution of Total Dissolved Solids (TDS) (averaged from the four sampling events) is shown on **Figure D6-26c**. None of the individual TDS analytical results exceeded the WDEQ Class I Standard or EPA MCL.

- The distribution of sulfate, averaged from June 2009 to December 2012, is shown on **Figure D6-26d**. None of the individual sulfate analytical results exceeded the WDEQ Class I Standard or EPA MCL.

- With the exception of one L monitor well (MB-12A), none of the monitoring wells exceeded the EPA uranium MCL of 0.03 mg/L in any quarter. The average distribution of uranium at individual wells from June 2009 to December 2012 is shown on **Figure D6-28c**.

- The average distribution of radium-226+228 is shown on **Figure D6-28d**. The WDEQ Class I Standard and EPA MCL for radium-226+228 is 5.0 pCi/L. **Table D6-15b** identifies those wells in each Horizon that exceed the radium-226+228 EPA MCL.

Piper diagrams were developed to compare groundwater quality between individual wells (**Figure D6-27c**) and between different Horizons (**Figure D6-27d**). The individual well comparison plots the average value for each of the wells for all of the samples analyzed. The piper diagram comparing different aquifers represents the average water quality for all wells sampled within individual Horizons (L, M and N). Groundwater within the shallow Battle Springs aquifers/Horizons beneath the Permit Area is a calcium-sulfate to calcium-bicarbonate type water. There is some variability in water chemistry when the wells are compared individually, but not much (LC606W being the exception).

Summary of Site Groundwater Quality

General water quality in the L, M, and N Horizon monitor wells, located within the Permit Area, tends to be relatively good, with the exception of the presence of radionuclides. TDS and sulfate values are all less than the WDEQ Class I standards. Laboratory pH measurements exceeded the WDEQ Class I Standard and EPA MCL Secondary Standard in 82 percent of the monitor wells sampled. Radium-226+228 exceeds the EPA MCL in approximately 60 percent of the samples collected (**Table D6-16b**) from the M and N Horizons. An elevated concentration of these constituents is consistent with the presence of uranium orebodies.

D6.5 Hydrologic Conceptual Model

This section is unchanged from **Section 2.7.4** of the approved Technical Report.

D6.5.1 Regional Groundwater Conceptual Model

This section is unchanged from **Section 2.7.4** of the approved Technical Report.

D6.5.2 Site Groundwater Conceptual Model

D6.5.2.1 Hydrostratigraphic Units

This section is unchanged from **Section 2.7.2.1** of the approved Technical Report.

D6.5.2.2 Potentiometric Surface and Hydraulic Gradients

Potentiometric surfaces for the DE, LFG, and HJ Horizons are illustrated as contour maps on **Figures 2.7-11a-f** in the approved Technical Report. 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 surface of the HJ Horizon indicates that groundwater flow across the permit area is to the west-southwest under a hydraulic gradient of 0.005 to 0.006 ft/ft (15.8 to 31.6 ft/mi), generally consistent with the regional flow system. The Lost Creek Fault acts as a hydraulic barrier to groundwater flow as demonstrated from water level differences of 15 feet across the Fault within the HJ Horizon and the pump test results. However, the Fault does not appear to strongly affect either the direction of flow or the hydraulic gradient within the HJ Horizon. **Figure 2.7-11d** in the approved Technical Report shows that the groundwater flow direction across the permit area, based on the potentiometric surface, is toward the west southwest on both sides of the Fault. The reason for the minimal impact of the Fault on groundwater flow direction within the permit area is because the Fault is only present across a small portion of the permit area, dying out to the east-northeast and west-southwest. The hydraulic gradient north of the Fault is approximately 0.005 ft/ft whereas on the south side of the Fault the hydraulic gradient is approximately 0.006 ft/ft. The pump tests indicate minor leakage of groundwater across the Fault when large head differences exist within the HJ aquifer across the Fault.

Groundwater flow direction and hydraulic gradients for the overlying (DE and FG) and underlying aquifers (UKM) are generally similar to that of the HJ Horizon. Groundwater flow on both sides of the Lost Creek Fault is toward the west-southwest at hydraulic gradients between 0.005 ft/ft to 0.007 ft/ft as shown in the potentiometric maps for the DE, LFG and HJ Horizons. The potentiometric heads decrease with depth. Differences in water level elevations between the LFG, HJ and UKM aquifers indicate that confining units are present between these hydrostratigraphic units.

Pump tests indicate the presence of confining units between the LFG and HJ aquifers and between the HJ and UKM aquifers, although some minor hydraulic communication exists between those units. The hydraulic communication only becomes apparent when large stresses (head differences) are applied to the aquifers through pumping.

Vertical hydraulic gradients range from -0.020 to 0.37 ft/ft between the LFG, HJ and UKM aquifers and consistently indicate decreasing hydraulic head with depth. The vertical gradients indicate the potential for groundwater flow is predominately downward. The vertical gradients also support the confining nature of the Lost Creek and Sagebrush Shale. The vertical gradient between the DE and LFG aquifers is minimal, consistent with observations that those hydrostratigraphic units coalesce in places within the Permit Area. An exception to this occurs in the eastern portion of the site where the vertical gradient between the DE and LFG aquifers is 0.28, indicating a strong downward potential.

Potentiometric surfaces for the L and M Horizons are illustrated as contour maps on **Figures D6-11i** and **D6-11j** and also on Cross Sections in **Plates D5-2a to D5-2h**. 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. The Figures and Plates show that the hydraulic gradient and groundwater flow direction across the permit area are similar to that seen in the overlying KM and HJ Horizons as discussed in **Section D6.2.2.2**.

A downward gradient to successively deeper Horizons (KM to L, L to M, and M to N) is consistent with the structural and stratigraphic location of the Project within the Great Divide Basin.

D6.5.2.3 Aquifer Properties

Transmissivity values for the HJ Horizon range from 35 to 400 ft^2/d (260 to 3,000 gpd/ft). Based on long-term pump test results, the estimated "effective" transmissivity (because of the impacts of the Lost Creek Fault) is 60 to 80 ft^2/d (450 to 600 gpd/ft) on both sides of the Fault. Because of the boundary effect of the Fault (e.g., the system is not an infinite-acting aquifer), the actual transmissivity of the aquifer, without impacts from the Fault, would be higher. Using the effective transmissivity and an average thickness of 120 feet, the "effective" hydraulic conductivity of the HJ Horizon is in the range of 0.5 to 0.67 ft/d. The actual hydraulic conductivity of the aquifer is probably between one and 1.5 ft/d. Storativity of the HJ Horizon ranges from 5.0 x 10^{-5} to 5.0 x 10^{-4}.

Based on more limited testing, the transmissivity of the LFG aquifer is lower than for the HJ Horizon ranging from 4.4 to 40 ft^2/d (30 to 300 gpd/ft). The range of transmissivity of the UKM aquifer is similar to but slightly lower than the HJ aquifer, ranging from 26 to 115 ft^2/d (195 to 860 gpd/ft). Transmissivity of the DE Horizon is variable, ranging from 1.3 to 130 ft^2/d (10 to 1,000 gpd/ft). Storativity values have not been determined for the overlying aquifer at this time because no multi-well pump tests have been conducted within that Horizon. However, it is expected that storativity values in the FG Horizon will be similar to the range observed in the HJ Horizon. The DE Horizon is at least partially under *unconfined* conditions and therefore will have a specific yield instead of a storage coefficient. As discussed in the previous section, the long-term, multi-well pump tests performed in the fall of 2007 provided data on the degree of connection between the overlying and underlying aquifers relative to the HJ Horizon.

Between 2007 and 2012, six additional pump tests were performed in the KM Horizon as discussed in **Section D6.2.2.3**. The pump test locations are shown on **Figure D6-13b**, the aquifer properties summarized in **Table D6-11**, and individual transmissivity values presented on **Figure D6-17b**.

Transmissivity values for the KM Horizon range from 26 to 224 ft^2/d (195 to 1,675 gpd/ft). As shown in **Table D6-11**, transmissivity is slightly variable north and south of the Lost Creek Fault, but the storativity is rather consistent at about 1.2 x 10^{-4}.

D6.5.2.4 Water Quality

Water quality within the hydrostratigraphic units of interest (the production zones and overlying and underlying aquifers) is generally good with respect to major chemistry. TDS and sulfate levels are typically less than their respective WDEQ Class I Standards and EPA SDWS, although occasionally, regulatory standards are exceeded. Chloride levels are low, (typically less than 10 mg/L) making this parameter a good indicator for excursion monitoring.

Trace metal concentrations are generally less than their WDEQ Class I Standards and EPA MCLs in the production zone and underlying aquifers. Exceptions include aluminum and iron. Aluminum concentrations exceeded EPA Secondary Drinking Water criteria (0.05 to 0.2 mg/L) in four L Horizon wells. Total iron concentrations exceeded the WDEQ Class I Standard (0.3 mg/L) in two L Horizon wells. Iron concentrations also exceeded the EPA's Secondary Drinking Water Standard (0.03 mg/L) in five L Horizon wells and three M/N Horizon wells. Lab pH measurements exceeded the WDEQ Class I/II Standards and the EPA Secondary Standard in nine different monitor wells.

Table D6-15b shows that uranium is present in all wells, but only one monitor well contained concentrations that exceed the EPA MCL of 0.03 mg/L. Radium-226+228 levels exceed the EPA MCL and WDEQ Class I Standard (5.0 pCi/L) in six L Horizon wells, three M Horizon wells and one N Horizon well. Dissolved radionuclide levels are commonly elevated in groundwater associated with uranium-bearing sandstones.

D6.5.2.5 Summary

The uranium bearing sandstones within the upper Battle Spring Formation appear to be suitable targets for ISR operations. The proposed production zone aquifer (KM Horizon) is bounded by a laterally extensive upper confining unit, as demonstrated by static water level differences and responses to pump tests. The L Horizon represents the underlying horizon to the KM production orebody. The hydrogeological relationship of the L, M, and N Horizons to the KM remains under investigation. However, based on previous "Regional" and "Permit Area" scale pump test results, there is demonstrated hydrogeologic communication between the KM Horizon and the underlying Horizons. The degree of communication diminishes with depth.

Future "Mine Unit" scale pump tests results combined with site specific geologic and hydrologic data, will be utilized to determine the appropriate operations monitoring scheme for each planned Mine Unit.

Aquifer properties (transmissivity, hydraulic conductivity and storativity) are within the ranges observed at other ISR operations that have successfully extracted uranium reserves. Water quality is generally consistent throughout the hydrostratigraphic units of interest. Elevated radionuclides are present in the groundwater, but this is consistent with the presence of uranium ore deposits within the sandstones. The Lost Creek Fault acts as a hydraulic barrier to groundwater flow and will need to be accounted for in mine unit design and operation.