3.0 Description of Proposed Facilities and Operations

Section Summary: This section describes various components of the project relative to operating characteristics including the ore bodies, mine units, and the injection/extraction circuits. The project sites under the Source and Byproduct Materials License SUA-1548 are described in Section 3.2.

Section 3.3 provides a description of the ore bodies at Smith Ranch and the North Butte, Gas Hills and Ruth Remo te Satellites. The Smith Ranch ore body description remains largely unchanged except that the reserve estimates have been revised to include Highland and Reynolds Ranch satellite facilities. Section 3.3.1.3 includes an updated schedule of mine unit development at Smith Ranch. The orebody descriptions have also been updated for the North Butte, Gas Hills and Ruth Remote Satellite facilities.

Section 3.4 provides an updated discussion related to geologic and hydrologic assessments of mine unit wellfields, including a commitment to provide the hydrologic testing packages to NRC for review. Section 3.4.3 discusses how potentially leaking old exploration drill holes will be located and sealed, if needed.

Section 3.5 discusses mine unit design, construction and operations and revisions, as follows:

- Section 3.5.1.1: Seven-spot and line-drive pattern descriptions have been added.
- Section 3.5.1.2: Monitoring well spacing and placement, unchanged.
- Section 3.5.2.3: Basic well completion techniques described for well installation have been modified slightly to account for improvements such as centralizer spacing and changes to well bore annulus requirements.
- Sections 3.5.2.4, 3.5.2.5 and 3.5.2.6: Alternative completion methods and well recompletion techniques employed for production and injection wells.
- Sections 3.5.2.6 and 3.5.2.7: Drill hole site preparation and hole abandonment have been revised to be consistent with State of Wyoming requirements.
- Section 3.5.2.8: Abandoned drill hole count has been updated.
- Section 3.5.2.9: Provides the Cameco well stimulation (well workover) program.
- Section 3.5.3.8: Special operational considerations for the Gas Hills Remote Satellite wellfields.

Section 3.6 provides the facility layout, equipment, processing circuit and wastewater management for Smith Ranch (including Highland and Reynolds Ranch) as well as the North Butte, Gas Hills and Ruth Remote Satellites.

- Section 3.6.1: References new figures and maps for the Smith Ranch main office, CPP and Highland CPF.
- Section 3.6.1.5: Describes the treatment of waste water at Smith Ranch including information regarding the new Class I UIC deep disposal wells installed since the last renewal.
- Section 3.6.1.6: Provides improvement to instrumentation and controls in header houses since the last renewal.
- Section 3.6.2: Provides updates to the Smith Ranch satellite facilities incorporating new and proposed satellite facilities in addition to new floor plan figures and maps for the facilities.
- Section 3.6.2.3: Provides information concerning Selenium Treatment Facility.

- Sections 3.6.3: Provides information on the North Butte Remote Satellite.
- Sections 3.6.4: Provides information on the Gas Hills Remote Satellite
- Sections 3.6.5: Provides information on the Ruth Remote Satellite

Section 3.7 discusses access roads; includes the addition of the roads at the remote satellite facilities.

A new section describing construction quality assurance is found in Section 3.8.6.

Section 3.9 discusses the updated project schedules and water balance for Smith Ranch and each of the remote satellite facilities.

Section 3.10 discusses potential impacts of operations on surrounding waters, primarily spills and excursions.

- Section 3.10.1.1 contains a summary of spills and releases.
- Section 3.10.1.2 provides an evaluation of the potential impact from spills.
- Section 3.10.1.3 provides an updated spill history section.
- Section 3.10.2 includes information regarding excursions by mine unit and corrective actions.
- Section 3.10.3 provides an updated discussion related to leakage at the lined ponds and the purge storage reservoirs.

3.1 Background

Since purchasing the Smith Ranch properties from RAMC in 2002, Cameco has operated Smith Ranch and the Highland Uranium Project (Highland) as one integrated property. Shortly after the acquisition, Cameco combined and consolidated the facilities and work force and relocated staff to the Smith Ranch facilities. The Highland CPF was placed on standby status in 2003 and has not processed uranium since that time. Cameco plans to refurbish the CPF[1] during the next renewal period and operate it again as an IX resin and yellowcake processing facility.

In March 2003, Cameco requested an amendment from NRC to combine the Highland Source and Byproduct Materials License (SUA-1511), the North Butte license (SUA-1540), the Ruth license (SUA-1539), and the Gas Hills license with the Smith Ranch license SUA-1548. On August 18, 2003, NRC issued Amendment No. 5 to SUA-1548 reflecting the consolidation of the licenses and establishing the Smith Ranch CPP complex as the main processing facility with Highland, North Butte and Ruth properties as satellite facilities. NRC Staff did not approve the inclusion of Gas Hills with this amendment, as their review of the 1998 request to amend the Gas Hills as a satellite to Highland had not yet been completed. Gas Hills was subsequently amended into SUA-1548 with Amendment No. 6 dated January 29, 2004.

In December 2004, Cameco requested an amendment to SUA-1548 to add the Reynolds Ranch satellite area. Reynolds Ranch is north of and contiguous with the Smith Ranch portion of the Smith Ranch Project (SUA-1548). The amendment would allow the construction of an additional IX satellite facility and mine units. NRC approved the request through Amendment No. 11 to SUA-1548 on January 31, 2007. WDEQ approval of the Reynolds Ranch amendment is still pending as of January 2012.[2]

---

[1] The CPF was 95% refurbished during 2013 but is currently (2014) not operating.

[2] The WDEQ approved the Reynolds Ranch Satellite with the approval of the Smith Ranch-Highland combination amendment in March 2014.

Future operations under the Source and Byproduct Materials License SUA-1548 will consist of continued mine unit installation and operation at Smith Ranch and Highland production areas **as** well as expansion to Smith Ranch (Reynolds Ranch) and the remote satellite areas North Butte, Gas Hills and Ruth. The development schedule is discussed in more detail later in this section.

The major components of the Smith Ranch Project (SUA-1548) are:

- The orebody at Smith Ranch, Highland, Reynolds Ranch Satellite, North Butte Remote Satellite, Gas Hills Remote Satellite, and Ruth Remote Satellite;
- The mine units;
- The lixiviant injection circuit;
- The uranium extraction circuit;
- Uranium precipitation, drying and packaging at the Smith Ranch CPP (and in the future at the Highland CPF);
- Wastewater management systems; and
- Aquifer restoration, decommissioning and surface reclamation.

Descriptions and operating characteristics of these components and processes are provided in detail in the following subsections. Wastewater management systems and aquifer restoration/surface reclamation are described in detail in Sections 4.0 and 6.0, respectively.

3.2 Site Description and Facilities Layout

3.2.1 Smith Ranch

The main office complex and the CPP are approximately 35 kilometers (22 miles) northeast of the town of Glenrock and 40 kilometers (25 miles) northwest of Douglas (see **Figure 1.3**). **Figure 1.3** also shows the general project location, access to the Smith Ranch license area, the location of process areas including satellite buildings, mine units, pipelines, impoundments, major roads, and the main office complex. As of January 2012, five satellite facilities and two processing plants are currently located at Smith Ranch. As discussed in Section 3.6.2, an additional satellite and associated wellfields are planned for the Reynolds Ranch area**.** **Figures 1.4** through **1.8** provide greater detail of the mining areas depicted on **Figure 1.3**. The Highland main office and CPF complex is located in the NE/NW Section 29, T36N, R72W.

The Reynolds Ranch Satellite (shown on **Figure 1.9**), when constructed, will be located in the SE1/4, Section 35, T37N, R74W. The building will occupy approximately 2,044 meters^2 (22,000 feet^2). The satellite will serve all mine units planned for the Reynolds Ranch Satellite area. The satellite will be designed with a maximum through-flow of 22,709 liters/minute (6,000 gallons/minute) during production operations. The original license amendment for Reynolds Ranch specified a maximum flow rate of 17,032 liters/minute (4,500 gallons/minute) and Cameco requests that the maximum flow rate be increased to 22,709 liters/minute (6,000 gallons/minute) through this LRA. The satellite equipment will include 3,785 liters/minute (1,000 gallons/minute) of final installed reverse osmosis (RO) capacity for groundwater restoration purposes. The RO capacity will be installed incrementally throughout the life of the operation as production increases and in accordance with the water balance estimates.

3.2.2 North Butte Remote Satellite

The North Butte Remote Satellite facility is located in southwest Campbell County, Wyoming. The site is approximately 80 kilometers (50 miles) from the City of Gillette and 64 kilometers (40 miles) from the

Town of Wright. The permit area contains approximately 410 hectares (1,015 acres) and includes portions of Sections 18 and 19 in T44N, R75W and Sections 13, 23, 24 and 25 in T44N, R76W.

The surface facilities at the North Butte Remote Satellite will include the mine units, header houses, buried pipelines, overhead and buried power lines, access roads, laydown yard, surge ponds, Class I UIC disposal wells, and the satellite IX building. The locations of the satellite building and associated facilities are shown on **Figure 1.10**. The satellite building will house IX columns, water treatment equipment, resin transfer facilities, pumps for injection of lixiviant, disposal well equipment, RO units and bioremediation materials for groundwater restoration, a laboratory area, offices, and an employee break room. **Figure 3.1, North Butte Remote Satellite Floor Plan** shows the equipment layout for the proposed satellite building. The building will occupy approximately 2,378 meters^2 (25,600 feet^2) and will be designed to operate with a maximum flow of 22,709 liters/minute (6,000 gallons/minute) during operations. The original license amendment for North Butte specified a maximum flow rate of 15,139 liters/minute (4,000 gallons/minute) and Cameco requests that the maximum flow rate be increased to 22,709 liters/minute (6,000 gallons/minute) through this LRA. The original plant design in the license amendment had a smaller building dimension than stated above (see Change No. 6, NRC Application, Page 1-6, Section 1.4.2 dated March 27, 1992).

The North Butte uranium orebody has been divided into five proposed mine units (**Figure 3.4)**. Preliminary geologic and hydrologic information has been developed by Uranerz and PMC and is presented in Appendices D5 and D6 of the North Butte WDEQ permit which accompany this LRA. Detailed geologic and hydrologic information of the individual mine units such as isopach maps, potentiometric surface maps and monitor well locations will be submitted as part of each mine unit hydrologic testing package.

3.2.3 Gas Hills Remote Satellite

As shown on **Figure 1.1**, the Gas Hills Remote Satellite is located in Fremont and Natrona Counties, approximately 105 kilometers (65 miles) due west of Casper. The permit area contains approximately 3,440 hectares (8,500 acres) and includes: Sections 1, 2 and 11 and portions of Sections 3, 10 and 12 in T32N, R90W (Fremont County); Sections 21, 22, 27, 28, 29, 32 and 33 and portions of Sections 31 and 34, T33N, R89W (Fremont County); and a portion of Section 6, T32N, R89W (Natrona County). The general layout of the proposed project site, including the five mine units and the surface facilities, is shown on **Figure 1.11** and **Figure 1.12**.

The surface facilities at Gas Hills will include the mine units, header houses, buried pipelines, overhead and buried power lines, access roads, evaporation ponds, and the satellite IX buildings. The locations of the satellite facilities and evaporation ponds are shown on **Figure 1.11**. The current plan is for the main office, one of the IX facilities and main water treatment facility to be located in the existing Carol Shop. No additional surface disturbance at the Carol Shop is anticipated to accommodate the planned operational and parking facilities. Depending on the interior condition of the Carol Shop, a new process/administration building may be necessary. This building would be constructed on previously disturbed land within the Carol Shop complex. The satellite buildings will house IX columns, water treatment equipment, resin transfer facilities, pumps for injection of lixiviant, disposal well equipment, RO units and bioremediation materials for groundwater restoration, a laboratory area, offices, and an employee break room. An additional satellite may be constructed at one of the two locations shown on **Figure 1.12** and will disturb approximately 1 hectare (2 acres), including parking and ancillary facilities. **Figure 3.2, Gas Hills Remote Satellite Carol Shop Floor Plan** shows the equipment layout for the Carol Shop satellite building. The process equipment in the Carol Shop building will occupy only a portion of the building and will be designed to operate with a maximum flow of 51,095 liters/minute (13,500 gallons/minute). However, the current plans are to operate the Carol Shop at only 34,063 liters/minute

(9,000 gallons/minute), with the remaining flow capacity of 17,032 liters/minute (4,500 gallons/minute) being provided by the proposed additional satellite facility described below.

An additional alternative remote satellite facility at Gas Hills may be installed as a remote IX, resin loading and unloading facility, and future restoration RO at one of the two locations shown on **Figure 1.12**. Bleed and restoration reject fluids from the associated wellfields will be transferred through pipelines to the central water treatment facility at the Carol Shop for treatment and disposal. The layout for the satellite is shown on **Figure 3.3, Gas Hills Remote Satellite Alternative Satellite Floor Plan**.

3.2.4 Ruth Remote Satellite

The Ruth Remote Satellite facility is located in southeast Johnson County, Wyoming, about 84 air kilometers (52 miles) north of Casper (**Figure 1.1**). The facility is about 21 air kilometers (13 miles) southwest of the North Butte Remote Satellite. The Ruth Remote Satellite includes portions of Sections 13, 14, 23, 24, 25, and 26 of T42N, R77W. The Ruth site has approximately 572 hectares (1,414 acres). Remaining facilities at the Ruth site are in a non-operational status. Currently, three buildings (process building, generator building, and warehouse), two evaporation ponds, and three monitoring wells remain on the property. An abandoned wellfield (0.3 hectares or 0.8 acres) and two topsoil storage areas also remain on the site. Topsoil Storage Pile #1 contains 13,587 meters^3 (17,771 yards^3) and Topsoil Storage Pile #2 contains 2,356 meters^3 (3,081 yards^3). Cameco does not plan to extract uranium at Ruth within the next 10 years, and an operations plan that details the mine unit wellfield layout, elution circuit, and other process details has yet to be developed. The license area for the Ruth Remote Satellite is shown on **Figure 1.13**.

3.3 Description of the Orebodies

3.3.1 Smith Ranch

3.3.1.1 Smith Ranch Orebody

The uranium ore deposits at Smith Ranch occur at depths of 61 to 366 meters (200 to 1,200 feet) below surface. The ore is hosted in fluvial, arkosic sandstones of the Paleocene Fort Union and Eocene Wasatch Formations. The Fort Union and Wasatch Formations are locally separated by a laterally continuous coal seam known as the School Coal. Individual host sand units have been correlated and named and are separated by semi-continuous, confining layers usually composed of shale or claystone. Faulting in these Tertiary sediments is rare.

The two most common uranium ore minerals are UO_2 and coffinite $[U(SiO4)_{1-X}(OH)_{4X})$, which occur as precipitated coatings on sand grains. These minerals both contain uranium in the +4 valence (or reduced) state. The chemical reduction of the uranium during ore emplacement is accomplished by the interaction of the oxidized ore-bearing groundwater with organic carbon and pyrite that were naturally present within the sandstones near these redox boundaries.

3.3.1.2 Smith Ranch Reserve Estimates

Smith Ranch currently has 18 mine units in a production, pre-restoration or restoration phase. For 2010, Cameco produced 817 metric tons (901 tons) of U_3O_8. The following table provides the official reserve and resource numbers (metric tons) reported by Cameco in 2010 for Smith Ranch and the associated satellites (Highland and Reynolds Ranch).

Proven Reserves	Probable Reserves	Measured Reserves	Indicated Resources	Inferred Resources
1,415 (1,560)	2,224 (2,452)	2,235 (2,464)	8,005 (8,824)	2,976 (3,280)
All units are in metric tons with tons given in parentheses.				

During the installation of each mine unit, it is very likely that the reserves will be slightly changed based on the results of final delineation drilling and pilot hole drilling for the mine unit pattern areas. The final outlines of the mine units will depend on the reserves encountered during the delineation drilling of each mine unit.

3.3.1.3 Smith Ranch Mine Unit Locations

Table 3-1, Mine Unit Development Schedule, lists current and proposed mine units for Smith Ranch, their status, and the proposed production sequence for the mine units as of January 2012. The CPP IX facility currently serves Mine Units 1, 2, 3 and 15/15A. Satellite 2 serves Mine Units C, D, D-Extension, F, E, H, and I. The Satellite No. 2 facility is designed to operate with a maximum flow of 3,200 gallons/minute during production operations. As of January 2012, Mine Units C and D-Extension are undergoing groundwater restoration. Mine Units H and I are in production. Mine Unit D-Extension is out of production and is being prepared for groundwater restoration. Satellite No. 3 serves Mine Units F, J and K. Satellite 3 may also serve additional mine units that are currently being geologically evaluated for future expansion in the western portion of the original Highland license area (i.e., west of Satellite No. 3). Satellite SR-1 serves Mine Units 3, 4, 15 and 15A. SR-1 may also serve additional mine units (i.e., Mine Units 7 and 8) being evaluated for future expansion. The southwest Satellite, SR-2, serves Mine Unit 9 and will serve planned mine units in the southwest area, including Mine Units 10, 11, and 12. The Reynolds Ranch Satellite will serve Mine Units 21 through 28. Further details related to the Smith Ranch CPP and associated satellite operations are provided in Section 3.6.

Physical descriptions of proposed Mine Units 8, 12, 13, 16, 17, H Extension, I Extension and M are summarized in Table 3-1.1. The proposed mine units are located adjacent to or in close proximity to existing mine units, possess the same production zones and have closely related geologic characteristics. Production aquifer data and representative cross sections of the adjacent mine units have been incorporated into the table by reference to existing reports.

The multi-step program used to develop an individual mine unit wellfield includes the collection and assembly of detailed geologic and hydrologic characteristics of the proposed mine unit, submittals to the Wyoming Department of Environmental Quality – Land Quality Division (WDEQ – LQD), for review, and approval through the ORC/SERP process described in Section 3.4.

3.3.1.4 Smith Ranch Mine Unit Flow Rate Predictions

Flow rates for the Smith Ranch mine units were estimated during the hydrological assessment of the mine unit wellfields, and this information is provided in the Mine Unit Hydrologic Test Documents for each mine unit. A Hydrologic Test Proposal will be developed for each of the Reynolds Ranch Satellite mine units and submitted to LQD for approval and NRC for review. The hydrologic testing program will be completed and the results presented along with final mine unit development plans, monitoring requirements, and baseline groundwater quality determinations in the Mine Unit Hydrologic Test Document.

3.3.2 North Butte Remote Satellite

The North Butte Remote Satellite and associated mine units will be operated as a remote satellite IX uranium extraction facility. Only IX uranium recovery, bleed treatment, groundwater restoration, and disposal activities will occur at the North Butte Remote Satellite. Proposed facilities are described in more detail in subsequent sections. The proposed mine plan for the North Butte orebody is to extract the economically recoverable uranium from approximately five mine units, beginning with Mine Unit #1. The license area and facilities layout are shown on **Figure 1.10**.

3.3.2.1 North Butte Orebody

The uranium mineralization is present as coffinite, a black uraniferous silicate mineral. The host sandstones are composed of quartz, feldspars, and rock fragments with locally occurring carbon fragments. Grain size ranges from very fine-grained to small granules. The sandstone is weakly to moderately cemented and friable. Pyrite and calcite cement are occasionally observed. The uranium is deposited on individual detrital sand grains or on and within authigenic clays in the interstices. The interstitial clays present are primarily montmorillonite with lesser amounts of kaolinite and smectite. Hematite is a common oxidation product of pyrite within the host rock, along with minor limonite. Accessory biotite and muscovite are also present.

In 2010, Cameco conducted a detailed mineralogical study on two North Butte cores at the Cameco Research Center at Port Hope, Ontario. The new mineralogical studies confirmed that the predominant mineral in the formation is coffinite.

Mineralogical characterization of the North Butte ore was done using bulk energy dispersive X-ray analysis (EDX), X-ray diffractometry (XRD) and microscopy of polished sections of unbroken ore pieces, and porosimeter measurements. The XRD results indicated that quartz, albite, the K-feldspars microcline and orthoclase as well as the phyllosilicates chlorite and muscovite/illite are the primary gangue minerals. XRD results confirmed the arkosic nature of the sandstone.

The Scanning Electron Microscope/EDX work showed the trace mineral content to be highly variable. The occurrence of unoxidized heavy minerals such as ilmenite and magnetite as well as leucoxene and limonite indicates that, overall, the sandstone was not strongly affected by weathering and diagenetic alteration. This conclusion is also supported by the relatively high amount of unaltered feldspar in the rock and some delamination and alteration of micas. Trace amounts of elemental selenium and ferroselite were identified as selenium-bearing minerals, and in one sample, trace amounts of nickel-arsenic-bearing pyrite were identified.

Thorium minerals were present in both drill cores and may have influenced some of the radiometric drill hole logging data. The uranium mineralization is fine grained and predominantly within the sandstone matrix. It often forms coatings on the sandstone detritus above or below layers of clay minerals that appear to be chlorite to montmorillonite in composition. Other than clay and regular detritus, uranium mineralization was also associated with iron-titanium minerals, pyrite, zircon, calcite and carbonaceous material. The predominant uranium mineralization is coffinite associated with tyuyamunite with a minor component of uraninite associated with tyuyamunite.

3.3.2.2 North Butte Reserve Estimates

The North Butte Remote Satellite has five proposed mine units. Each mine unit will contain reserves ranging from 455 to 817 metric tons (502 to 901 tons) of uranium. The following table provides the official reserve and resource numbers (metric tons) reported by Cameco in 2010 for North Butte.

Proven Reserves	Probable Reserves	Measured Reserves	Indicated Resources	Inferred Resources
0	3,723 (4,104)	620 (683)	2,714 (2,992)	408 (450)
All units are in metric tons with tons given in parentheses.				

During the installation of each mine unit, it is very likely that the reserves will be slightly changed based on the results of final delineation drilling and pilot hole drilling for the mine unit pattern areas. The final outlines of the mine units will depend on the reserves encountered during the delineation drilling of each mine unit.

3.3.2.3 North Butte Mine Unit Locations

Detailed information on the individual mine units will be submitted in each mine unit hydrologic testing package. Approximate mine unit locations are shown on **Figure 3.4, Smith Ranch Mine Unit Location Map** and the site layout map, **Figure 1.10**. **Figure 3.5, North Butte Mine Unit 1 Location Map,** shows the configuration of Mine Unit 1. As additional mine unit delineation drilling occurs, the shape and configuration of these mine units may change to some degree.

3.3.2.4 North Butte Mine Unit Flow Rate Predictions

In 1992, Hydro-Engineering Inc. modelled wellfield groundwater flow for the then proposed Mine Unit 1 to simulate anticipated wellfield pattern configurations at various bleed and well flow rates to determine whether flow paths would cross the original permit boundary. This study is provided in **Appendix B, North Butte Wellfield Modeling Study**. The model simulations indicate that solution containment within the original permit boundary is possible with the planned operational bleed rate of approximately 1%, with the specific mine unit pattern configuration used in the study (injection/production wells located as close as 37 meters (120 feet) from the license boundary). A bleed rate of 0.5 to 1.5% was also used in the model prediction to produce a larger buffer zone between the patterns and the license boundary. This is due to the aquifer properties of the "B" Sand in the area of proposed Mine Unit 1 and the fact that the license boundary in the area of interest is upgradient from the proposed mine unit pattern activity. A cumulative impact analysis has been performed for the North Butte Remote Satellite to predict potential drawdown effects from other operations in the area as well as effects of North Butte operations on other groundwater users in the area. This analysis is discussed in Section 4.4 of the ER.

Because the exact mine unit pattern configuration is not presently known and will not be known until delineation drilling is completed, the simulations will be re-run after the mine unit planning has been completed to confirm and assure that normal bleed rates will, in fact, contain the lixiviant within the production pattern areas during the production phase. This simulation will be included with the mine unit hydrologic data package for Mine Unit 1, which will be submitted to LQD for approval and NRC for review.

3.3.3 Gas Hills Remote Satellite

The Gas Hills Remote Satellite and associated mine units will be operated as an IX uranium recovery and yellowcake slurry production facility. Loaded IX resin and yellowcake slurry will be transported in DOT-approved containers to either the CPP or the CPF for final processing. Proposed facilities are described in more detail in subsequent sections. The proposed mine plan for the Gas Hills orebody is to extract the economically recoverable uranium from five mine units, beginning with Mine Unit 1. The five mine units correspond to the following deposits: Muskrat, Bountiful, Peach, Buss, and Pix, respectively. Cameco's goal is to extract sufficient uranium from the Gas Hills mine units to yield as much as 1,134 metric tons (1,250 tons) of yellowcake per year over a production period of 20 years or longer.

3.3.3.1 Gas Hills Orebody

The Gas Hills uranium ore deposits are found within the Puddle Springs Arkose Member of the Eocene Wind River Formation. Alluvial fans were formed when high energy bed load streams with headwaters in the Granite Mountains deposited sedimentary loads on an incised erosional surface. After deposition and burial, uranium-bearing oxidized groundwater solutions migrated down the permeable axes of the fluvial fans. Lobes of alteration spread parallel to the axes, and uranium was deposited at an oxidation-reduction interface (roll front) in a tongue-like geometry. Faulting and folding of the surface then altered the original stratigraphic relationships. The NRC Staff has reviewed this information in an amendment to SUA-1548 as it pertains to the proposed operations at the Gas Hills Remote Satellite.

The Gas Hills area is comprised of four distinct Eocene Wind River Formation alluvial fans and roll front systems. These are (from east to west): Deer Creek, Canyon Creek, Coyote Creek, and Muskrat Creek. The Gas Hills Remote Satellite production area lies within a large segment of the Canyon Creek system and the eastern margin of the Coyote Creek system. The uranium mineralization is contained in a series of Wind River Formation sand and shale units. The sand units are numbered by even increments of ten starting with the deepest sand unit designated as the 10 Sand.

The uranium orebodies within the Gas Hills Remote Satellite license area are contained within channel sandstones and conglomerates of the Wind River Formation. The orebodies, which occur as roll fronts, are typically as much as 48 meters (156 feet) thick and vary in width from a pinch out to 30 meters (100 feet). The fronts are anisotropic with the bulk of the high grade ore being contained within a few feet of the oxidation/reduction contact and the balance of the ore grading out from the contact point.

The two most common uranium ore minerals are uraninite, UO_2, and coffinite, (Frondel et al., 1967), with both minerals occurring as intimate intergrowths (Ludwig and Grauch, 1980; King and Austin, 1966; Hazen Research, 1996). These minerals both contain uranium in the 4+ valence state, which is the reduced oxidation state for uranium. The chemical reduction of the uranium during ore emplacement was accomplished by the interaction of groundwater with organic carbon and pyrite. This has resulted in an intimate association of the uranium minerals with carbon, an association which has been verified by electron microprobe analysis (Ludwig and Grauch, 1980; Hazen Research, 1996).

3.3.3.2 Gas Hills Reserve Estimates

Cameco's goal is to extract sufficient uranium from the Gas Hills Remote Satellite ore to yield as much as 1,134 metric tons (1,250 tons) of yellowcake per year over a production period of 20 years or longer. The initial annual production rate will be approximately 454 metric tons (500 tons) of yellowcake. The following table provides the official reserve and resource numbers (metric tons) reported by Cameco in 2010 for Gas Hills.

Proven Reserves	Probable Reserves	Measured Reserves	Indicated Resources	Inferred Resources
0	8,611 (9,492)	1,530 (1,687)	1,029 (1,134)	585 (645)
All units are in metric tons with tons given in parentheses.				

During the installation of each mine unit, it is very likely that the reserves will be slightly changed based on the results of final delineation drilling and pilot hole drilling for the mine unit pattern areas. The final outlines of the mine units will depend on the reserves encountered during the delineation drilling of each mine unit.

3.3.3.3 Gas Hills Mine Unit Locations

The ore deposits contained within the mine units are vertically stacked, and twinned or multiple completion well installations will be used (see Section 3.5). The Gas Hills orebody geology is complex, and in some cases uranium will be extracted from multiple vertical zones within the same production area. Therefore, each mine unit is discussed in detail below to explain the local variations in Gas Hills stratigraphy and the need for multiple well completions. The locations of the mine units are shown on **Figures 1.11** and **1.12**. The orebody hydrology is complex and has been impacted over the years by conventional mine dewatering and pit reclamation. To determine potential hydrologic problems concerning water quantity and quality, Cameco will perform mine unit hydrologic tests and evaluations prior to production in each mine unit. Should the testing and evaluation identify potential production problems due to geological or hydrological concerns, operational plans will be developed to ensure potential problems have been considered.

Mine Unit 1

Mine Unit 1 is located in the west central portion of the Gas Hills Remote Satellite license area. Uranium deposits within this mining unit are contained within what is locally called the 70 Sand. The 70 Sand is part of the Coyote Creek Fan System, within the Wind River Formation. This is a single sand layer with no identified traceable faults, and typically has several hundred feet of hydrostatic head (confined water pressure).

The 70 Sand consists of medium to very coarse grained arkosic sandstone. This sand ranges in thickness from 6 to 24 meters (20 to 80 feet), and is generally underlain and overlain by continuous claystone and siltstone beds that act as confining layers for groundwater within the unit. The upper confining unit is continuous throughout the region and ranges in thickness from 17 to 46 meters (55 to 150 feet). It separates the 70 Sand from several thin layers of discontinuous sandstones. The lower confining unit ranges in thickness from 6 to 15 meters (20 to 50 feet) and separates the 70 Sand from the 50 Sand (sand units are not necessarily continuous throughout an area, e.g., in this case, the 60 Sand is not encountered beneath the 70 Sand as anticipated).

The 70 Sand in Mine Unit 1 is separated from underlying formations by as much as 61 meters (200 feet) of Wind River Formation sediment. The underlying Pre-Tertiary units are Triassic in age. The Jasper Fault and the HBow Fault lie to the south of Mine Unit 1. There has been no previous mine development within the production area of Mine Unit 1.

Overlying the 70 Sand within the Mine Unit 1 area are the 80, 90 and 100 Sands. Since the 80-Sand is discontinuous within Mine Unit 1 and is a production target in the immediately adjacent Mine Unit 2, the 90-Sand has been designated as the overlying aquifer. Underlying the 70 Sand within Mine Unit 1 are the 60, 50, 40 and 30 Sands. For the most part, the 60 Sand is absent from the Mine Unit 1 area. Where it is present, it coalesces with the 70 Sand and does not make a good candidate for an underlying aquifer. **Therefore the 50 Sand is designated the first underlying aquifer to the production sand in Mine Unit 1.**

Mine Unit 2

Mine Unit 2 is located in the east central portion of the Gas Hills Project site. Uranium deposits contained within this mine unit are roll fronts within multiple sands (40, 50, 60, 70, and 80 Sands) which in this area are part of the Canyon Creek Fan System. Based on preliminary mine planning, a single production interval will be developed from some combination of the 40 through 80 Sands at different locations within Mine Unit 2. For example, the 40-50 Sands may be targeted at one location within the mine unit while the 70-80 Sands may be targeted at a different location. The exact sand combination and location will be determined during mine unit development drilling. Due to the complexity of the Mine Unit 2 deposit as a result of overlapping multiple ore trends contained within one or more stratigraphic horizons, well twinning or recompletions may be used. During mine unit planning and design, Cameco will evaluate the technical and economic merits for each type of well installation technique, and the most technically and economically viable plans will be developed and used during pattern development.

The proposed area of pattern development would cross two traceable faults, the Bountiful and the Uranium Point Zone (UPZ) Fault. The Bountiful Fault has a displacement of 12 to 15 meters (40 to 50 feet). The UPZ Fault has up to 15 meters (50 feet) of displacement. Prior to mine development in this area, the faults will be mapped and hydrologically tested to determine their potential impact on mining (see Section 3.5.3.8 of this TR).

The Mine Unit 2 sands consist of medium to very coarse arkosic sandstones with cobble and boulder conglomerate interbeds. The individual sandstones within this area range in thickness from a pinchout to 30 meters (100 feet). The sands are typically separated vertically by confining units of shale that can be up to 6 meters (20 feet) thick. In the planned vicinity of ore development, the confining units tend to be continuous. East of the planned development area, the shale interbeds disappear. The upper confining unit for the 70 Sand consists of siltstone and claystone. It is continuous throughout the east central portion of the site and has a thickness that ranges from 23 to 122 meters (75 to 400 feet). The confining unit below the 40 Sand is the Triassic Chugwater Formation. This formation is predominantly composed of shale and siltstone and is not considered an aquifer (i.e., it would not yield significant quantities of groundwater). The total thickness of the Chugwater Formation is about 305 meters (1,000 feet). Because the 40 Sand directly overlies the Chugwater aquitard, there is no underlying aquifer within Mine Unit 2. Between the sand layers of the Mine Unit, there are shale layers that range from 2 to 6 meters (5 to 20 feet) thick.

Previous mining has occurred in the vicinity of Mine Unit 2. The UPZ mine shaft is located on the southern edge of Mine Unit 2. Federal American Partners commenced construction of this shaft in 1979. Construction was halted in 1983, at which time, the TVA poured a concrete floor in the bottom of the shaft and allowed it to flood. At the end of construction, the shaft was 268 meters (880 feet) deep. Pump stations were installed at 76 and 151 meters (250 and 495 feet) and the shaft is concrete lined. The shaft was reclaimed in 1991 and filled with materials removed from the shaft during its construction, as well as broken concrete from the reclaimed surface facilities, and capped with concrete. Impacts of prior mining operations will be evaluated during hydrologic testing as discussed in Section 3.4.

Mine Unit 3

Mine Unit 3 is located in the western portion of the Gas Hills Remote Satellite. The uranium production zones in this mine unit are roll fronts within multiple sands (30, 40, and 50 Sand) that are part of the Coyote Creek Fan System. Based on preliminary mine planning, a single production interval will be developed from some combination of the 30 through 50 Sands at different locations within Mine Unit 3. For example, the 40-50 Sands may be targeted at one location within the mine unit while the 30-40 Sands may be targeted at a different location. The exact sand combination and location will be determined during mine unit development drilling. Due to the complexity of the Mine Unit 3 deposit as a result of overlapping multiple ore trends contained within one or more stratigraphic horizons, well twinning or recompletions may be used. During mine unit planning and design, Cameco will evaluate the technical and economic merits for each type of well installation technique, and the most technically and economically viable plans will be developed and implemented during pattern development. This orebody is a southern extension of the Pathfinder Lucky Mc open pit mine. Dewatering of the Lucky Mc open pit over the years has lowered the potentiometric surface within the northern portion of the mine unit (i.e., water levels have been reduced because water was drained from the sand unit). Because of insufficient water pressure, the upper geologic section of this unit may be excluded from development. This mining unit has two traceable faults as well as the abandoned Atlas underground mine. In order to develop this mining unit, additional mapping and hydrological testing will be required for pattern design as discussed in Section 3.4.

The 30, 40, and 50 Sands consist of medium to coarse grained arkosic sandstones. The individual sands range in thickness from a pinchout to 15 meters (50 feet). Within the planned development area, the sands are generally separated by confining claystones and siltstones that can be up to 9 meters (30 feet) thick. The 30 through 70 Sands coalesce along the northwest side of Mine Unit 3 and form a single hydrostratigraphic unit. Therefore, the 80 Sand is considered to be the overlying aquifer within Mine Unit 3.

The upper confining unit to the 70 Sand is a claystone that is continuous throughout the proposed development area. This claystone ranges from 2 to 12 meters (5 to 40 feet) in thickness. The confining unit immediately below the 30 Sand is composed of claystones and mudstones of the Wind River Formation or shales of the Pre-Tertiary Formations.

The 30-Sand within Mine Unit 3 is underlain by confining units within the Wind River Formation. Underlying these confining units are the Morrison, Cloverly, Thermopolis, Muddy, Mowry, and Frontier Formations. The Morrison, Thermopolis, and Mowry Formations are not considered to be aquifers. The Cloverly Formation, which is considered to be an aquifer, is separated from the proposed production sand by the Wind River Formation confining units. There are no aquifers within the Muddy Formation, and there is very little aquifer potential within the Frontier Formation.

The proposed development area for Mine Unit 3 would intersect the traceable PCH Fault. Hydrological testing would be performed to determine its potential impact on the proposed mining. The Peach pump test, performed in 1996, indicates a zone of higher transmissivity near the Jasper Fault. In addition, water level data collected from wells in the area indicate that the Lucky Mc Fault located north of the planned development, may represent a hydrological barrier.

The Atlas underground mine was developed in the area of Mine Unit 3 in the 1960s and was reclaimed in the 1980s. It is located in the western portion of the site. This mine developed ore in the 30, 40, and 50 Sands. Impacts of previous mining activities will be evaluated during hydrologic testing as discussed in Section 3.4.

Mine Unit 4

Mine Unit 4 is located in the eastern portion of the Gas Hills Remote Satellite license area. The uranium production targets in this mine unit are roll fronts located in the 50 through 90 Sands. These sands are part of the Canyon Creek Fan System. Based on preliminary mine planning, a single production interval will be developed from some combination of the 50 through 90 Sands at different locations within Mine Unit 4. For example, the 50-60 Sands may be targeted at one location within the mine unit while the 60-70 Sands may be targeted at a different location, etc. The exact sand combination and location will be determined during mine unit development drilling. Due to the complexity of the Mine Unit 4 deposit as a result of overlapping multiple ore trends contained within one or more stratigraphic horizons, well twinning or recompletions may be used. During mine unit planning and design, Cameco will evaluate the technical and economic merits for each type of well installation technique, and the most technically and economically viable plans will be developed and implemented during pattern development. Ongoing geologic analysis suggests the 40 Sand may also be mineralized in the southern portion of the mine unit. If enough mineralization is present, the 40 Sand will also be targeted for extraction.

The Buss open-pit mine is located in the northeastern portion of the planned development area. It was reclaimed in 1995. The mine extracted ore from the 60, 70, 80, and 90 Sands. Prior dewatering of the open pit has lowered the groundwater level surface within portions of this mining unit. Roll fronts in the higher part of the section near the open pit mine may be excluded from development because of insufficient water pressure.

The mine unit will intersect at least one known traceable fault, the Buss Fault. This fault has a vertical displacement of about 15 meters (50 feet). A hydrological testing program will be used to determine the potential impact of this fault on ISR development. The sand units of Mine Unit 4 consist of medium to very coarse grained arkosic sandstones with cobble and boulder conglomerate interbeds. The individual sandstones within this area range in thickness from 9 to 30 meters (30 to 100 feet). The sands can be separated vertically by mudstone or siltstone interbeds, which can range from absent to 5 meters (15 feet) thick. These confining units are not always continuous and frequently pinch out, allowing the sand units to coalesce.

An upper confining unit overlies the uppermost uranium-bearing sandstone (90 Sand) throughout the production area south of the Buss Fault. It has a thickness that ranges from 3 to 30 meters (10 to 100 feet). A thinner (3 to 12 meters), locally continuous confining bed overlies the 80 Sand south of the Buss Fault. The confining unit north of the Buss Fault is shale on top of the 60 Sand (the 70 and 80 Sands are generally unconfined - the top surface of the groundwater is at atmospheric pressure). The shale on top of the 60 Sand has a thickness that ranges from 3 to 6 meters (10 to 20 feet). The confining unit below the 50 Sand ranges from 1.5 to 9 meters (5 to 30 feet) in thickness and is continuous throughout the production area. This confining unit separates the 50 Sand from the underlying East Canyon Conglomerate.

Mine Unit 4 is underlain locally by a lower confining unit and over 91 meters (300 feet) of East Canyon Creek Conglomerate, which either rests on the Wind River Formation shale or unconformably overlies the Jurassic Sundance Formation.

Mining and reclamation of the Buss open pit mine has affected the overall water quality in the vicinity of Mine Unit 4. In addition, upper ore zones (80 and 90 Sands) were mined in the Two States and Blackstone Pits. An underground drift was developed south of the Two States Pit. Other open-pit mines in the area include the Cap, Bengal, and Mars Pits, which have been backfilled above the water table. Impacts of these previous operations on future mining activities in this mine unit will be evaluated during hydrologic testing, discussed in Section 3.4.

Mine Unit 5

Mine Unit 5 is located in the northeastern portion of the Gas Hills Remote Satellite license area. The mine unit is near several open-pit mines, such as the Veca mine, and several hundred acres of Abandoned Mine Land Program (AML), Umetco, and TVA reclamation. In addition, the Rox and Thunderbird underground mines, which are located within the Thunderbird Graben and within Mine Unit 5, were abandoned in the 1960s and reclaimed in the 1980s. The uranium production areas in this mine unit are roll fronts within the 50 Sand of the Canyon Creek Fan System. The 50 Sand in the vicinity of Mine Unit 5 consists of medium to very coarse grained arkosic sandstones with interbeds of cobble and boulder conglomerate. The thickness of the 50 Sands in this area ranges from 15 to 21 meters (50 to 70 feet). Because of the complexity of the sand layers in the vicinity of Mine Unit 5, and the lack of detailed geologic information, no isopach map has been prepared for the 50 Sand. Isopach maps will be prepared after additional delineation drilling has been performed and prior to submittal of a hydrologic test proposal. Ongoing geologic analysis suggests the 60 Sand may also be mineralized within the mine unit. If enough mineralization is present, the 60 Sand will also be targeted for extraction.

An upper confining unit overlies the 50 Sand throughout the Mine Unit 5 area and ranges from 5 to 12 meters (15 to 40 feet) thick. Overlying this confining unit is the 70 Sand, which is currently considered to be the overlying aquifer. The confining unit below the 50 Sand ranges in thickness from 6 to 12 meters (20 to 40 feet). This confining unit separates the 50 Sand from the underlying East Canyon Conglomerate, which is currently considered to be the underlying aquifer. The mine unit is underlain by a lower confining unit and 76 meters (250 feet) of East Canyon Conglomerate, which unconformably overlies the Jurassic Sundance Formation.

Mine Unit 5 will intersect one traceable fault, marking the southern side of the Thunderbird Graben, which is characterized by two parallel striking faults. The stratigraphic section between these two faults is downthrown by about 46 meters (150 feet).

The former Umetco Gas Hills Project facility is located on the border between Fremont and Natrona Counties, near proposed Mine Unit 5. The site, including the tailings disposal and heap leach areas, covers approximately 777 hectares (1,920 acres), of which Umetco owns 113 hectares (280 acres) and the remaining area is under the jurisdiction of the BLM (see Section 3.1.8.2 of the ER and the associated Figure 3.1.9.1 of the ER). The facility was constructed in 1959, and operations began in 1960. Heap leach activities at the site began in 1963. Mill operations were put into standby status in 1984 and later shut down in 1987. **In 2002 the NRC approved Umetco's application for Alternate Concentration Limits (ACLs) for the groundwater plume moving south toward Mine Unit 5. In 2004 the NRC approved an ACL for the Umetco mill tailings impoundment.** Reclamation was completed in 2006.

Mine Unit 5 is located near the previously mined Umetco site which exhibits poorer groundwater quality than the proposed mine unit. The Operations and Reclamation Plans in the Power Resources, Inc. dba Cameco Resources Gas Hills Permit to Mine No. 687 address baseline characterization, mine unit design, production and restoration activities in locations near previously mined areas that exhibit groundwater quality poorer than the proposed mine unit. The procedures were developed to prevent groundwater excursions or incursions during the production and groundwater restoration phases of operation and include a hydrologic evaluation of the proposed mine unit area. The procedures can be found in Operations Plan Section 5.5.3-Wellfield Setback from Mine Workings and Section 5.5.5-High TDS Groundwater Movement Assessment, and Reclamation Plan Section 2.2.2-Groundwater Restoration Strategy. Preventing an incursion from the Umetco site will factor into the wellfield design including minimum setbacks from the mine workings. The hydrologic testing plan for Mine Unit 5 will include pumping tests that monitor the sands affected by the Umetco ACL (the Western and Southwestern Flow Regimes). The sands affected by the ACL will be identified in relation to the production, overlying and underlying aquifers of Mine Unit 5 so that wellfield production and groundwater restoration activities can be designed to avoid drawing water towards or into the wellfield pattern area.

Historic open pit mining has affected water quality in the vicinity of Mine Unit 5. The Thunderbird/Rox Mine is located within the northern portion and is likely to affect operations in the area. The Mine Unit 5 hydrological testing program will address the potential impacts of previous mine development, including the potential downgradient movement of high total dissolved solid (TDS) water from the abandoned mine reclamation. The movement of high TDS water in reference to future ISR operations is further discussed in Section 3.5.3.8.

3.3.3.4 Gas Hills Mine Unit Flow Rate Predictions

To estimate the flow rates expected during production at the Gas Hills Remote Satellite, flow models have been developed and run for each of the first four mine units where there is adequate data to effectively model the hydrology. These estimated flow rates will assist with production planning and groundwater restoration programs, because they simulate the natural limits of the hydrogeologic system, which must be known to effectively plan and control the operation. Where estimated flow rates are low, due to low permeability and/or low available hydraulic head, the economics of ISR can be impacted to the point that the uranium mineralization may be unrecoverable. In addition, the estimated flow rates have been used to determine the production and groundwater restoration schedules. Therefore, the model estimates of this section are important to the overall planning of the Gas Hills Remote Satellite operations, but are still only model estimates, which will be modified as the property is developed and additional data are accumulated.

A discussion of the modeling used for the Gas Hills Remote Satellite is included as **Appendix C, Gas Hills Groundwater Modeling**. The following is a summary of the flow model results.

Simulation Method

An analytical groundwater model was used to predict maximum flow rates for the Gas Hills Remote Satellite. The model, PATH v.5.0, was developed for the ISR industry and allows the input of numerous wells and well patterns. Superposition is used to simulate the additive effects of varying flow rates from multiple wells. The final predicted flow rate is based on the available injection or production pressure, the aquifer characteristics and fluid properties, and the geometry of the patterns.

Five areas of differing geology and hydrogeologic conditions were identified for analysis: Mine Unit. 1, Mine Unit 2, Mine Unit 3 south of the Atlas Mine, Mine Unit 3 north of the Atlas Mine, and Mine Unit 4. Mine Unit 5 has not yet been adequately defined for hydrologic modeling purposes. Three geometric patterns were used to analyze each area:

1. “Single row 5 spot” - single row of connected 5-spot patterns with the injectors located on the outside and the producers located on the pattern interior.
2. “Double row 5 spot” - two connected rows of single row 5 spots. This can be extended to a block 5 spot pattern by adding rows of 5-spots.
3. “Groundwater sweep” - single or double row of production wells.

Figure 3.6, Modeled Pattern Configuration shows these three pattern configurations and **Figure 3.7, Simulation Index Map** shows the areas modeled. The aquifer and fluid properties were determined from pump test analyses and reflect reasonable estimates of the anticipated hydrogeologic conditions within each mine unit. Model sensitivity analysis supports the selection of aquifer permeability within the observed range of pump test data. The ore thickness, depth to the static water level (SWL) and the depth from the SWL to the center of the ore were obtained from the potentiometric surface map and geologic cross sections of the five analyzed areas.

The following model input data was constant for the five analyzed areas.

Porosity	0.27
Viscosity	1.0 centipoise
Compressibility	2.8 E-5
Ore thickness	6 meters (20 feet)
Spacing between like wells	24 meters (80 feet)

A discussion of the input data is included in Gas Hills WDEQ Permit Addendum OP 2.

Flow Rate Results

In each modeled area, the single row 5-spot pattern exhibited the highest flow rate, and the groundwater sweep pattern exhibited the lowest flow rate. The estimated flow rates that result in a pressure differential match for each analyzed area and pattern configurations are summarized in **Table 3-2, Gas Hills Flow Rate Estimates**. The estimated flow rates during production and groundwater restoration have been used to determine the project schedule and to design the water treatment facilities.

Achievable flow rates will be the physical limitation on both the rate of recovery and the rate of groundwater restoration possible at the Gas Hills Remote Satellite. As summarized in **Table 3-2**, maximum production flow rates for the double row 5-spot patterns are predicted to range from 34 to 76 liters/minute (9 to 20 gallons/minute) per production well, which are acceptable for economic recovery of the uranium reserves. However, because of the potential for limited static water level above the ore zone in the Gas Hills (limited static head), pumping rates during groundwater sweep--when there is no re-injection--are conservatively estimated to be 8 to 38 liters/minute (2 to 10 gallons/minute) per pumped well after one year. During the RO phase of groundwater restoration, when 75 to 95% of the produced fluids are re-injected back into the ore zone, sustainable flow rates are estimated to be from 15 to 76 liters/minute (4 to 20 gallons/minute) per pumped well. Given the available measured head information, these flow rates represent the ability of the aquifer to yield water. Additional testing will be performed in each mine unit as part of the mine unit development to further determine actual flow characteristics within each mine unit.

Mine Unit Simulations of Groundwater Flow Paths

The movement of groundwater near previous reclaimed open pit mines and underground mines was investigated to determine the impact of the mined-out areas on the proposed ISR operations to improve pattern design and to account for the hydrologic gradient. PATH V.5.0. was used to simulate flow rates and pathlines in five areas of interest at the Project (**Figure 3-7**):

1. Mine Unit 1;
2. Mine Unit 2;
3. Mine Unit 3 South, located south of the Atlas underground mine workings;
4. Mine Unit 3 North, located north of the Atlas underground mine workings and south of the PMC reclaimed pit; and
5. Mine Unit 4 near the reclaimed Buss pit.

The purpose of the simulation was to estimate injection and production rates, which will control flow at the margins of the patterns, and prevent the migration of high TDS water, associated with previously mined areas, from migrating toward the ISR operation.

Simulation Methods

The planned mine unit geometry, geology, and hydrology were used to estimate the achievable flow rates for the areas to be developed by ISR. These estimated flow rates are based on a calibration of injection and production pressures as discussed in Section 3.3.3.4. Pathlines showing the direction of groundwater flow were modeled based on (1) estimated flow rates; (2) the wellfield pattern; (3) the sand thickness, porosity and permeability; and (4) the potentiometric surface elevations.

Output from the model is displayed as pathlines of groundwater movement in two modes. The Injection Mode (forward tracking) shows the pathline of a particle of water that was injected through an injection well into the aquifer. The Extraction Mode (backward tracking) shows the pathline that a particle of water in the aquifer would travel to reach and be produced from a production well. The Injection Mode is important in tracking the flow of lixiviant to ensure that lixiviant does not migrate away from the production area. The Extraction Mode indicates the degree of dilution that can be expected during production and will be important in tracking the migration of groundwater from previously mined areas toward the mine unit area. If an initial simulation showed migration to or from an area of concern, such as a previously mined area, then the wellfield pattern and/or the injection and production rates could be adjusted to reduce the outward migration of lixiviant (flare) or the inward migration of groundwater (sweep).

Simulation Results

The estimated model input data and the results for each simulation case are summarized in **Table 3-3, Summary of Groundwater Flow Path Simulation**. A Production Plot (Injection Mode), a Production Plot (Extraction Mode), a Groundwater Sweep Plot (Extraction Mode), the input formation data for each simulation case are presented in **Table 3-3**. The model results for each mine unit indicate the following:

1. Injection and production rates can be modified to meet the site-specific hydrologic conditions such that lixiviant control is assured at the Project with the existing hydrologic conditions.
2. The 1% bleed rate, which is used in the waste water handling section of this application, will be adequate to maintain the necessary control in each mine unit which has been modeled.
3. The areal extent of the "flare" during mining has been used to model the volume of affected groundwater, which must be recovered and treated during groundwater restoration.

3.3.4 Ruth Remote Satellite

At stated in Section 3.2.4, remaining R&D facilities at the Ruth Remote Satellite are non-operational and on stand-by status. Currently, three buildings, two topsoil stockpiles, two evaporation ponds and three monitoring wells are all that remain on the property. Cameco **does not** plan to extract uranium at Ruth within the next **license period**. **Therefore**, an updated operations plan that details the extraction and production plans, including mine units, satellite layout and other details **has** yet to be developed. Cameco anticipates that the existing evaporation ponds and building structures that were used in the R&D operation will also be used in the commercial operation. The existing environmental information provided in the ER will be updated when Cameco decides to go forward with Ruth development. It is anticipated that the Ruth Remote satellite and associated mine unit(s) will be operated as a satellite IX uranium extraction facility to the Smith Ranch CPP or Highland CPF. Only IX uranium recovery, water treatment and disposal activities will occur at Ruth.

3.3.4.1 Ruth Orebody

The uranium mineralization at Ruth occurs in the Wasatch Formation. The ore “A Sand” is approximately 163 meters (535 feet) deep and generally 15 meters (50 feet) thick. The unit overlying the A Sand is called the "B Sand," and an aquitard of approximately 12 meters (40 feet) of shale exists between the A and B Sands. A thinner aquitard exists below the A Sand and above the next underlying aquifer termed the 1 Sand.

In the Ruth ore deposit, the uranium mineralization is present as amorphous uranium oxide or sooty pitchblende, with some subordinate carnotite. The host sandstones are composed of quartz, feldspars, and rock fragments with locally occurring carbon fragments. Occasional occurrences or pyrite and calcite as cementing materials can be observed. The uranium is deposited upon individual grains or upon and within authigenic clays in the interstices. The interstitial clays present are primarily montmorillonite with less amounts of kaolinite. Biotite and muscovite are also present.

3.3.4.2 Ruth Reserve Estimates

The Ruth Remote Satellite facility has three proposed mine units. The following table provides the official reserve and resource numbers (metric tons) reported by Cameco in 2010 for Ruth.

Proven Reserves	Probable Reserves	Measured Reserves	Indicated Resources	Inferred Resources
0	0	0	1,850 (564)	76 (23)
All units are in metric tons with tons given in parentheses.				

During the installation of each mine unit, it is very likely that the reserves will be revised based on the results of final delineation drilling and pilot hole drilling for the mine unit pattern areas. The uranium orebody will be divided into three mine units comprising in total about 58 hectares (142 acres). The mining units are designated as Mine Unit I (19 hectares or 47 acres), Mine Unit II (16 hectares or 41 acres) and Mine Unit III (22 hectares or 54 acres). Detailed information on the individual mine units will be submitted in each mine unit Hydrologic Testing Document.

3.3.4.3 Ruth Mine Unit Flow Rate Predictions

During the Uranerz Ruth R&D project, the groundwater flow from each production well was approximately 57 to 95 liters/minute (15 to 25 gallons/minute). The total flow rate from all of the mine units will be approximately 3,780 liters/minute (1,000 gallons/minute).

Because the exact mine unit pattern configuration is not presently known and will not be known until drilling is completed, groundwater simulations will be completed after the actual installation of wells within Mine Unit I to confirm and assure that anticipated bleed rates will, in fact, contain the lixiviant within the production pattern areas. This simulation will be included with the mine unit Hydrologic Testing Document for Mine Unit I, which will be submitted to LQD for approval and NRC for review.

3.4 Detailed Geologic and Hydrologic Assessment of Wellfields

3.4.1 General

WDEQ Permit Appendices D-5 and D-6, respectively, contain baseline geologic and hydrologic information pertaining to the Smith Ranch Project SUA-1548 facilities including Smith Ranch, North Butte, Gas Hills, and Ruth Remote Satellites. Prior to developing individual mine unit wellfields, detailed geologic and hydrologic information is collected and assembled so that pattern areas can be defined, geologic and hydrologic parameters quantified, hydrologic monitoring programs developed, and groundwater quality adequately defined in advance of production.

To accomplish the above, a multi-step program is conducted which includes submittals to LQD for review. The following sections contain a detailed description of the data that is collected for new mine unit wellfields.

3.4.2 Hydrologic Testing Proposal

Prior to installing monitor wells in a new mine unit, a Hydrologic Testing Proposal is developed and submitted to LQD for review and comment. Cameco will approve the hydrological test plan/results through the ORC/SERP process and will retain a copy onsite for NRC review. **Cameco does not currently plan to produce from unconfined aquifers. The hydrologic test is where the aquifer characteristics are identified and analyzed. Production from an unconfined aquifer will not proceed without proper analysis and a plan that is approved by LQD.**

The proposal typically contains the following:

1. A map showing the general location of the proposed production pattern areas, proposed monitor wells, and topsoil salvage locations.
2. Information supporting the proposed monitor well spacing and location for monitor wells for the mine unit.
3. Isopach maps of the proposed production zone sand, overlying confining unit and underlying confining unit.
4. Geologic cross sections and cross section location maps which show geologic conditions of the proposed mine unit. Geophysical logs used to develop the cross sections will either be shown on the cross sections or provided in an appropriate scale and format to allow direct overlay of the logs onto the cross sections.
5. Information describing proposed pump test procedures including the well(s) to be pumped and monitored, estimated pumping rate(s) and the expected duration of pumping. The primary objective of the pump test will be to demonstrate hydraulic connection between the ore zone and the “M” monitor wells and to determine the degree of isolation of the ore zone from overlying and underlying zones, the “MO” or “MS” and “MU” or “MD” monitor wells. The secondary objective will be to determine aquifer properties, including transmissivity, permeability, storage coefficient, and anisotropy. These aquifer properties can be used in hydrologic modeling to simulate production activities.
6. Wetlands information and/or mitigation plans, if applicable.

Additional objectives will be determined for each mine unit to address specific geologic and hydrologic conditions including the position and hydraulic properties of faults or discontinuities within a particular mine unit and vertically stacked ore horizons that may exist within the same exempted aquifer system. Potential impacts of past surface and underground mining and reclamation activities will be evaluated along with anticipated differences in water quality due to previous mining activities.

Following review and comment of the Mine Unit Hydrologic Testing Proposal by LQD, the pump test(s) is conducted according to the proposal. Water quality data will also be collected at this time to allow determination of the groundwater Class of Use and the calculation of Upper Control Limits (UCL) and RTV (see Sections 3.4.6 and 3.4.7 of this TR).

3.4.3 Hydrologic Testing Document

Following completion of the field data collection, data reduction and interpretation, a Hydrologic Test Document will be prepared and submitted to LQD for review and comment. Cameco will approve the hydrological test plan/results through the ORC/SERP process and will make a copy available onsite for the

NRC to review. Injection of lixiviant will not occur until the LQD has reviewed and commented on this document.

Prior to performing the mine unit hydrologic test, Cameco will have completed delineation drilling in the proposed mine unit area and will generate very detailed geological maps/cross sections within the proposed hydrologic unit test area. Using this geological information, Cameco will evaluate the presence and continuity of aquifers, aquitards, and other potential geological structure or discontinuity that could impact the hydrologic test and the proposed mine unit resource recovery plan.

The mine unit hydrologic test will be the primary tool used for determining whether there are abandoned drill holes, wells, faults, old underground and/or surface mine workings or other discontinuities which could allow hydraulic communication between the mine production zone and over or underlying aquifers. If these features are present and hydraulically connected with the test well, aquifer pump testing drawdown data should indicate either a recharge or a temporary recharge boundary condition. Once a boundary condition is identified through testing, available data (borehole location maps, geologic fault maps, etc.) will be used to identify the potential source(s) of these boundaries and then mitigate potentially adverse effects, to the extent necessary. While vertical subsurface mine workings may provide the most obvious routes of hydraulic communication between overlying and underlying units, horizontal mine workings, faults and improperly abandoned drill holes or wells also could provide hydraulic interconnection.

If the mine unit hydrologic testing indicates communication between the production zone and an adjacent aquifer, Cameco will investigate the source(s) of the leakage prior to initiating injection and take appropriate action to ensure that vertical excursions will not occur during production of the mine unit. The investigation will address subsurface geology, the presence or absence of faults, possible leaking drill holes or wells and other potential discontinuities. For example, should the pump test results show drawdown in an overlying monitor well although no natural discontinuities (such as faults, or other natural discontinuities) are known, the possibility of improperly abandoned drill holes or wells or inaccurate pump test data will be investigated. If no problems are identified with the pump test data, information from the abandoned drill hole map will be used to locate previously abandoned drill holes on the ground. Additional mini pump tests may also be performed in the area of interest to further refine the location of possible old holes. Vegetation and soil will then be stripped from the area in an effort to visually identify old abandoned drill holes in the area of the pump test anomaly. Each visually identified abandoned hole will be reentered and sealed from the bottom of the hole to the surface. During startup of injection in a new wellfield area, a visual ground survey will be performed to look for surface leakage expressions and/or significant water level changes in adjacent aquifer monitor wells. Should leakage be identified, injection will be halted until the leaking drill holes have been found and sealed. Other protective measures that could be taken to prevent vertical excursions due to hydrologic discontinuities include:

1. Installing trend wells between the edge of the mine unit and the problem area;

2. Over-recovering that portion of the mine unit with the apparent hydrologic discontinuity to ensure that the lixiviant flare does not reach the area of leakage; and/or

3. Eliminating production from the portion of the mine unit in close proximity to the point(s) of leakage.

Each Hydrologic Test Document will contain:

1. A description of the mine unit wellfield areas.
2. A map(s) showing the wellfield pattern areas and locations of monitor wells.
3. Revised geologic cross-sections and cross-section location map incorporating the new monitor well data. Geophysical logs of the monitor wells will either be shown on the cross sections or provided separately in an appropriate scale and format to allow direct overlay of the logs onto the cross sections.
4. Revised isopach maps of the production zone sand and overlying and underlying confining units using the monitor well data.
5. Discussion of how the hydrologic test(s) was performed, including well completion records.
6. Discussion of the results and conclusions of the hydrologic test(s) including raw test data, pressure (drawdown) curves and analysis, potentiometric surface maps, water level graphs, drawdown maps and, where appropriate, directional transmissivity data and graphs.
7. Information verifying that the monitor wells are placed at adequate distances and elevations to serve their intended functions.
8. Discussion of potential impacts from faulting, surface and underground mining and reclamation activities, and leaking abandoned boreholes located in or near planned production areas, including proposed actions to mitigate potential impacts.
9. Baseline groundwater quality data, calculated UCL and RTV.
10. Discussion of projected pre-restoration improvements that may be needed prior to restoration of the mine unit.
11. Other information pertinent to the tested mine unit.

3.4.4 *Baseline Water Quality Determination*

The collection of baseline water quality conditions within each mine unit is very important since the groundwater class of use/aquifer exemption, excursion UCLs and the groundwater RTVs are determined based on this baseline water quality data. Baseline water quality conditions are determined from water samples collected from wells installed in the production zone and, where present, in the overlying and underlying aquifers in accordance with accepted procedures and the guidance provided in LQD Guideline No. 4 and associated Reference Documents 4, 9 and 10, and NUREG 1569, Sections 2.7 and 5.7.8. Established procedures and methods will be used for sample collection, preservation and quality control. The types of monitor wells, their spacing and placement are discussed in Section 3.5.1.2 of this TR.

3.4.4.1 Data Collection

The general procedure for determining the baseline groundwater quality of each proposed mine unit will be as follows:

1. Water quality samples will be collected and analyzed from monitor wells utilizing accepted sampling and analytical procedures.
2. At least four samples will be collected from each MP well at least two weeks apart. The first and second sampling events will be analyzed for all parameters listed in Table 3-4, Baseline Water Quality Parameters. The third and fourth sampling events may be analyzed for a

reduced list of parameters as defined by the results of the first two sampling events (i.e., parameters not detected during the first two sampling events need not be analyzed for during the third and fourth sampling events).

3. At least four samples will be collected from each M, MT, MO and MU well at least two weeks apart. The first and second sampling events will be analyzed for all parameters listed in Table 3-4. The third and fourth sampling events may be analyzed for a reduced list of parameters as defined by the results of the first two sampling events (i.e., parameters not detected during the first two sampling events need not be analyzed for during the third and fourth sampling events).

3.4.5 *Statistical Assessment of Baseline Water Quality Data*

Baseline water quality is determined by averaging the data collected for each parameter, for each zone that is monitored, over the entire mine unit. The variability of the data is also calculated. Outliers are determined using accepted statistical methods. Values determined to be outliers are not used in the baseline calculations. If a majority of the baseline values for a well are excluded as outliers, a separate UCL will be established for that well.

Where wells are not uniformly distributed, the average may be determined by weighting the data according to the fraction of area or water volume represented by the data. Baseline conditions are determined as follows:

1. MP Wells - Data for each parameter are averaged. If the data collected for the entire mine unit indicate that waters of different underground water classes (WQD Rules and Regulations, Chapter 8) exist together, the data are not averaged together, but treated as sub-zones. Data within specific sub-zones are averaged. Boundaries of sub-zones, where required, are delineated at halfway between the sets of sampled wells which define the sub-zones.
2. M and MT Wells - Data for each parameter are averaged. As with the mineralized zone wells, if sub-zones are present which differ in underground water classes, data within the specific sub-zones are averaged separately.
3. MO Wells - Data for each parameter are averaged.
4. MU Wells - Data for each parameter are averaged.

Outliers in the baseline data are eliminated for the purpose of determining UCL using the following statistical method:

1. UCL parameter water quality data are evaluated as a group. For example, if 40 wells are sampled and analyzed three times each for chloride, all 120 chloride concentrations are pooled for calculation as a group.
2. A tolerance test (see Loftis et al., 1987) is applied in which $x = kS$, where x is the mean concentration of the group of samples, S is the standard deviation of the group, and k is the tolerance limit factor. The values for k are provided in Appendix A of LQD Guideline No. 4.
3. Concentrations outside the tolerance limits as defined by the above test are considered anomalous outliers and are eliminated from use in determining the UCL.
4. If all sample concentrations from an individual well are eliminated by the above process, discrete UCL values are determined separately for this well.

3.4.6 Upper Control Limit Determination

Monitor wells are installed within the production zone around the pattern area (M wells) and within overlying (MO) and underlying (MU) aquifers to detect vertical and lateral movement of the lixiviant from the defined production zone. The bleed (wellfield purge), in combination with production activities (pumping and injection rates), assists in keeping the lixiviant within the production zone.

The UCLs are based on the baseline water quality data and LQD Guideline No. 4, Reference Document 4 and are determined as follows:

1. Chloride UCL - baseline mean plus five standard deviations, or the baseline mean plus 15 mg/L, whichever is greater.
2. Bicarbonate or Total Alkalinity UCL - baseline mean plus five standard deviations.
3. Conductivity UCL - baseline mean plus five standard deviations.

3.4.7 Restoration Target Value Determination

As discussed earlier, MP wells are installed and sampled to determine the baseline water quality of the production zone so that RTVs can be established. As discussed in Section 6.1.2, the MP well baseline data for each mine unit are screened for outliers and averaged over the mine unit for each parameter. RTVs are established for each mine unit as the baseline mean plus two standard deviations.

3.4.8 Twinned or Recompleted Wells

Baseline groundwater quality will be established in the same manner as for single well completions. For example, if the multiple/twinned ore completions are within the “O” Sand portion of the exempted aquifer system, the “MO” and “MU” monitor wells will be completed in the same aquifers as would be done for a single well completion. The “M” wells will be located at the same surficial locations but will be completed through the entire sand interval containing the multiple/twinned completions to ensure that potential excursions during operation are detected in a timely manner. The MP wells will be completed so as to best characterize the production zone and allow them to be used as a production well during operations. This could be either dual MP wells in places or single MP wells with larger screened intervals. Excursion monitoring of “MO,” “MU,” and “M” wells will be performed in the same manner as would be done for single ore zone completions.

If baseline water quality determination is to be made for a mine unit using twinned or recompleted wells, the data will be presented to LQD with the Wellfield Data Package, including any additional monitoring that may be needed. For an example of an approved Wellfield Data Package that addresses baseline characterization in stacked ore horizons, refer to Volume III-V of Permit 633 which is the Wellfield Data Package for the Smith Ranch-Highland Mine Unit 7.

3.5 Mine Unit Design, Construction and Operation

3.5.1 Mine Unit Design

3.5.1.1 General Well Pattern Types and Spacing

The geometrical configuration of the mine unit boundaries as well as the wellfield patterns within the mine unit is subject to several governing factors. The outline of the ore, the grade and thickness of the ore, the number of ore intercepts of economic viability, the permeability of the sand units, and the location of the edges of the economic ore are considered when determining the type of patterns employed and their spacing. The primary mine unit pattern design is a five-spot configuration. In areas of lower permeability a seven-spot configuration may be employed. Five-spots, alternating line drives, staggered line drives, and other configurations may be employed as conditions warrant. The spacing within the patterns will range from 15 to 37 meters (50 to 120 feet) between injection and production wells, once again depending on the aforementioned governing factors.

The five-spot configuration is common in ISR, especially in areas of higher permeability. In a five-spot pattern, four injection wells surround a central recovery well in a rectangular or square configuration. In an actual mine unit pattern area of repeating five-spot patterns, each injection well services four recovery wells, and each recovery well is serviced by four injection wells. An example of the five-spot pattern is shown in **Figure 3.8, Typical 5-Spot Pattern.**

The seven-spot pattern configuration is typically used in areas of lower permeability. In a single isolated pattern, six injection wells in a hexagonal configuration are employed with a central recovery well. Solutions enter the ore zone through the injection wells and are recovered from the recovery well. In a large array of patterns, each injection well services three recovery wells, and each recovery well is serviced by six injection wells. The exception to this is along the boundary of the mine unit pattern area where a slightly higher ratio of injector-to-recovery wells is required. **Figure 3.9, Typical 7-Spot Pattern, illustrates the seven-spot configuration.**

In both the five-spot and seven-spot patterns, the spacing of the wells will vary, but the completion of each well will be similar allowing each well to be used for injection or recovery, depending on the configuration of the ore and economic considerations.

Line drives, whether alternating or staggered, will be used to exploit narrow portions of the orebody where five or seven-spot configurations are impractical. Line drives consist of alternating injection and recovery wells. The offset placement of injectors and recovery wells yields a staggered line drive. As in the five and seven-spot patterns, the role of each well may be reversed as required. The spacing and distance between wells is controlled by the width of the ore **Figure 3.10, Line and Staggered Line Drive Patterns, illustrates the line and staggered line drive patterns**.

3.5.1.2 Monitor Well Spacing and Placement

As many as five types of monitor wells may be used. The actual density, spacing and location of monitor wells vary from mine unit to mine unit and will be determined during orebody delineation and defined in the Hydrologic Testing Proposal document for each mine unit. “M” wells are installed in the ore sand aquifer, laterally from the production zone, to detect lateral movement of lixiviant from the ore zone. In accordance with LQD Rules and Regulations Chapter 11, Section 6 and LQD Guideline 4, and associated Reference Documents 9 and 10, the location and spacing of these wells will be determined by a technically sound method, which may include but is not limited to, hydrologic modeling, delineation drilling data, gradient consideration, dispersivity of recovery fluids, the calculated operational flare and calculated excursion recoverability within 60 days. The density and spacing of M wells is determined for each mine unit during the detailed geohydrologic assessment of each mine unit.

“MO” wells are installed in the next overlying aquifer to detect vertical migration upward of lixiviant from the ore zone. One MO well is installed for each hectare (3 acres) of proposed pattern area.

“MU” wells are installed in the next underlying aquifer, if present, to detect lixiviant downward vertical migration from the ore zone. One MU well is installed for each hectare (3 acres) of proposed pattern area. For the North Butte Remote Satellite, WDEQ/LQD agreed that if delineation drilling in a mine unit determined that the underlying aquitard is 15 meters (50 feet) thick or greater, MU wells would not be required.

"MP" wells are installed in production zone pattern areas to characterize the baseline quality of the groundwater within the ore zone. One MP well is installed for each hectare (3 acres) of proposed pattern area. Class of Use and RTVs are established for the MP wells using the baseline water quality data as described in Section 3.4.4. Detailed discussions of the production zone geology and hydrogeology for each mine unit is provided in WDEQ Permit Appendices D-5 and D-6 for Smith Ranch, North Butte Remote Satellite and Gas Hills Remote Satellite.

"MT" wells, although optional, may be installed near pre-existing conventional mine workings or areas where it is known that the adjacent groundwater quality will be significantly different from what is present in a particular Mine Unit. This type of well can also be used as an early warning of a potential excursion. For this purpose, MT wells are typically located between the pattern edge and the "M" wells. Water quality data from these wells is not reportable to the agencies. The use of these wells is a preventative measure to allow greater operational control of recovery fluids and to decrease the possibility of an excursion reaching a reportable monitor well.

The actual density, spacing and location of monitor wells will vary from mine unit to mine unit at each facility and will be determined during the hydrologic testing and assessment of each mine unit.

3.5.1.3 Monitor Well Installation

In determining the number, location and construction of monitoring wells and the frequency of monitoring, the following criteria are considered:

1. Pre-ISR groundwater use for affected or potentially affected aquifers.
2. Proximity of the ISR operation to points of non-ISR water use.
3. Local geology and hydrology.
4. Operating pressures and whether a negative pressure gradient is being maintained in the production zone.
5. Nature and volume of the injection fluids, recovery fluids, formation water, and process byproducts.
6. Injection well density.

Monitor wells are installed using the procedure described in Section 3.5.2.3 of this TR to ensure that they are constructed in compliance with state and federal requirements. All monitor wells having a diameter of 10 centimeters (4 inches) or more will be permitted through the WSEO.

3.5.2 Well Construction and Completion Techniques

3.5.2.1 General

Several types of wells are installed at the Smith Ranch Project SUA-1548 license areas including injection, production, and monitor wells. Wells are constructed in such a manner to ensure that the well annulus is sufficiently sealed to prevent communication between the production zone with overlying or underlying aquifers that have been penetrated by the well. Wells will be constructed in accordance with WSEO, WQD and LQD rules and regulations. Construction of these facilities will not result in additional disturbed acreage, as they are contained within the mine unit (monitor well ring) disturbed surface footprint. Multiple completion zone wells may be installed at Smith Ranch and the Remote Satellite facilities.

Cameco ensures that the annular space of wells drilled meets state requirements. In June 2011, the WSEO revised Part III, Chapter 3, Section 2(c)(ii) to state: "All wells shall be constructed with at least a 5 centimeter (2 inch) annular space surrounding the outermost casing and extending not less than 6 meters (20 feet) below ground surface (bgs)". LQD Rules and Regulations Chapter 11, Section 6(c)(i) state: "The drill hole shall be of sufficient diameter for adequate sealing and, at any given depth, at least 7 centimeters (3 inches) greater in nominal diameter than the diameter of the outer casing at that depth". **Figure 3.11, Typical Injection Well**, **Figure 3.12, Typical Production Well**, and **Figure 3.13, Typical Monitor Well** are schematic drawings showing construction details of each type of well.

3.5.2.2 Well Construction Materials

The typical well casing used is rigid polyvinyl chloride (PVC) Standard Dimension Ratio 17 (SDR-17) with a nominal 13 centimeters (5 inches) outside diameter (Certainteed or similar). However, should a larger pump size be required, larger diameter casing may be used. Each joint of PVC casing typically has a length of approximately 6 meters (20 feet) and a wall thickness of 0.83 centimeters (0.327 inches). The pipe is rated for 1.24 MPa (180 psi) maximum internal pressure and 1.54 MPa (224 psi) for resistance to hydraulic collapse (i.e., external pressure where the casing fails)[3]. The maximum working pressure is the pressure rating for the pipe and does not take into consideration the cement backing in the well. The collapse pressure is important during well cementing and development. Once the grout has cured around the annulus of the casing, the collapse pressure caused by the slurry is eliminated. The current casing is joined mechanically using pipe threads or a water tight O-ring seal with a high strength nylon spline. Metal screws, *although used in the past*, are no longer used to support the joining of casing sections. Alternative casing materials, such as fiberglass or steel, may also be used as long as they meet applicable standards of the American Society for Testing and Materials (ASTM) and American Petroleum Institute specifications for well casing and are found suitable for the required service.

Wells are sited and constructed in accordance with LQD Rules and Regulations Chapter 11, Section 6(b) through (h). The top of each well casing ends above grade, and where possible, above known high water conditions of flooding from runoff or ponded water. The immediate area around each well collar slopes away from the well to direct surface runoff away from the well. Wells are not located in the channel or floodplain of perennial or intermittent drainages. If wells must be located in ephemeral drainages, they are not located in the flow course. Precautions will be taken during installation to minimize damage to the channel from erosion and sedimentation, protect the well from erosion damage, and prevent surface runoff from entering the well. This is typically ensured by siting wells as far as practical from the streambed and using appropriate best management practices (BMP) to prevent erosion and sedimentation into the channel. A temporary channel diversion may be required. The primary sediment/erosion control measure is to re-establish a vegetative cover as soon as possible after well completion using a temporary seed mix followed by interseeding with the permanent seed mix. Temporary sediment and erosion control measures, such as silt fences, rock check dams, sediment traps, contour ditches, mulch, geotextile fabric or other BMP, may be implemented where needed until vegetation is re-established.

When not in use, each well is covered with a well cap to prevent the introduction of undesirable materials into the well. Injection and production wells use insulated hard covers to protect the wellhead during inclement weather conditions. The current well boxes are constructed from high density polyethylene (HDPE) corrugated pipe 0.6 meter (2 feet) diameter by 0.9 meter (3 feet) tall. The wellhead box covers are typically white or black and are made of insulated weather proof materials such as metal or fiberglass. Wells are clearly marked with identification. The surrounding area of each wellhead is kept clear of excessive vegetation and/or debris so that well identification is clearly visible.

[3] Certainteed Corporation, 2008

Wells constructed near buildings or power lines are located at a distance from the building or power line sufficient to allow access for repairs, maintenance, sampling, etc. At a minimum, a well must clear building projection by at least 1 meter (3 feet) and power line by at least 3 meters (10 feet).

3.5.2.3 Typical Well Completion Technique

The following well completion techniques will be used at SUA-1548 license areas:

1. Two completion techniques include the following: A pilot hole (nominally 13 centimeters [6 inches] in diameter) will be drilled through the ore zone by use of a rotary drill and a drilling mud system. The second method employs the use of a larger bit (Polycrystalline Diamond Compact [PDC]) that provides an annular space adequate to meet the WSEO and LQD requirements. Drift control will be maintained using weighted drill collars and close supervision during drilling. The drill holes will not be drilled into the underlying confining unit by more than 2 to 3 meters (5 to 10 feet).
2. The drill hole will be geophysically logged using natural gamma, spontaneous potential, and single point resistance tools to determine lithology, grade, thickness and distribution of the ore. Deviation logs will be run to determine the location of the bottom of the hole.
3. Upon verification that the well location is suitable for its intended purpose, the pilot hole will be reamed to a nominal diameter that provides an annular space adequate to meet the WSEO and LQD requirements described in Section 3.5.2.1. Holes drilled with PDC bits do not require reaming.
4. Prior to installing the casing, water or drilling mud will be circulated through the borehole to remove loose drill cuttings, rock chips or other obstructions.
5. The hole will be cased with a nominal 11 to 15 centimeters (5 to 6 inches) diameter SDR-17 PVC well casing. Fiberglass or steel casing may also be used. The casing will extend from the top of the target zone to approximately 0.6 meters (2 feet) above ground level. Each joint of SDR-17 casing will be connected by a water tight O-ring seal which is locked with a high strength nylon spline. No glue or screws will be used with these types of well casing materials. Centralizers will be placed at a maximum spacing of one per 12 meters (40 feet) to ensure there is sufficient annular space for the placement of the sealing grout.
6. Pursuant to LQD Rules and Regulations Chapter 11, Section 6(c)(iv), the casing will be grouted in place with a neat cement slurry, sand-cement grout, or bentonite-clay mixture as approved by the LQD Administrator. Casing may also be grouted in place with a cement-bentonite grout slurry or cement-pozzolan grout slurry as approved by the LQD Administrator. The grout slurry will be pumped down through the casing and up the annulus of the well at a rate adequate to maintain turbulent flow in the slurry to prevent channeling. The cement within the casing will be displaced with a volume of water or drilling mud sufficient to displace the cement to the surface. A wiper plug may also be used to displace the grout slurry. The well casing will be pressure sealed with the casing secured in place, and the sealing grout will be allowed to cure for approximately 24 hours. Maintaining the pressure inside the well casing ensures that the sealing material remains in the annulus until it is cured.
7. After curing, the well annulus at the surface will be topped off with additional sealing material. If the grout slurry does not return to the surface, or settling during curing is more than 12 meters (40 feet), a tremie pipe will be used to complete the sealing to the surface to ensure that bridging does not occur. If casing is set above the production zone, the wiper plug or

sealant column in the bottom of the casing will then be drilled out. If casing is set through the production zone, then the wiper plug or sealant will be left in the bottom of the casing. An under-reaming tool will then be lowered into the well creating a cavity approximately 28 to 36 centimeters (11 to 14 inches) in diameter where the well screen will be placed.

8. The well screen will then be lowered through the casing and secured within the casing joint above the screen interval using a K-packer assembly. Depending on the competency of the formation and/or the proposed use of the well, the annulus outside the well screen will either be gravel packed or left for natural well development (eg., monitor wells).
9. If gravel packed, a properly sized silica sand filter pack will be pumped from the surface through the drill pipe and out through a one-way valve, located at the bottom of the screen assembly, into the under-reamed zone to form a filter pack around the screen.
10. After well completion, casing integrity will be verified by conducting the approved MIT. If defects are found, they will be repaired. If repairs are not possible, the well will be plugged and abandoned and may be replaced with a new well.
11. The completed well will then be developed by pumping and surging formation water using methods such as swabbing and/or pumping.
12. A well construction completion report will be prepared for each well and will be maintained on site for review by LQD.

3.5.2.4 Alternative Well Completion Techniques

In areas where multiple ore trends overlap within one hydrologic unit, alternative well completion techniques including recompletion or twinning may be used to produce these multiple zones. The same well may be recompleted (a.k.a. multiple completion) after a lower roll front zone has been depleted. The screen across the depleted zone is sealed with cement, the remaining casing across an upper ore zone is removed by underreaming, and a new screen assembly is installed across the upper ore zone within the same well casing. Another alternative for simultaneously producing from multiple ore zones is installing a pair of horizontally closely-spaced wells, each screened in a separate ore zone, known as twinned wells or twinning. The need for well recompletion or twinning will be assessed during the mine planning of each individual mine unit. Well recompletion or twinning eventually may be desirable in a mine unit at a project site, depending on whether a single roll front ore body or multiple stacked roll fronts are being produced. If a single roll front ore body is being produced, the associated injection/production wells will typically consist of a single completion interval. However, if multiple roll front zones are being produced, an injection/production well may have multiple completion zones or a twinned well to maximize capture of the economic uranium reserves. Depending on the dimensions and geographic location of a particular roll front, these ore zone intervals may be as close as a few feet or as far apart as 50 or more feet. Wells are recompleted or twinned only within the same production sand unit, not in units separated by a confining bed. Therefore, they would be treated similarly to what would occur with single completions. If the separation distance between the ore intervals is small (+/- 15 feet), mining will be the same as for a single completion unit.

If these alternate well completion techniques are to be employed within any proposed mine unit, they will be presented to LQD with the Wellfield Data Package, including any additional monitoring that may be needed. For an example of an approved Wellfield Data Package that addresses baseline characterization, groundwater monitoring, and safely mining and restoring stacked ore horizons, refer to Volume III-V of Permit 633 which is the Wellfield Data Package for the Smith Ranch-Highland Mine Unit 7.

3.5.2.5 Well Integrity Testing Procedures

All cased wells are tested for integrity following completion and prior to their initial use in accordance with EPA techniques to ensure there are no leaks in the casing and no movement of fluid into an unauthorized zone. The integrity of injection wells is retested on a schedule of at least once every 5 years. Wells are also tested after undergoing physical alteration from under reaming or after workover operations involving the use of a cutting tool that may have caused casing damage. Integrity testing will also be performed on a well that may be suspected to be damaged from an operational issue that may arise, such as over-pressurization of the well. If a well fails an MIT after being in service as an injection well, Cameco will assess the cause of the failure and investigate if the well failure may have released fluids to a non-exempt aquifer. If a monitor well is converted to an injection or recovery well, it will be tested for mechanical integrity prior to the conversion and will be retested at 5-year intervals.

Only MIT techniques that have been approved for use by the EPA are used. The primary method consists of a pressure-packer system approved by the EPA for Class III ISR injection wells constructed with PVC or fiberglass casing.

The primary MIT procedure is as follows:

1. One or two inflatable packers will be installed in the casing. The bottom packer will be set just above the well screen, and the upper packer will be set at the wellhead. Alternatively, a well cap can be used at the wellhead instead of the upper packer.
2. The packer(s) will be inflated and the casing then pressurized to 125% of the expected maximum operating pressure.
3. The well and packer system will then be "closed in", and the pressure maintained for a minimum of 10 minutes.
4. If more than 10% of the "closed in" pressure is lost during this time period, the well will be deemed unacceptable for use and will be repaired and retested, or plugged and abandoned, within 120 days.

At no time will Cameco use an injection pressure greater than 90% of the pressure rating of the casing.

Upon passing the MIT, a well will be deemed acceptable for service. Class III injection wells failing the MIT will be retested. If a well fails the mechanical testing procedure, the MIT information will be logged into a database, and the failed MIT will be reported to the NRC and LQD (see Section 1.10.12 and **Table 1-6** of this TR for more information regarding failed MIT). All MIT results will be documented and maintained on file at the Project site.

If the well fails the second test, the well will be repaired or plugged within 120 days of the testing which indicates a lack of mechanical integrity to prevent lixiviant leakage into unauthorized zones. If the well is repaired rather than plugged, the MIT will be repeated within 120 days after the repair has been completed. The repaired well will not be used for injection purposes until written notification has been received from the applicable regulatory agency concurring that the well demonstrates mechanical integrity.

Furthermore, Cameco will investigate the cause of an MIT failure and the potential for released fluid to reach a non-exempt aquifer. If a well fails the MIT, procedures developed by Cameco (detailed below) will be implemented to determine if an MIT failure has potentially affected groundwater outside the production zone. These procedures include the following:

- When possible, the interval of casing failure is determined through pressure packer placement during the MIT process.
- When available, the well geophysical log will be reviewed to determine the proximity of permeable sediments (i.e., sand versus claystone or shale) to the failed casing interval
- If the MIT cannot isolate the failed interval, geophysical logs will be reviewed to identify permeable zones that could potentially receive lixiviant during a casing failure.
- In locations within the C, E, and F Mine Units where well casing failures are known to have occurred, investigative monitoring wells will be installed within shallow, permeable target zones that may have received lixiviant via the casing failure.
- Groundwater from investigative monitoring wells will be collected, as possible, and analyzed for key chemical parameters to determine if lixiviant has migrated into the monitored interval. Groundwater monitoring data will be mapped to define a potential lixiviant plume.
- Monitoring well installations and water quality summaries will be reported to the NRC and the LQD in Casing Leak Investigation Quarterly Monitoring Reports.

3.5.2.5.1 Summary of Major Actions Related to Casing Leak Investigations

Cameco has worked closely with the Wyoming Department of Environmental Quality – Land Quality Division (WDEQ – LQD) in establishing potential impacts resulting from casing leakage and in developing a characterization and corrective action strategy for current and future impacts, should they exist. Cameco has closely communicated progress and milestones with the NRC as this issue has evolved over the years, and are captured within the NRC ADAMS database. Below is a summary of major actions related to Casing Leak Investigations (CLI).

- **December, 1999: Cameco initiated and submitted an Environmental Audit Report to the WDEQ – LQD and TFN 3 2/290 was issued.**
- **August, 2000: WDEQ – LQD issuance of an Administrative Order of Consent related to Casing Leak Investigative necessary actions.**
- **October, 2000: Submittal of a CLI Compliance Schedule and Permit Revision to the WDEQ – L QD.**
- **2001 through 2011: Mitigative and remedial actions related to casing leakage and the submittal of quarterly monitoring and progress reports to both WDEQ – LQD and the NRC.**
- **March, 2012: Development and submittal to the WDEQ – LQD and NRC of a CLI Sampling and Analysis Plan to further characterize potentially impacted areas and to evaluate past remedial and mitigative efforts.**
- **September, 2015: Termination of the August, 2000 Administrative Order of Consent.**
- **September, 2015 to Present: Work closely with the WQED – LQD to establish a path forward on past and future CLI's, so that Permit 633 and NRC License SUA-1548 capture investigative, remedial, and mitigative methodologies.**

Based upon past efforts described above, Cameco has developed a framework to remain compliant and address future and past Casing Leak Investigations. Cameco is currently closely working with both

the WDEQ – LQD and the NRC to capture the CLI Compliance Framework within all associated Permits and Licenses.

3.5.2.6 New Drill Hole Site Preparation

Prior to drilling an exploration, delineation or well pilot drill hole, topsoil will be removed from the mud pit location and stockpiled on native ground at a sufficient distance to avoid affects by drilling activities. Subsoil excavated from the mud pit will be stockpiled on native ground, separate from the stockpiled topsoil and near the mud pit (see **Figure 3.14, Typical Drill Site in Even Terrain**).

Drill sites located on steep slopes such as those proposed for the Gas Hills Remote Satellite also will require excavation/grading of a level pad and preparation of a safe access route. Topsoil will be stripped from the pad, mud pit, and access road and windrowed to the uphill side of the drill hole location. Subsoil excavated from the mud pit will be stockpiled next to the pit and downhill from the topsoil stockpile (see **Figure 3.15, Typical Drill Site in Rough Terrain**). The drill rig and water truck will then move onto the site and drill the hole.

Cameco has developed and implements BMPs that will be used during drilling and well installation activities to minimize impacts to vegetation, topsoil and the general environment. These BMPs are summarized below.

1. To minimize vegetation and topsoil disturbance, access routes to each drill location or group of locations will be plainly marked with survey stakes or similar types of markers. Vehicles will be required to travel only on these designated access routes and existing roads and trails. Should the designated access routes become compacted from use, they will be scarified and seeded as part of the drilling reclamation program.
2. To the extent possible, crossing perennial and intermittent drainages with drill equipment and vehicles will be avoided. If it becomes necessary to cross a drainage to reach a drilling site, a stream crossing will be constructed at right angles to the channel with adequate embankment protection and installation of adequately-sized culverts.
3. Mobilization of the drill rig from hole to hole during exploration and delineation drilling activities will be restricted to dry or frozen ground conditions.
4. Drill rigs will be inspected by the contractor prior to project startup and daily during the project; leaks will be repaired prior to drilling.
5. Spill containment and cleanup equipment, such as drip pans, absorbent cloths, dams, etc., will be readily available at each drill site. In the event of a spill (not contained by the drip pan) by drilling rig malfunction(s), drilling will be suspended, all contaminants will be cleaned up before drilling resumes.
6. All petrochemicals will be stored in approved containers.
7. Site clearing and preparation will be minimized to the extent possible to avoid excessive surface disturbance. However, drilling sites located on extremely steep slopes may require excavation of a level drill pad as well as an excavated access route into the location. Stripped topsoil will be windrowed to the uphill side of the drill site and access road. Subsoil excavated from the mud pit will be stockpiled next to the pit and downhill from the stockpiled topsoil. The surface disturbance footprint for each delineation drill hole, excluding access routes, will typically be approximately 74 $meters^2$ (800 $feet^2$). Each drill hole site will have an earthen mud pit excavated with a backhoe and sized to contain the drill cuttings and drilling fluid from the

proposed total depth of the hole. Topsoil will be removed from each mud pit location and stockpiled on native soil at a sufficient distance to avoid impacts by the drilling activities. Topsoil stockpiles will be cordoned off and marked with flagging or other signage. A tackifier may be applied to topsoil stockpiles to prevent migration by sedimentation. Subsoil excavated from the mud pit will be stockpiled on native soil separate from the stockpiled topsoil and near the mud pit.

8. All drill hole, well sites and access roads will be located, constructed and maintained to minimize erosion. BMPs to minimize erosion and offsite sedimentation will vary with specific site conditions, such as slope, vegetative cover and proximity to surface waters of the state. BMPs may include silt fencing, straw bales, vegetation buffers, slope roughening, mulch, geotextile fabrics, and other measures designed to reduce erosion and minimize the transport of sediment from the disturbed area.
9. No drill holes or wells will be installed within 30 meters (100 feet) of the edge of perennial or intermittent drainage without first consulting with Cameco's environmental staff to determine the specific spill and erosion protection measures to be implemented at each drilling location.

3.5.2.7 Abandoned Exploration Drill Holes

All drill holes will be abandoned in accordance with W.S. 35-11-404 and LQD Rules and Regulations Chapter 8 and Chapter 11, Section 8 using an approved abandonment material. The abandonment material will be mixed with water and circulated through the drill pipe filling the drill hole from bottom to top. Each drill hole will be completely filled to the collar of the hole or securely capped at a minimum depth of 0.6 meters (2 feet) below either the original land surface or the collar of the hole, whichever is at the lower elevation. If capped, the cap will be made of concrete or other material satisfactory for such capping. A metal tag with the drill hole number stamped on it will be affixed to the top of the cap for future hole identification. The remaining hole above the cap will be backfilled to the original land surface. If the hole cannot be plugged immediately after probing, it will be securely covered until plugging is performed.

Following abandonment of the drill hole, the mud pit will be allowed to dry out prior to backfilling. After backfilling the pits with subsoil, the pits will be allowed to settle before applying topsoil and performing final grading. Compaction may be used to further reduce potential settling of reclaimed pits. Steep slope sites and access routes will be reclaimed using a dozer, track hoe or similar equipment to minimize the surface disturbance.

Those drill sites that will become part of a mine unit within one year of drilling the hole will not be seeded until wellfield construction is complete. Those sites that will not become part of a mine unit within one year will be seeded after mud pit reclamation is complete. In either case, seeding will take place during the next available seeding window, spring or fall. All seeding is completed using the approved permanent seed mixture.

3.5.2.8 Historical Drill Hole and Well Abandonment

A computer database has been generated for all Wyoming properties listing the coordinates, elevation, depth drilled, and completion date, of all known exploration and mine development drill holes completed by previous mineral owners and Cameco. More than 50,000 existing drill holes are located within the SUA-1548 license areas. Approximately 2,700 drill holes were drilled and abandoned in the North Butte license area between 1967 and 2010. More than 14,000 holes were drilled within the Gas Hills Remote Satellite area. Drill hole tables and maps of known abandoned drill holes are provided in: Section 7.0 of Appendix

D-5 for Smith Ranch; in Section 4.0 of Appendix D-5 for North Butte; and in Appendix D5 and Addendum D5-3 for the Gas Hills Remote Satellite area.

From 1967 to 1983, approximately 1,120 exploration, predevelopment, development and in situ leach wells were drilled in and around the Ruth Remote Satellite area. These holes were drilled by Conoco, Kerr-McGee and Uranerz. Beginning in 1979 and continuing through 1988, approximately 60 cased wells were installed at Ruth. These wells were used as in situ leaching wells for the Ruth R&D project or as monitor wells in conjunction with the pilot project. Excepting three monitoring wells, all of the wells have been plugged and abandoned. Detailed tables and maps showing the locations of the boreholes/wells are provided in the Ruth ISL Project, Volumes I-III, Supportive Information for WDEQ Permit to Mine Application and USNRC Source Material Applications prepared by Uranerz USA, Inc. (October 1988). Section 3.4.3 of this TR provides Cameco's approved methodology for finding potentially improperly abandoned drill holes and wells.

3.5.2.9 Well Stimulation Program

The well stimulation method or work over program typically uses well swabbing. The well swabbing program involves pulling a swabbing cup up the well, thereby lifting the column of fluid above the swab tool to the surface. This reduces the pressure beneath the swab and pulls water from the formation through the screened interval into the well, in effect "flushing", and thus cleaning the screen. The flushed fluids will be captured in an enclosed water tank and disposed of through the wastewater treatment system.

3.5.3 Mine Unit Operations

3.5.3.1 Lixiviant Composition

The selection of an appropriate ISR lixiviant must consider the ability of the lixiviant reagents to mobilize the uranium minerals, the cost and availability of those reagents, their effect on other minerals present in the uranium orebody, and their effect on the ore sand aquifer relative to the achievement of groundwater restoration. Since the mid-1980s, virtually all uranium ISR operations in the United States have used a lixiviant containing oxygen gas or hydrogen peroxide as an oxidant, carbon dioxide gas or sodium bicarbonate as the uranium complexing ion, and mineral acids or bases for pH and bicarbonate/carbonate ratio control.

Careful characterization of the mineralogy before mining and Cameco's extensive leach testing and operating experience confirms that the chosen lixiviant for the Smith Ranch SUA-1548 license areas is chemically compatible with the major constituents that could cause formation damage or loss of formation permeability. Based on extensive pilot and commercial operating experience at Smith Ranch, and laboratory and pilot studies on ore from the North Butte, Gas Hills and Ruth Remote Satellites, the chosen lixiviant is compatible with the ore mineralogy, as it has been shown to provide effective uranium recovery and successful groundwater restoration.

The key factors in lixiviant compatibility are clay mineralogy and chemical compatibility. The clay mineralogy at Smith Ranch is predominantly kaolinite, which is compatible with an ISR operation in that (a) it does not swell, which would result in reduced formation permeability, and (b) its cation exchange processes are not aggressive, which could adversely alter the water chemistry. The addition of sodium through the use of sodium bicarbonate could induce clay swelling if substantial quantities of divalent smectite clays were present.

The clay mineralogy at North Butte is predominantly chlorite to montmorillonite, which can exchange ions with percolating fluids. Cameco's lab testing program has shown that the effect of sodium exchange on the clays is more profound at higher pH and sodium concentrations. Higher pH (above 9) tends to cause clay swelling problems. The operating pH for the North Butte Remote Satellite will be 7 to 7.5. Operating experience at Christensen Ranch, Smith Ranch Satellite SR2, and Crow Butte Resources has shown that sodium bicarbonate lixiviant can be used without adverse effects on the formation.

The clay mineralogy of the Gas Hills Remote Satellite orebody is predominantly kaolinite with lesser concentrations of monovalent smectites (Hazen, 1996). As discussed above for Smith Ranch, kaolinite is favorable for ISR.

Chemical compatibility of the formation mineralogy with the ISR process is important. Elevated calcium, sodium and sulfate concentrations often occur during ISR and can result in the precipitation of calcite or gypsum in the ore sand, consequently reducing formation permeability. Operating experience has shown that the lixiviant in use at Smith Ranch is chemically compatible with the major constituents that could cause formation damage or loss of formation permeability.

The lixiviant used at Cameco's Wyoming operations consists of native groundwater fortified with a carbonate complexing agent of sodium carbonate, sodium bicarbonate and/or carbon dioxide, and an oxidant consisting of oxygen or hydrogen peroxide. The target concentrations of oxidant and complexing agents are typically less than 1 g/L oxygen and less than 5 g/L bicarbonate. These target oxidant and complexing agent concentrations in the lixiviant result in a mine unit production fluid with the following typical concentrations:

Parameter	Average Concentration
Na	50-200 mg/L
Cl	50-900 mg/L
HCO_3	200-1200 mg/L
TDS	500-1850 mg/L
pH	6.2-6.5 pH units
O_2	10-600 mg/L

The North Butte orebody mineralogy and depositional environment are similar to other ore deposits in the surrounding area, suggesting that it will be amenable to the same ISR chemistry used nearby. Both the Ruth ore deposit to the south and the Christensen Ranch ore deposit to the west were tested using standard ISR technology and a sodium bicarbonate/carbonate, oxygen-enhanced lixiviant. Both of these deposits as well as Irigaray to the northwest, Reno Creek to the southeast, and Nichols Ranch Smith Ranch to the south, have demonstrated amenability to in situ extraction methods.

North Butte ore is very amenable to carbonate/bicarbonate leaching, as determined through testing of core material recovered from two locations in the North Butte project during the installation of hydrologic test wells. These cores were subjected to standardized leach tests in Uranerz' (a Cameco predecessor) laboratories. Cameco also collected North Butte cores in 2009 and conducted pressurized bottle roll leach and column leach testing programs. The core leaching program showed that recoveries as high as 85% can be achieved using a standard carbonate lixiviant of 1 g/L sodium bicarbonate. Potential metallurgical problems identified during the leach testing program included elevated vanadium content in the ore and a higher content of carbonaceous material.

The ore mineralogy at the Gas Hills Remote Satellite is similar to that at other Wyoming uranium ISR sites that use a carbonate/oxygen lixiviant. Because of the mineralogical similarities between these deposits and site-specific core leach studies, Cameco proposes to use a carbonate/oxygen lixiviant at the Gas Hills Remote Satellite. The carbonate will be supplied by dissolved carbon dioxide gas, sodium bicarbonate or a combination of the two agents to achieve the required carbonate concentration to complex the uranium. Results of leach studies conducted by Cameco on Gas Hills cores indicate that, in order to counteract uranium adsorption by the clays and other minerals in the host rock, bicarbonate concentrations of up to 5 g/L may be required to achieve acceptable uranium recovery results. Supplementation of sodium bicarbonate to the CO_2 lixiviant may be used as necessary to achieve target strengths for the complexing ion.

The oxidant will be supplied as gaseous oxygen supplemented with hydrogen peroxide as necessary; hydrogen peroxide is not currently used as an oxidant at the Smith Ranch Project. The oxygen concentration will be adjusted in each mine unit in a manner which will use all of the available head above the ore zone to maximize oxygen dissolution. The target average oxygen concentration will be 400 mg/L. If the available head is inadequate to achieve acceptable oxygen concentration and uranium production rates, hydrogen peroxide may be used to fortify the lixiviant oxidant concentration. If hydrogen peroxide were to be used, the reagent injection rate would be kept low enough to avoid problematic outgassing.

The results of the Ruth R&D program (1983-1984) demonstrated the technical feasibility of using sodium carbonate and various oxidants for the lixiviant as well as successful restoration of the affected groundwater. Cameco will perform further leaching and lixiviant compatibility studies on Ruth cores during the satellite design phase.

When uranium is recovered, a small portion of the radium content is also mobilized. Depending on site conditions, trace elements such as arsenic, selenium, and/or vanadium may also be oxidized and mobilized in low concentrations. Minor increases in selenium concentration in the leach solution have occurred during Smith Ranch commercial operations. However, after more than 20 years of continuous operation, there is no evidence that other trace elements are being mobilized during leaching.

Vanadium can cause leaching problems in carbonate leach solutions by co-precipitating in the formation during the recovery process as a calcium-uranium vanadate, such as tyuyamunite. The precipitation of tyuyamunite in carbonate systems is dependent on pH and carbonate content and can be controlled through proper lixiviant control. Carbonaceous material is a reductant and probably played a role in the deposition of the uranium orebody. The carbonaceous material will also act as a scavenger for the oxygen used during the production process, which will result in higher oxygen consumption. Hydrogen peroxide can also be used in place of gaseous oxygen during uranium recovery.

3.5.3.2 Anticipated Geochemical Reactions

Uraninite and coffinite have been shown to be effectively mobilized during ISR by a two stage process. The first stage is the oxidation of U^{+4} to U^{+6}, which can be accomplished by an oxidizing reagent that increases the redox state from negative to positive. The second stage is the complexation of the oxidized uranium, which results in increased solubility in the recovered groundwater. This can be accomplished with a number of anions, including bicarbonate, chloride, and sulfate. The most common and efficient complexing anion has proven to be bicarbonate. Based on more than 20 years of operating experience, Cameco has developed an efficient and cost-effective carbonate leaching solution consisting of varying concentrations and combinations of sodium carbonate (Na_2CO_3), sodium $NaHCO_3$, oxygen (O_2), H_2O_2, and/or CO_2 added to the native groundwater.

Uranium in the U^{+4} oxidation state is insoluble in water at near neutral pH. Therefore, the first step in uranium ISR is to increase the oxidation potential of the groundwater in contact with the uranium from less than zero to greater than zero. This redox reaction is typically accomplished by adding gaseous oxygen or hydrogen peroxide.

The basic uranium oxidation step using oxygen gas can be represented by the following reaction:

$$(1)\ 2UO_2\ (s) + O_2\ (g) = 2UO_3\ (s)$$

The oxygen can also be provided by hydrogen peroxide. Hydrogen peroxide decomposes rapidly to oxygen and water by the following reaction:

$$(2)\ 2H_2O_2\ (l) + H_2O\ (l) = O_2\ (g) + 3H_2O\ (l)$$

Therefore, the choice of gaseous oxygen or liquid hydrogen peroxide is mostly based on cost. However, the theoretical solubility of oxygen gas in water, which is temperature and pressure dependent, is limited by the following relationship:

$$(3)\ \text{ppm } O_2 = (170\ P)(1.082 - 0.0304 \ln P)/35.5 + T$$

where P is pressure in psi (actual) and T is temperature in degrees Celsius. Where limited head (i.e., water pressure) is available above the ore to allow dissolution of adequate gaseous oxygen, hydrogen peroxide may be selected.

Following oxidation of the uranium minerals as represented by reaction (2) above, the uranium is in the oxidized U^{+6} valence state and is now soluble in water and capable of combining with a complexing anion. As discussed above, the complexing anion of choice is the bicarbonate ion. The bicarbonate ion may be introduced into the lixiviant by adding a solution of sodium carbonate into the natural groundwater. The addition of the sodium bicarbonate solution adds operational flexibility by maintaining the bicarbonate at optimal levels for the best leaching conditions. The addition of sodium bicarbonate provides a measure of operational safety by limiting the maximum possible pH of the injection solution to 8.5.

A second method for introducing bicarbonate into the lixiviant is by injection of gaseous CO_2, which causes the dissolution of carbonate from the contained formation calcite and creates a slight acidic condition in the lixiviant. If calcite ($CaCO_3$) and CO_2 are present in adequate quantities, the following reactions take place:

(4) $CO_2\ (g) + H_2O = H_2CO_{3,}$ which lowers the pH of the lixiviant, and

(5) $CaCO_3\ (s) + H_2CO_3 = Ca^{2+} + 2HCO_3$

Bicarbonate (HCO_3) formed by the addition of CO_2 is the least expensive on a molar basis and creates minimum geochemical disturbance with no attendant clay swelling. The complexation reactions that occur between the oxidized uranium minerals and the bicarbonate complexing agent can be represented by the following reaction:

$$(6)\ UO_3 + 2HCO_3 = UO_2(CO_3)^{2-}{}_2 + H_2O,$$

which shows the dissolved oxidized uranium species to be the uranium bicarbonate ion. This oxidized species is highly mobile in water at a near neutral pH.

3.5.3.3 Mine Unit Piping, Instrumentation and Operation

Introduction

The uranium-rich groundwater is pumped from the recovery wells to the IX extraction circuit located at the CPP, satellites and/or the remote satellite locations. Following uranium extraction, the barren fluid is refortified with oxygen and carbon dioxide and returned to the ore zone via the injection wells.

Injection fluids are transported to the mine unit wellfield areas via pumps located at the satellites, remote satellites or the CPP. Booster pumps may be installed along the mine unit trunklines as necessary to maintain required flows and pressures.

Mine Unit Piping

The facility layout and pipeline systems have been designed to facilitate production and allow restoration activities to begin as soon as production has ceased within a mine unit or a portion of a mine unit. Production and restoration flow to and from the satellite and header houses of each mine unit will be through separate but parallel pipelines. This arrangement, along with the central water treatment design, minimizes groundwater use, particularly during concurrent production in one mine unit, aquifer restoration via groundwater sweep in another, and water treatment and reinjection in a possible third mine unit. Excess water from a mine unit may be used in another mine unit (i.e., for RO make-up). This design also minimizes disposal volumes.

All mine unit pipelines are constructed of HDPE. The pipe diameters vary from 3.2 to 5.1 centimeters (1.25 to 2 inches) in diameter (well to header house) to as much as 46 centimeters (18 inches) main trunklines to and from the satellite. All pipelines are pressure tested for leakage prior to use. The smaller diameter piping used to connect individual wells with the header houses are typically one continuous run of pipe with no field joints, which greatly reduces the potential for leakage in the burial trench. The HDPE piping is welded together using a manufacturer approved butt fusion technique.

All buried pipelines are installed a minimum of 1.5 meters (5 feet) bgs to protect from freezing. Protection from vehicle vibration damage is pursuant to design guidelines provided by the Plastic Pipe Institute in their *Handbook of Polyethylene Pipe, Second Edition*. Chapter 6, Section 3 of the manual provides the criteria to be used to prevent piping damage due to vehicle loading. Using the Standard Trench or Embankment Installation Category, which applies to pipes installed with 46 centimeters to 15 meters (18 inches and 50 feet) of cover, the pipe must have a minimum cover of at least one pipe diameter or 46 centimeters (18 inches), whichever is greater. The Campbell County regulations will be used for the North Butte, and Ruth Remote Satellite pipeline construction. As Fremont, Johnson and Converse Counties do not have specifications for buried pipelines, Gas Hills Remote Satellite will also follow the Campbell County regulations.

There are several types of buried pipelines used for various purposes. The production and restoration pipelines (one each for injection and recovery flows) run from the satellite to the mine unit header houses, with smaller buried lines running from the header houses to the individual injection and recovery wells. During production, the injection fluid pipelines carry barren lixiviant from the satellite to the Mine Unit, and the production fluid pipelines carry pregnant lixiviant from the mine unit to the satellite for uranium recovery. During restoration, these pipelines and/or the restoration pipelines convey restoration fluids to and from the mine unit wellfield areas.

A smaller pipeline, called the cleanout line, may be used to carry wastewater produced by well cleaning operations from the mine unit to the satellite for uranium removal prior to being directed to the waste treatment system. A separate pipeline may be used to carry oxidant from a centralized location in the mine unit or near the satellite to the mine unit header houses for introduction into the barren lixiviant prior to injection.

Additional pipelines may be installed during mine unit construction and/or operation to facilitate restoration and to carry carbon dioxide to the header houses during production. Finally, a buried wastewater pipeline conveys groundwater treatment (RO) reject flow from the wastewater treatment system in the satellites to the purge storage reservoir or directly to a deep disposal well.

The goal in the design and layout of pipelines is to install all the necessary pipelines in a single trench at the same time along mine unit access routes to minimize initial surface disturbance and ground re-disturbance of the same area prior to groundwater restoration. The preferred trenching method for piping less than 20.3 centimeters (8 inches) in diameter will be either a trenching machine or a spider plow. These types of excavation machines do not require topsoil segregation and reduce the overall soil disturbance footprint. Depending on the nature of the disturbance, topsoil and subsoil excavated using a backhoe or trackhoe will be managed as described in **Table 3-5, Topsoil/Subsoil Management**. Following pipeline installation and testing, the excavated material from the trench is returned in the reverse order it was excavated. Trench backfill is compacted to avoid future settlement.

Pipelines constructed with field welds will be cleaned and pressure tested. Pipelines that do not have field welds will be inspected for manufacturing flaws and transportation damage prior to installation. During operation, continuous service pipelines will be equipped with high- and low-pressure sensors and flow meters to provide safe shutdown in the event of abnormal operating conditions such as breaks or blockages.

3.5.3.4 Pattern Balancing, Injection Pressures and Flow Rates

Pattern Balancing

Flow models are often used to predict the expected flow paths of the lixiviant from the injection to the production wells, such that the pattern design can be optimized for maximum ore contact and extraction with a minimum number of wells. These same models may be used to design lixiviant control methods to prevent excursions when working near hydrologic boundaries (e.g., faults, etc.).

During the operational phase of an ISR facility, approximately 99% of the water withdrawn is returned to the ore zone. Thus, the impact on regional pressure changes, groundwater gradients and flow paths is minimal. Pressure changes are generally limited to localized gradients to control flow between injection and production wells.

The ISR process is operated as a closed system, with the injection rate to the mine unit maintained below the total production rate from the mine unit. The water which is removed from the mine unit is referred to as bleed or purge. The bleed creates a hydrologic cone of depression, or flow towards the pumping well, within the production zone, which prevents the unwanted migration of lixiviant away from the production area.

The bleed is removed from the closed system after the lixiviant passes through the IX columns for uranium removal. The volume of bleed required to maintain a zone of control around a mine unit is dependent in part on the hydraulic gradient. Typically, the greater the hydraulic gradient across the mine unit, the greater the bleed rate must be to maintain the same zone of control. The bleed rate typically varies from 0.5% to 1.5% across a mine unit and is distributed across the mine unit based on an engineering design that considers geologic and hydrologic factors unique to each situation. Fluid volumes removed during well workover activities also contribute to the total bleed.

At Smith Ranch and North Butte, this excess water will be disposed using deep disposal well injection and/or land application (Smith Ranch only). At Gas Hills, the excess water will be disposed of using evaporation ponds, but Cameco is also investigating the efficiency of using deep disposal well injection.

The disposal options at Ruth have not yet been developed but will likely be a combination of the same options being used at the current and planned operations.

Injection Pressures

Injection pressures within well casing above the ground surface as well as associated wellhead piping are typically less than 0.82 MPa (120 psi) and will be at least 10% below the pressure rating of the casing. Because the well casing is cemented into the bore hole, downhole pressures can substantially exceed the pressure rating of the casing without adversely affecting the integrity of the casing.

Downhole injection pressures for all Class III injection wells will be maintained below the formation fracture pressure as required in LQD Rules and Regulations Chapter 11, Section 11(c)(i). Injection well pressures are typically much lower than the formation fracture pressure due to materials used and MIT limits. Cameco uses the more conservative value of 4.8 KPa (0.7 psi) as the pressure gradient at the Smith Ranch SUA-1548 license areas. By comparison, a commonly used formation fracture pressure gradient in the southern Powder River Basin is 4.8 KPa (0.7 psi) for every 31 centimeters (12 inches) of depth (Pinu/Halliburton, 1983). Neunan/Champion Oil (1983) reports a gradient of 16.5 KPa/m (0.72 psi/**foot**) for the Manning field near the Smith Ranch. Based on sedimentary rock density data, Hubbert and Willis (1957) report a pressure gradient of 20 KPa/m (0.87 psi/**foot**) at shallow depths, which should increase to about 23 KPa/m (1 psi/**foot**) at 1,524 meters (5,000 feet) depth.

To ensure that the formation fracture pressure is not exceeded, a maximum injection pressure is calculated for each header house and is posted near the injection trunk line pressure gauge. The posted maximum operational pressure is based on MIT test pressure limits and shall not exceed the maximum surface injection pressure. The pressure of the injection trunk line is monitored daily in each mine unit header house. The surface injection pressures are not allowed to exceed the maximum surface pressures posted in each header house. Average and maximum injection pressures are reported in quarterly and annual reports to the LQD. The maximum allowable surface pressures will be determined using the calculation below:

IPsurf = {[FG - 0.433psi/ft x SG] x (depth)}

Where:

FG = the fracture gradient in units of pounds per square inch per foot (psi/feet; 0.7 formation fracture pressure Smith Ranch Project (SUA-1548)

0.433 = pressure that one foot of fresh water would exert on the formation in units of pounds per square inch per foot (lb/in^2)

SG = the specific gravity

Depth = depth from the surface to the top of the injection zone (feet

The maximum allowable MIT test pressure for a given header house is the most restrictive of the calculated injection pressures.

In accordance with LQD Rules and Regulations Chapter 11, Section 4(a)(xi), the following information concerning the production zone is determined and calculated for new Class III wells or mine units where the production zone is in a receiving stratum which is naturally water-bearing:

1. Fluid injection pressure;
2. Fracture pressure; and

3. The physical and chemical characteristics of the receiving strata fluids.

Flow Rates

Production well flow rates will vary from well to well depending on screen thickness, the variable hydraulic characteristics of the ore zone aquifer, the available hydraulic head, the depth to the ore zone, the flow rates of associated injection wells, and the capacity of pumps. Production well flow rates range from 19 to 151 liters/minute (5 to 40 gallons/minute), and injection well flow rates range from 7.5 to 114 liters/minute (2 to 30 gallons/minute). To maximize resource extraction and to maintain hydrologic control, each mine unit is normally operated at the maximum sustainable flow for each pattern. This maximum flow rate is adjusted to maintain an adequate head on the ore zone aquifer such that the oxygen and carbon dioxide in the lixiviant remain in solution.

Injection rates vary for each well and are based on “balancing” the mine units. Balancing of the production patterns refers to keeping the injection rate minus the bleed in each pattern matched with the production rates to maintain the cone of depression. The term therefore describes a hydrologic balance in the aquifer. Balanced patterns achieve optimum pattern production and minimize the “flare” of production fluids outside of the pattern areas. Balanced patterns prevent the excursion of production fluids from the mine unit areas. Records of well flow rates and injection pressures are documented and retained on site until termination of the license. Injection rates, including the average and maximum daily rate and the volume of fluid injected are provided to LQD quarterly.

The relationship between injector flow rates and producer flow rates is established based on the maximum flow obtained by the pattern as a whole. A producer may have injection fed by one or more injection wells. The production well flow rate is the sum total of the injection feeding it. An injection well may feed one or more production wells.

Once each day the flow rates for each injection and production well is measured and recorded. These measurements are compared to targets for each well, and the rates are adjusted to maintain the mine unit pattern balance. The required flow rates are determined by the well balancing program and the actual flow rates are adjusted, if required. The adjusted flow rates are re-entered into the program and the required flow rates recalculated.

Header house flow data are recorded and delivered to the Wellfield Operations Superintendent or designee. The Wellfield Operations Superintendent is responsible for maintaining these data and the mine unit balance.

3.5.3.5 Power Transmission and Communication Lines

Electrical power is supplied to Smith Ranch by Rocky Mountain Power using established power lines in the vicinity. Electrical power supplied to Smith Ranch is through pole-supported overhead transmission lines. Powder River Energy Corporation will provide power to the North Butte and Ruth Remote Satellites through existing power lines to the site metering point.

Electrical power lines (High Plains Electric) have been installed to the Carol Shop at the Gas Hills Remote Satellite and were used when the facility was a conventional mine. In 2008, Cameco contracted with an independent power line service company to inspect and tighten the Carol Shop 69 kV power line service. This task was completed in the fall of 2008. Cameco will install the mine unit electrical distribution lines. Power lines from header houses to individual wells are buried. Whenever practicable, power lines and pipelines are located within a single right-of-way (ROW), with reasonable separation for safety, to minimize ground surface disturbance. All overhead power lines are built in accordance with the guidance provided in "Suggested Practices for Raptor Protection on Power Lines – The State of the Art in 2006," published by the Avian Power Line Interaction Committee. Secondary power transmission lines deliver power to transformers located in the mine units. The transformers step down the voltage for delivery to the header houses and downhole submersible pumps. Power lines from the transformers to the header houses and production wells are typically buried. Telephone and optical fiber communication lines are also buried.

In 2010, Cameco installed fiber optics lines at several of the Smith Ranch operational facilities to provide more rapid detection of and response to leaks that may occur. Fiber optics lines were installed at the following locations:

- Booster Station 7 & 8 in Mine Unit 15A to Header Houses 15-19, 15-20, 15-21, and 15-19 to 15-22, 15-22 to 15-23;
- SR1 to Bell Hole 4-SR1, Bell Hole 4-SR1 to SRHUP NO. 10 DDW, Bell Hole 4-SR1 to Booster 4;
- Satellite 2 to Morton 1-20 DDW; and.
- Vollman 33-27 DDW to Bell Hole tie-in (Mine Unit E); Bell Hole tie-in to SRHUP NI. 9 DDW.

The locations of these fiber optics lines are shown on **Figures 1.4** through **1.8**.

Pipeline and power lines will follow access roads to the extent practicable. **Figures 1.10, 1.11** and **1.12,** depict the proposed locations of main and secondary access roads. Additional detail and wellfield access roads for Gas Hills Mine Unit 1 are shown on **Figure 3.16, Mine Unit 1 Delineation Drilling** and **Figure 3.17, Mine Unit 1 Wellfield Development**.

3.5.3.6 Mine Unit Maintenance

Each production well is protected by a flange mechanism installed on the well head and by a fiberglass or plastic well cover installed over each well. Each well house is clearly marked for ease of well identification. Debris or refuse are routinely removed from mine unit pattern areas to facilitate access by mobile equipment. Access is maintained to each well site to facilitate routine well maintenance or monitoring, including potential re-entry to a well by a drill rig.

3.5.3.7 Subsidence Risk Due to Mine Operations

During the 20 + years of Smith Ranch ISR operation, there has been no surface subsidence due to ISR. The uranium which is present in the orebody represents only about 0.1 weight % of the rock, or about 0.03 volume %. The ore minerals occur between the sand grains, in the interstitial pore spaces of the rock. Because the lixiviant is specific for uranium minerals, it will not dissolve constituents of the host rock. Because of the very low volume percentage of the uranium minerals, the leaching process does not affect the structural integrity of the host rock. Therefore, no void spaces are created by ISR, and no subsidence due to ISR is anticipated.

3.5.3.8 Special Considerations for Gas Hills Remote Satellite Wellfield Operations

Wellfield Operations near Discontinuities, Previous Mining and Mine-Related Reclamation

The Gas Hills Remote Satellite is similar to Smith Ranch in that the license area and adjacent properties have been previously disturbed by conventional uranium mining operations. Cameco is experienced at operating an ISR operation adjacent to these historic disturbances. With respect to the Gas Hills Remote Satellite, Cameco recognizes the need for special operational considerations near discontinuities such as faults, improperly abandoned drill holes, abandoned underground mine workings, existing water-filled mine pits and existing reclamation areas or backfilled mine pits. The primary ISR concern is loss of fluids, cross communication of intercepted sands and/or mixing of different quality groundwater. Cameco develops a detailed understanding of local aquifer properties and baseline groundwater quality through wellfield delineation and hydrologic unit testing. This wellfield hydrogeologic model is the first step in planning to prevent loss of fluids and/or mixing of differing quality groundwater. The primary engineering controls include production pattern balancing, scheduled development near mine workings or areas of high TDS groundwater, minimum setbacks of production pattern areas from mine workings or high TDS groundwater, and groundwater monitoring. In the event that the primary engineered controls are inadequate, secondary controls such as a “water fence” may be considered. In faulted areas, the production zone may be extended to include juxtaposed overlying or underlying aquifers. These operational considerations are further discussed below.

Mine Unit Production Pattern Balancing

Production pattern balancing to maintain a consistent bleed across a production area within a mine unit has been shown to be effective for preventing production fluid excursions in areas of relatively flat groundwater gradients. Cameco will use balancing programs which incorporate the geometry, geology and hydrology within each mine unit.

Due to the groundwater gradient at the Gas Hills Remote Satellite, the designed production pattern balance may result in an uneven bleed across a mine unit. Groundwater modeling (see **Appendix C**) indicates the anticipated adjustments to the production pattern balancing that will be required to control flare and sweep under the varying hydrologic conditions for each mine unit. For example, in Mine Unit No. 3, located south of the Atlas Mine workings, injection rates in downgradient injection wells may need to be reduced by approximately 15% of the conventionally balanced rate, while injection rates in upgradient injection wells would be increased by approximately 15%. The overall bleed from the patterns would continue to be 1% but would not be consistently applied across the pattern area. The upgradient over-injection will push against the groundwater moving toward the wellfield and create a barrier preventing dilution of the injection fluid with natural groundwater. As the distance increases upgradient from the pattern area, a point will be reached where the injection will be equally balanced against the natural groundwater flow. The resulting flare would still be less than 24 meters (80 feet) from the pattern area. Similarly, under-injection will be needed along the downgradient side of the mine unit to prevent migration of injected fluids downgradient toward the Atlas Mine workings. The information provided in **Appendix C** shows the balanced flare that will result from the 15% over injection upgradient and the 15% under injection downgradient of the mine unit.

Modeling will be an integral part of the production pattern balancing program for each mine unit. As mine units are brought into production, the detailed hydrologic data from the pump tests will be used along with operational data and experience to continue evaluation and adjustment of the balancing program.

Production Area Setback from Old Mine Workings

Conventional mining took place within and adjacent to the Gas Hills Remote Satellite. PMC has mined and reclaimed the Central Gas Hills trend, and Umetco Minerals has mined and reclaimed the East Gas Hills trend. Also present within the license area (Mine Unit 4 and 5) are numerous properties, mined by various operators, which have been reclaimed by the WDEQ AML Division. Several known underground mine operations were also present and were reclaimed by AML. These include the UPZ Shaft, Atlas-Peach, Thunderbird, Rox and Buss Underground. The underground mining operations were simply capped (surface plugged) and surface facilities removed and reclaimed.

Two surface mine pit disturbances, Buss and Cap Pits, were reclaimed by PRI. The open pit operations were backfilled with area mine spoils and, since reclamation, have exhibited groundwater recovery. In some cases, groundwater has not fully recovered, and a cone of depression remains. Once a full recovery is achieved, upgradient groundwater will enter these reclaimed mine pits, mix with interstitial groundwater and pass through to a downgradient position. The natural groundwater undergoes a change in water quality, which often results in increased concentrations of TDS, sulfates, and certain metals including Fe, Mn, Al, Se, As, U, and Ra-226. In some locations there is a local lowering of pH. As the water continues downgradient, it mixes with area groundwater and is diluted to essentially baseline concentrations. Because of the nature of the geochemical processes within the abandoned and reclaimed mine pits, these water quality changes continue to differing degrees as additional pore volumes pass through the mine pits. Cameco's proposed Mine Units 4 and 5 are downgradient from AML reclamation and may intercept this groundwater of variable quality although Cameco's ongoing baseline monitoring has not detected a change in water quality.

A mine unit, or a production pattern area within a mine unit, may be sited near a previously mined and/or reclaimed area exhibiting groundwater quality different from its established baseline quality. To prevent incursion of this lesser groundwater quality into the wellfield during operation, Cameco will install trend monitor wells to track movement of this groundwater. An incursion is defined as the migration of different, typically poorer quality (i.e., higher TDS) groundwater into the mine unit. Incursions are most likely to occur during the groundwater sweep phase of restoration. The groundwater flow modeling (**Appendix C**) evaluates sweep during restoration as well as during production. For the example (Mine Unit No. 3), the anticipated sweep that will occur at the end of three years of production is 24 meters (80 feet). In other words, over a period of 3 years, groundwater located approximately 24 meters (80 feet) from the production area may be drawn into the production area due to a wellfield bleed of 1%. Similarly, during the groundwater sweep phase of restoration over a period of 1.5 years, groundwater is anticipated to travel 36.6 meters (120 feet) towards the production area. Therefore, locating the edge of the production area patterns 91 meters (300 feet) from the edge of the old mine workings or the edge of the groundwater plume will result in a buffer zone of unaffected groundwater between the two areas. Figure ADD2-11 of **Appendix C** shows the predicted groundwater flow path lines during groundwater sweep for Mine Unit 3 south of the Atlas Mine workings. **Appendix C** also discusses the other production units and anticipated setback distances from previously existing mine workings.

Minimum setbacks from the mine workings to prevent excursions and incursions will be refined for each mine unit using hydrologic data to be collected during hydrologic testing. Preliminary modeling of Mine Unit 3 - South Area, using the baseline hydrologic properties presented in this TR, supports a minimum setback of 91 meters (300 feet) from the Atlas Mine workings. Similarly, modeling of the Mine Unit 3 - North Area also supports a minimum setback of 91 meters (300 feet) from the Atlas Mine workings. The planned pattern areas for Mine Unit 3 - North Area and Mine Unit 4 are located approximately 305 meters (1,000 feet) from the PMC reclaimed area and the Buss Pit, respectively. According to the models for these areas, the 305 meters (1,000 feet) separation is adequate to hydraulically isolate the ISR operations from the previous mining locations. These minimum setbacks will be reevaluated as more detailed geologic, hydrologic and operational data is obtained. The Hydrologic Testing Proposal for each specific mine unit will contain the proposed pattern areas and information supporting the proposed monitor well locations and spacing. This document will also contain detailed information supporting the minimum setbacks from mine workings, as this will affect monitor well location and spacing.

Operational Controls to Address Conductive Faults

Several faults are located near or within all of the proposed mine units at the Gas Hill Remote Satellite. Delineation drilling will provide more detailed mapping of the faults, and the hydrologic tests will investigate the potential for conductivity along these faults. Geologic and hydrologic testing data will be used to assess confining unit competency near faults in the ore zone.

Cameco has developed a decision tree for operating near faulted areas. If geologic cross-sections show the potential for juxtaposition, production zone wells, overlying aquifer wells and underlying aquifer wells will be installed on both sides of the fault. Water levels will be measured in these wells as an initial indicator of communication or isolation of the sands. However, a site specific “fault pump test” may be required to further confirm water level data. If the data indicates that a particular fault provides hydraulic communication between the production zone and the overlying and/or underlying aquifer, Cameco will decide on several operational methods including primary engineering controls, secondary engineering controls, or extension of the production zone. These three options are discussed below.

1. Primary engineering controls (production area pattern balancing, scheduling, setbacks, monitoring) can be used to isolate the ISR operations from the fault. Production area pattern balancing, wellfield development scheduling and groundwater monitoring are effective when the fault does not intersect the planned production pattern area or flare area. If the fault intersects the planned production pattern area or the anticipated flare area, minimum setbacks from the fault to the production pattern area may be determined, or the use of secondary engineering controls may be required. Economics will be considered during planning of primary or secondary controls for production. For instance, if the ore were low grade and the uranium price was low, setbacks from the fault would be assessed, ore near the fault would not be targeted for production and Cameco would “stay away from the problem area.” If the ore was high grade and the uranium price was high, Cameco would further investigate the use of secondary controls to allow recovery of the uranium near the fault.
2. Secondary engineering controls (e.g. water fence) may be used to allow ISR operations in close proximity to a fault. A “water fence” is formed by injecting clean water via a line of injection wells into the production zone. This forms a high pressure ridge which prevents migration of fluids across the fence from either direction. The “water fence” is temporary and will only block groundwater flow while injection is ongoing. This option would be considered when clean water for injection is plentiful and aquifer conductivity is low to moderate. Secondary controls may also be needed near faults or mine workings during the groundwater sweep phase of restoration to prevent incursions.
3. In the unlikely event that primary controls fail and an excursion cannot be retrieved, secondary controls may be evaluated to control the excursion. While a water fence is not planned for a specific location at this point in time, the use of this and other engineered barriers near mine workings or faults will be continually evaluated on a site specific basis.
4. Under certain geologic conditions, it may be preferable to extend the production zone definition to include the juxtaposed aquifers above or below the ore zone sand. The overlying and/or underlying aquifers may be operated as portions of the production sand thus requiring restoration. The second overlying and/or underlying aquifer, if present, may require testing and monitoring. This option may necessitate bonding adjustments to account for the additional impacts to the groundwater. Geologic conditions that may warrant this operational method include low conductivity faults of limited extent. The overlying/underlying aquifer impacts would be relatively small and easily restored.

The Hydrologic Testing Document for each Gas Hills Remote Satellite mine unit will include a detailed fault assessment, evaluation of abandoned drill holes in the area, evaluation of abandoned mines and underground workings as this information is required for mine unit design including monitor well spacing and placement.

Operational Controls to Address Areas Where Previous Mining and Mine-Related Reclamation has Occurred

As discussed above, the effect of previous mining and mine-related reclamation will be assessed prior to development of a mine unit. Operational setbacks, i.e. installing new ISR wells as far away as possible from previous mine areas, will be the primary means of addressing concerns that different water quality from an offsite source may impact wellfield production (due to ISR bleed) and restoration. In addition, Cameco will consider engineered controls previously discussed including pattern balancing, scheduling, monitoring or secondary controls such as water fences.

Different groundwater quality may be moving through a mine unit under the natural groundwater gradient. Until ISR mining operations commence, Cameco may continue to collect and evaluate new baseline data to keep this characterization current. As requested by WDEQ/LQD to supplement the WDEQ/LQD updated permit, Cameco collected an additional set of baseline groundwater samples from the Gas Hills Remote Satellite monitor wells in October 2011. This updated information has been incorporated into the LRA.

If the baseline (natural pre-ISR) groundwater movement and change in water quality is evident within a mine unit over time, then engineered controls would be ineffective in segregating the differing quality groundwater. In this case, Cameco would propose UCL and RTV concentrations for the high TDS groundwater for LQD and NRC's review and approval.

Cameco has developed a decision tree that outlines the process for investigating the movement of variable groundwater quality (high TDS example) into a mine unit. The decision tree indicates that engineered controls will be planned when high TDS groundwater intersects a mine unit due to ISR operations.

3.6 Uranium Recovery Processing Facilities

3.6.1 Smith Ranch

3.6.1.1 General Facility Layout

The Smith Ranch main office and CPP are located in the NE/NW Section 36, T36N, R74W (see **Figure 1.3**). The CPP complex occupies approximately 16.2 hectares (40 acres) and is located in the area of the reclaimed Kerr McGee Bill Smith underground mine complex. The current complex consists of several buildings, impoundments, chemical storage areas, and an office building. A security fence surrounds the CPP site.

The northern end of the CPP houses an IX facility with a design capacity of 17,032 liters per minute (4,500 gallons/minute). Currently, approximately 5,677 liters per minute (1,500 gallons/minute) of the design capacity is being used for groundwater restoration activities. The facility also contains two RO units for restoration with a feed capacity of approximately 757 liters per minute (200 gallons/minute) each. The remainder of the building contains resin transfer, elution, yellowcake processing, and drying/packaging facilities. The CPP IX facilities currently serve Mine Unit 1, Mine Unit 2 and Mine Unit 3. This area also includes a lined, two-celled wastewater storage pond, the former O- and Q-Sand pilot plant building, construction and maintenance shops, warehouse facilities and the "boneyard" storage area. **Figure 3.18, CPP Site Map** shows the plan view of the CPP facilities.

The catchment basins shown on **Figure 3.18** were originally constructed by Kerr McGee for the Bill Smith Mine. They are now used as part of the storm water control process for the Smith Ranch CPP. The depression area to the west of the CPP complex was the “Sand Borrow” area used by Kerr McGee during the construction of the Bill Smith Mine. This area is now used to store wood pallets, cable spools, etc. until they are disposed during periodic permitted controlled burns.

Central Processing Plant Equipment

The CPP building contains IX columns, water treatment equipment, resin transfer facilities, pumps for injection of lixiviant, disposal well equipment, RO units and bioremediation materials for groundwater restoration, an upstairs laboratory area, offices, and employee break rooms. The principal equipment used in the yellowcake production process consists of surge tanks, elution/precipitation tanks, a thickener, vacuum drying systems, and the piping, pumps and valves required to control and move the solutions among the various process components. **Figure 3.19, CPP Floor Plan** shows the layout of process equipment in the CPP. This figure also shows the layout of the laboratory and yellowcake storage areas expansions that were completed during the last renewal period.

Highland Uranium Project Central Processing Facility

The former Highland main office and CPF complex is located in the NE/NW Section 29, T36N, R72W (see **Figure 1.3**). The main office and CPF are currently on stand-by status, and all yellowcake processing occurs at the Smith Ranch CPP. The CPF building houses uranium processing facilities including the uranium elution circuit, yellowcake precipitation, dewatering, drying and packaging equipment. The site plan of the CPF area is shown on **Figure 3.20, Highland CPF Site Map**. The current interior process equipment layout is shown on **Figure 3.21, Highland CPF Floor Plan**. Cameco plans to refurbish the Highland CPF and resume IX processing and yellowcake processing activities. This will require the replacement of the dryer equipment and the majority of the existing processing equipment. Third-party toll processing of IX resin or yellowcake slurry is also planned at the CPF once the facility is upgraded. Third-party toll processing has been previously evaluated and approved by NRC in the form of license amendments.

3.6.1.2 Uranium Recovery Process

Ion Exchange/Lixiviant Makeup Circuit

The uranium-bearing solution pumped from a mine unit is piped to the CPP or satellites for extraction of the uranium by use of down-flow IX columns to remove the uranium. As the solution passes through the resin in the IX column, the uranium is preferentially removed from the solution by attachment to the resin. The following IX reaction occurs when the uranium bearing lixiviant contacts the resin:

$$2RCl + (UO_2)(CO_3)_2^{2-} \rightarrow R_2UO_2(CO_3)_2 + 2Cl^-$$

where “R” denotes the IX resin.

Once the resin in a column is sufficiently loaded with uranium, the vessel is isolated from the normal process flow, and the resin is removed from the column for elution. In the elution process, the resin is contacted with a strong sodium chloride/sodium carbonate solution, which displaces the uranium and regenerates the resin in a process very similar to regenerating a conventional home water softener. The eluted resin is then placed back in service for additional uranium recovery. The uranium-rich fluid (rich eluate) is pumped to the precipitation circuit for further processing.

The barren solution leaving the IX units normally contains less than 2 mg/L (ppm) of uranium. After the barren solution leaves the IX columns, a small bleed, or purge (averaging 0.5 to 1.5% of the total flow), is removed and sent to the wastewater treatment and disposal system. This ensures that there will always be a net cone of depression within the mine unit, thereby reducing the chance of excursions. The remainder of the barren solution is refortified with carbon dioxide and/or carbonate/bicarbonate as necessary to return the carbonate/bicarbonate concentration to the desired operating level. The solution is then pumped back to the mine unit, with the oxidant (O_2 gas and/or H_2O_2) added either as it leaves the CPP or satellite, or just before the solution is re-injected into the production zone.

3.6.1.3 Elution and Precipitation Control

A chloride brine and soda ash solution is used to remove the uranium from the resin. The following chemical reaction occurs:

$$R_2UO_2(CO_3)_2 + 2NaCl \rightarrow Na_2UO_2(CO_3)_2 + 2RCl$$

The rich eluate containing the uranium is pumped to tankage in front of the precipitation circuit for temporary storage. To initiate the precipitation cycle, hydrochloric or sulfuric acid is added to the uranium bearing solution to break down the uranyl carbonate present in the solution. It is then transferred to the precipitation circuit, and hydrogen peroxide is then added to the acidified eluate to effect precipitation of the uranium as uranyl peroxide. The addition of hydrogen peroxide reduces the pH of the solution. To optimize crystal growth and settling, a base (e.g., sodium hydroxide or ammonia) is added as a pH adjustment.

The uranium depleted eluate or supernate solution is removed and stored for re-use in future elutions or for disposal. Sodium chloride and sodium carbonate are added to the recycled eluate, as needed for refortification. Storage tanks and/or lined storage ponds are used to collect and store excess process waters from this circuit, such as the excess spent eluate, prior to disposal via deep well injection.

3.6.1.4 Yellowcake Dewatering, Drying and Packaging

The resulting slurry from the elution/precipitation circuit is transferred to a thickener allowing the uranium to precipitate for maximum crystal growth and gravity consolidation. The yellowcake slurry is dewatered as it settles, and the eluate is decanted by a weir and transferred back to the elution circuit or sent to the wastewater treatment and disposal system. The yellowcake slurry is routed to a filter press for washing to remove soluble contaminates followed by de-watering prior to drying. The yellowcake is dried using a rotary vacuum dryer and packaged in 208-liter (55-gallon) steel drums for storage and shipment. With this type of dryer, the off-gases generated during drying are filtered to remove entrained particulates. The sealed vacuum system provides ventilation while the dryer is being loaded and unloaded into drums. This type of dryer eliminates airborne effluents. Drummed yellowcake is stored in an enclosed, secured room adjacent to the yellowcake drying area prior to shipment.

The drummed yellowcake is shipped by exclusive use transport to an offsite NRC licensed facility for further processing. During periods of inclement weather or other interruptions in product shipments, drums will be stored on site in a designated storage area. Yellowcake shipments comply with applicable NRC and DOT packaging and transportation requirements.

3.6.1.5 Wastewater Management

There are five primary process wastewater streams for the Smith Ranch CPP:

1. Wellfield bleed, averaging up to 1.5% of production flow rates;
2. Groundwater restoration wastewater;
3. Excess water from resin transfer, elution and precipitation circuits;
4. Well workover water; and

5. Wash down water.

All of these waste streams are combined and treated at the CPP or satellites as follows:

1. Filtration to remove suspended solids;
2. Disposal via a Class I UIC injection well(s); or
3. Radium and selenium removal and disposal at PSR-2 Land Application Facility.

Wastewater disposal at the Smith Ranch site consists of Class I UIC injection wells and land application. As production and restoration progresses at a site, additional disposal capacity may be necessary. Cameco projects these needs on an annual basis by updating the water balance and surety estimate to take into account activities that have occurred during the year and operations that are planned for the coming year. Additional wastewater disposal facility decisions are made dependent upon the results of these annual updates. Additional disposal capacity may be created through the permitting of additional deep disposal wells, land application facilities and possibly solar evaporation ponds. Other technologies may also be considered such as enhanced evaporation techniques, enhanced water treatment and recycling or other methodologies**.**

Class I Injection Wells

As of January 2012, Smith Ranch is permitted for 10 WDEQ/WQD Class I UIC injection wells to dispose of excess water generated by both mine unit and yellowcake processing operations. **Table 3-6, Deep Disposal Well** Information lists the well ID's, UIC permit numbers, injection rates and analytical requirements for these disposal facilities. The locations of these wells are shown on **Figures 1.4** through **1.8**.

Two injection disposal wells, SR DW#1 and SR DW#2, are now approved to operate under Class I UIC Permit 99-347 for injection into the Parkman, Teapot and Teckla Formations. Well SR DW#1 is used for wastewater disposal at the CPP, and SR DW #2 is used for disposal at Smith Ranch Satellite SR1. Well SR DW#1 is located in the NE¼ of Section 35, T36N, R74W, approximately 0.8 kilometers (0.5 miles) west of the CPP. Well SR DW#2 is located in the NE¼ of Section 27, T36N, R74W, approximately 244 meters (800 feet) north of Satellite SR-1.

Satellite SR1 also uses deep disposal well SRHUP #10. Deep disposal well SRHUP #6 services Smith Ranch Satellite SR2. Deep disposal wells SRHUP #7 and SRHUP #8 have been permitted but not yet (January 2012) installed. The Reynolds Ranch well DW#1 has been permitted and drilled but is not yet operating.

Wastewater Storage Ponds

Two small, lined storage ponds (East and West Ponds) are in operation at the CPP. These ponds were initially constructed in 1981 and authorized under the Q-Sand Pilot Project WDEQ Permit to Mine 633 and NRC License SUA-1387. These ponds are located just north of the CPP and are used for limited process effluent disposal and solids retention prior to transfer to the deep disposal injection wells. The capacity of each pond is 962 meters^3 (0.78 acre-feet) of water. Each pond is 30 meters x 30 meters and 2.4 meters deep (100 feet x 100 feet x 8 feet deep). During operations, **0.9** meters (**3 feet**) of freeboard is maintained in each pond to protect the berms from wave action damage due to wind.

Each pond is constructed with a compacted sandy clay base overlain by a 1-mm (30-mil) thick Hypalon liner. The bottom of each pond has a two-way slope toward the center. A sand layer is placed over the bottom of the pond with the synthetic liner on top of the sand. For each pond, a perforated PVC pipe is installed in the sand layer parallel to the bottom slope. The perforated pipe is connected to a collection sump. The sumps are monitored for leaks of process solutions.

3.6.1.6 Equipment, Instrumentation and Control

Header House Instrumentation and Control

The production and injection headers within each new header house are instrumented to shut down a header house and associated patterns in the event of a piping failure. In new header houses, a process logic controller (PLC) monitors the injection and production header pressure transducers. Each new header house has a combination pressure reducing and shutoff valve on the injection side. The valve controls the injection pressure at the header house to a predetermined pressure setting and shuts down the header house injection in the event of a problem in the header house. The PLC monitors the production and injection pressure and the presence of water in the header house basements. Depending on the programmed pressure set points, a pressure change (high or low) will be detected by the PLC and will shut the injection fluid control valve and turn the pumps off in the header house. A beacon installed on the outside of the header house illuminates to alert the operator of a problem in the house. For all newer houses in production, the PLC also indicates to the control room computer that a header house has shut down.

The oxygen system in each header house has solenoid-operated valves that close in the event of a loss of power or when a header house shuts down. This prevents the continued delivery of oxygen to the header house in the event of a loss of flow. The carbon dioxide injection system installed at some of the header houses or at the satellites have reagent addition and/or pH control. The carbon dioxide system uses solenoid valves that close in the event of a loss of power or when the header house shuts down.

Instrumentation to monitor pH is installed in the header house or satellite as part of the carbon dioxide system. The pH is monitored by the PLC. Unlike the other satellites at Smith Ranch, the bicarbonate addition system at Satellite SR-2 is equipped with pH meters. This type of bicarbonate system will be installed at the Reynolds Ranch Satellite and at the remote satellites.

A conductivity probe, a level transducer, or a float has been installed in each new header house to detect fluids on the floor and/or basement of the house. There are two separate alarm stages associated with the floor leak detection system. The first will alarm when water is at a depth of about 7 centimeters (3 inches) at which time the sump pump will automatically start pumping water from the sump. The second will alarm when water has reached a few feet in depth, indicating that the leak is larger than the sump pump can handle. If fluids are detected at the second alarm level, the PLC shuts down the injection flow and the production wells in the header house. A beacon on the outside of the header house is activated in the event water is detected, and the PLC will alarm on the main control computer in the Control Room at the satellite facility that the header house has shut down. The only exception is Mine Unit F, where there are currently no fiber optic capabilities to connect it to the satellite and it acts as an independent or "stand-alone" mine unit. Starting in Mine Unit J at Smith Ranch, header houses were installed with earthen basements in an effort to contain spilled fluids. This did contain the fluids successfully, but presented problems with removing contaminated soils from the basement areas during reclamation. To prevent spilled fluids from soaking into the basement soils, Cameco began constructing header house basements with leak resistant floors beginning with Mine Unit 15. Currently all newly constructed header houses are equipped with cement basements. Each new header house floor or basement has a sump and a sump pump capable of pumping spilled fluids from the floor back into a production pipeline. The flow from individual production and injection wells is measured using turbine meters, which are located in the header house. The individual well flows are measured and adjusted daily. A flow meter is used to measure the total production and injection flow rates from each header house. The flow meters' instantaneous flow rate is monitored by the PLC. Starting with Mine Unit 15A (i.e., newer header houses), the PLC sends an alarm to the satellite in the event of a flow problem. Except for Satellite 2, each production header house can be remotely shut down from the satellite.

All injection and production collection headers are monitored for pressure and flow. High and low pressure targets are set to detect abnormal operations. The totalized flow through the headers is compared to the total flow of all operating wells feeding the header to determine if there are flow balance discrepancies.

Header houses that have leak detection equipment are tested at least once each month and documented. Each header house is also inspected at least once each day and documented. Starting in Mine Unit 15A, leak detection instrumentation has been installed on both production and injection wells. The production well leak detection instrumentation has been tied to the running control such that if there is a leak on an individual well, it will be shut down until the well is fixed.

To prevent flow through a shutdown header house, an automatic valve (Cla-Val™) is installed in the injection header just as it enters a header house. This valve automatically closes should the leak detection system shut down a header house. Previous failures of this type of valve have led to the current practice of backing up the Cla-Val with a motor-operated valve that is actuated by a power failure and operated by an uninterruptible power supply.

Main Trunkline Instrumentation

The main trunk pipeline pressure is monitored and trended by the PLC at the satellite. During normal operation the trends are consistent. If an upset condition occurs, the pressure trends may become erratic. If an unexplained upset occurs in the system, alarms alert the operator to make an inspection. Each valve manhole has a leak detection alarm that will give the operator a visual alarm if the manhole becomes filled with water. Each manhole is routinely inspected and documented.

3.6.2 Smith Ranch Satellite Facilities

3.6.2.1 General Facility Layout

As of September 2011, a total of five satellite IX facilities have been constructed at Smith Ranch, with four in operation. Satellites 1, 2 and 3 are located on the Highland portion of the Smith Ranch license area, and Satellites SR-1 and SR-2 are located on the Smith Ranch. Satellite 1 is not operational at this time as Mine Units A and B, that served Satellite 1, are no longer in production and have completed active groundwater restoration. Restoration of Mine Unit A has been approved by the WDEQ and NRC. Mine Unit B has been approved by the WDEQ. NRC approval is pending approval of an ACL application, which was submitted to NRC in May 2013. A sixth satellite facility will be built at the Reynolds Ranch expansion area to service the Reynolds Ranch mine unit wellfields. Construction of the Reynolds Ranch Remote Satellite is pending approval from the LQD[4]. The NRC has approved Reynolds Ranch as an amended area to SUA-1548.

Satellites 2, 3, SR-1 and SR-2 are all operational and currently providing production and/or restoration support to Smith Ranch. The satellite buildings typically house IX columns, water treatment equipment, resin transfer facilities, pumps for injection of lixiviant, RO units and bioremediation materials for

[4] The WDEQ approved the Reynolds Ranch Satellite with the approval of the Smith Ranch-Highland combination amendment in March 2014.

groundwater restoration, a laboratory area, offices, and an employee break room. CO_2 and O_2 are stored in compressed form adjacent to each satellite building or in the mine unit areas.

Satellite 1 is located in the NW¼ Section 21, T36N, R72W, and the building occupies approximately 743 $meters^2$ (8,000 $feet^2$). The location of Satellite 1 is shown on **Figure 3.22, Satellite 1 Site Map**. As discussed above, Satellite 1 serves Mine Units A and B and is currently not in operation. No interior equipment layout is provided since this facility is not operational. During production operations, this facility had a capacity of approximately 6,804 liters/minute (1,800 gallons/minute).

Satellite 2 is located in the NE¼ Section 14, T36N, R73W. The building occupies approximately 1,208 $meters^2$ (13,000 $feet^2$). Satellite 2 serves Mine Units C, D, D-Extension, F, E, H, and I. The Satellite 2 facility is designed to operate with a maximum flow of 12,111 liters/minute (3,200 gallons/minute) during production operations. As of September 2011, Mine Units C, D, D-Extension and E are undergoing groundwater restoration. Mine Units H and I are in production. The location of Satellite 2 is shown on **Figure 3.23, Satellite 2 and Selenium Plant Site Map**. Satellite 2 uses CO_2 and O_2 and has one operating RO unit used for groundwater restoration purposes. Additional RO capacity was been added to Satellite 2. The interior layout for this satellite is depicted on **Figure 3.24, Satellite 2 Floor Plan**.

Satellite 3 is located in the SE¼, Section 20, T36N, R73W, and the building occupies approximately 1,208 $meters^2$ (13,000 $feet^2$). Satellite 3 and associated facilities serve Mine Units D-Extension, F, J and K. The piping is set up such that Mine Units D-Extension and F can be served by Satellite 3 as well as Satellite 2. Satellite 3 may also serve additional mine units that are currently being geologically evaluated for future expansion in the western portion of the original HUP license area (i.e., west of Satellite 3). The Satellite 3 facility is designed to operate with a maximum flow of 22,709 liters/minute (6,000 gallons/minute) for production operations. The location of Satellite 3 is shown on **Figure 3.25, Satellite 3 Site Plan**. The interior equipment layout is depicted on **Figure 3.26, Satellite 3 Floor Plan**.

Satellite SR-1 is located in the SE¼, Section 27, T36N, R74W. The building occupies approximately 1,784 $meters^2$ (19,200 $feet^2$). Currently, this facility serves Mine Units 3, 4, 15 and 15A. Satellite SR-1 is designed to operate with a maximum flow of 17,032 liters/minute (4,500 gallons/minute) for production operations. The satellite also contains 1,892 liters/minute (500 gallons/minute) of RO capacity for groundwater restoration purposes. The location of Satellite SR-1 is shown on **Figure 3.27, Satellite SR-1 Site Plan**. The interior equipment layout is depicted in **Figure 3.28, Satellite SR-1 Floor Plan**.

The southwest Satellite, SR-2, is located in the NE¼, Section 17, T35N, R74W, and the building occupies approximately 1,784 $meters^2$ (19,200 $feet^2$). This satellite serves Mine Unit 9 and will serve mine units planned in the southwest area, including Mine Units 10, 11, and 12. Satellite SR-2 is designed to operate with a nominal flow of 18,924 liters/minute (5,000 gallons/minute) for production operations. The satellite also contains 1,892 liters/minute (500 gallons/minute) of RO capacity for groundwater restoration purposes. The location of Satellite SR-2 is shown on **Figure 3.29, Satellite SR-2 Site Plan**. The interior equipment layout is depicted in **Figure 3.30, Satellite SR-2 Floor Plan**.

As discussed in Section 3.2.1, The Reynolds Ranch Satellite will be located north of the CPP complex (see **Figure 1.3**) and will serve all mine units planned for the Reynolds Ranch satellite area. The satellite will be designed with a maximum through-flow of **22,709** liters/minute (6,000 gallons/minute) during production operations and will also contain **1,892** liters/minute (500 gallons/minute) of RO capacity for groundwater restoration purposes. The location of the Reynolds Satellite site is shown on **Figure 3.31, Proposed Reynolds Ranch Site Map**, and the interior layout is shown on **Figure 3.32, Proposed Reynolds Ranch Floor Plan**.

3.6.2.2 Ion Exchange/Lixiviant Makeup Circuit

The IX/lixiviant makeup circuit for the Smith Ranch satellites is described in Section 3.6.1.2 above.

3.6.2.3 Wastewater Management

General

The primary process wastewater streams for the Smith Ranch satellites will be similar to the Smith Ranch CPP except that (a) the wellfield bleed will only average 1% of the production flow rates, and (b) because yellowcake is not produced, no excess water from the elution and precipitation circuits will be generated.

All of these waste streams will be combined and treated in the satellite as follows:

1. Filtration to remove suspended solids;
2. Disposal via a Class I UIC injection well(s) or land application.

As capacity is added to the CPP and/or satellites to meet production and restoration levels, disposal capacity will be added in the form of deep disposal injection wells or approved alternative disposal facilities.

Radium settling basins, purge storage reservoirs, and a Selenium Treatment Facility have been installed, in addition to disposal wells, to assist in the wastewater disposal. **Figure 3.33, Mine Unit Piping Diagram** provides a schematic describing wastewater treatment at the satellites.

Class I Injection Wells

Smith Ranch is permitted for ten Class I UIC injection wells to dispose of excess water generated by both mine unit and yellowcake processing operations. **Table 3-6** lists the well ID's, permits, authorized injection rates and analysis requirements for these disposal facilities. The locations of these wells are shown on **Figures 1.4** through **1.8**. Cameco will comply with permit conditions identified within the individual UIC permits.

Two wells, SR #1 and SR #2, are now approved to operate under Class I UIC Permit 99-347. Well SR #1 is located in the NE¼ of Section 35, T36N, R74W, approximately 0.8 kilometer (0.5 mile) west of the CPP. Well SR #2 is located in the NE¼ of Section 27, T36N, R74W, approximately 244 meters (800 feet) north of Satellite SR-1. Both wells are permitted to inject into the Parkman, Teapot and Teckla Formations.

In 2009, WQD approved Class I UIC Permit 09-054 authorizing the use of seven additional disposal wells: Morton 1-20, Vollman 33-27, and SRHUP #6 through SRHUP #10. The Morton 1-20 is located in NW¼ NW¼, Section 20, T36N, R72W; the Vollman 33-27 is located in NW¼ SE¼ Section 27, T36N, R73W (see Smith Ranch WDEQ Permit Plates OP-1-1 through OP-1-5). Both the existing Morton 1-20 well and the Vollman 33-27 are completed in a deep injection zone 2,446 to 2,785 meters (8,024 to 9,138 feet) below the surface and are permitted for injection into the Teckla, Teapot and Parkman Formations.

Satellite 1 Radium Settling Basins

The radium settling basins were constructed in 1987 to settle residual radium-barium sulfate out of the Satellite 1 wastewater after filtration and prior to land application. The area consisted of two 3,700 meters^3 (3 acre-feet) lined ponds located east of Satellite 1. Water that passed through these basins then went to the Purge Storage Reservoir 1 (PSR-1), where it was stored prior to periodic land application. The Radium Settling Basins were originally permitted by WQD under Permit 87-042R prior to being amended into the LQD Permit to Mine 603.

Cameco has initiated the decommissioning and reclamation of the radium settling basins. Most of the clay liner has been removed and disposed of as 11e.(2) byproduct material. A small amount of clay liner remains with low levels of uranium and Ra-226. Assessments are being made to complete final reclamation and decommissioning of the basins.

Purge Storage Reservoir 1

PSR-1 is located east of Satellite 1 and was used to store treated mine unit purge water and treated water from Mine Units A and B restoration activities. The reservoir contains 66,600 meters^3 (54 acre-feet) when at full capacity. Water stored in the reservoir was periodically land applied by sprinkler irrigation on a 23.5 hectare (58 acre) irrigation area when weather conditions permitted. PSR-1 was originally permitted by WQD under Permit No. 93-178, and later by Permit No. 95-156R. The PSR-1 and associated leakage pump back system are permitted under the LQD Permit to Mine No. 603. PSR-1 is currently in an interim stabilization status and contains no water except during times of precipitation or snowmelt. There is an on-going investigation at the PSR-1 and associated land application area, including annual sampling of soils and vegetation, to assist in determining the best management of the facilities in the future as well as the reclamation and surety requirements.

The reservoir is underlain by a natural clay soil that contains an average permeability of approximately 1.8E-8 centimeters/second (7.1E-9 inches/second). Use of the reservoir began in January 1988 with the start of production from the Satellite 1 area. The reservoir performed as designed until August 1994, at which time a small amount of leakage was discovered seeping at the two ephemeral drainages located immediately east and south of the reservoir. In correspondence dated October 3, 1994, PRI submitted to NRC and LQD a Corrective Action Plan (CAP) describing planned installation of two pump back sumps (North and South Pump Back Sumps). It was determined that the seepage resulted from erosion of the natural clay liner along the easternmost portion of the reservoir. The erosion was caused mostly by wave action. Erosion of the clay liner exposed an underlying sandstone, which allowed seepage to move out of the reservoir, to the south and east, where the sandstone outcropped in the ephemeral draws.

On November 9, 1994, the treated excess water was diverted to Purge Storage Reservoir No. 2 (PSR-2) to dry out PSR-1 and allow repairs to the liner. Due to the abnormally wet spring of 1995, construction activities, which included repair of the clay liner and the addition of a geotextile fabric along the eastern side of the reservoir to protect against erosion, were not completed until August 1995. The CAP also included the construction of a 244-meter (800-foot) long interceptor trench approximately 91 meters (300 feet) south of PSR-1 in August 1996. The trench captures subsurface seepage from the south side of PSR-1 and pumps it back into the reservoir. The pumping system is fully automatic and continuously operates. The interceptor trench has been very effective in preventing seepage from PSR-1 from surfacing and entering the drainage south of the system. After the interceptor trench went into service, it was no longer necessary to operate the South Pump Back Sump. Both the interceptor trench and North Pump Back Sump are on standby. PSR-1 is not currently in use. The system is monitored in accordance with requirements of the LQD. As part of the CAP, visual inspections, sampling of the seepage water, vegetation monitoring, and soil monitoring are conducted.

Figure 3.34, PSR-1 Interceptor Trench Details shows the details of the interceptor trench and associated pump back sump. The trench is approximately 1.8 to 5.5 meters (6 to 12 feet) deep depending on the topography. The bottom of the trench intercepts the fractured sandstone unit, which transmitted the seepage. Approximately 46 to 61 centimeters (18 to 24 inches) of 2-centimeter (0.75-inch) gravel was placed in the bottom of the trench and surrounded the 10 centimeter (4-inch) PVC drain pipe. A plastic liner was installed along the downgradient side of the trench to assist in capturing seepage. The drain pipe conveyed seepage to the concrete sump which contains a submersible pump capable of pumping approximately 76 liters/minute (20 gallons/minute). When operating, the pump activates automatically by a float switch, and seepage is pumped back to PSR-1 through a buried 5-centimeter (2-inch) HDPE pipe. Although the reservoir has not held water for several years, minor seepage continues to enter the pump back system. Therefore, this part of the system is still used.

Purge Storage Reservoir 1 Land Application

The PSR-1 Land Application Areas 1A and 1B are located east of Satellite No. 1 near PSR-1. The area consists of a center pivot irrigation system, which covers 23.5 hectares (58 acres). There has been no land application for several years at this site.

The PSR-1 Land Application Area was originally permitted by the WDEQ WQD under Permit No. 92-077, later under Permit No. 95-156R, and is now part of WDEQ LQD Permit to Mine No. 603. Monitoring requirements for vegetation, soils, etc. are included in **Table 3-7, Purge Storage Reservoir No. 1 Land Application Monitoring Program**.

Purge Storage Reservoir 2 and Associated Land Application Area

The PSR-2 Land Application Area is used for the disposal of wellfield purge and groundwater restoration fluids from mine units served by Satellite Nos. 2 and 3. During months of land application, irrigation fluid is sampled monthly from the pump intake line using an automatic sampler and analyzed for the parameters listed in **Table 3-8, Purge Storage Reservoir No. 2 Land Application Monitoring Program**. The samples are composited on a monthly basis and analyzed.

PSR-2 has a capacity of approximately 40 hectare-meters (321 acre-feet) of water. The land application area comprises approximately 46 hectares (116 acres). The locations of Satellite No. 2, PSR-2, land application area and the 10-centimeter (4-inch) HDPE pipeline used to transport treated water from Satellite No. 3 to Satellite No. 2 and PSR-2 are shown on **Figure 1.3**. Similar to PSR-1, PSR-2 is underlain by several low permeability clay units. PSR-2 and associated land application facilities were originally permitted by WQD under Permit No. 93-410 prior to being amended into the LQD Permit to Mine No. 603.

Selenium Treatment Facility

A Selenium Treatment Facility has been constructed and is operating at a location approximately 9 meters (30 feet) southwest of Satellite No. 2. The facility houses the selenium treatment circuit and is connected to Satellites No's. 2 and 3 through buried pipelines. After selenium treatment, the water is returned to Satellite No. 2 for wastewater disposal. See **Figure 3.23** for the selenium plant floor plan.

Satellite No. 2 and the Selenium Treatment Facility both process wastewater currently being discharged into PSR-2 for subsequent land application. The treatment facility removes selenium to a target average concentration of 0.1 mg/L. The average selenium concentration of all samples taken from the PSR-2 compositor during the entire operating season (approximately March-October) must not exceed 0.1 mg/L selenium. The treatment facility includes a radium removal circuit that replaced the radium removal previously done at Satellites No. 2 and No. 3.

Waste/remediation water is first treated for radium removal using a barium chloride solution that precipitates radium. The radium compound precipitate is allowed to gravity settle and is then concentrated by a filter press. The filtered solids are disposed at an NRC licensed 11e.(2) byproduct material disposal facility.

Following radium removal, the remediation stream is processed in selenium removal columns. The spent media of the columns is cleaned in sand washing equipment. The resulting precipitate is allowed to gravity settle and is then concentrated in a filter press. The filtered solids are disposed at an NRC licensed 11e.(2) byproduct material disposal facility.

The washed sand media is recharged with iron to reestablish the 5:1 volume ratio and put back into the selenium removal columns for further processing.

3.6.2.4 Equipment, Instrumentation and Control

The satellite buildings will house IX columns, water treatment equipment, resin transfer facilities, pumps for injection of lixiviant, disposal well equipment, RO units (SR-1 and SR-2) and chemical reductant/bioremediation materials for groundwater restoration, a laboratory area, offices, and employee break rooms. Satellite No. 2 uses CO_2 and O_2 and has one operating RO unit used for groundwater restoration purposes. The interior layout for this Satellite is depicted on **Figure 3.23**. Satellite No. 3 uses CO_2 and O_2 and does not have a RO unit. The interior equipment layout is depicted on **Figure 3.26**. Satellite SR-1 uses CO_2 and O_2 and has one operating RO unit used for groundwater restoration. The interior equipment layout for this satellite is depicted on **Figure 3.28.** Finally, Satellite SR-2 uses sodium bicarbonate, CO_2, and O_2 and has one operating RO unit used for groundwater restoration. The interior layout for this Satellite is provided on **Figure 3.30**. As shown on the figures, each satellite IX system consists of varying numbers of fixed bed IX vessels. The layout and size of each building is different. CO_2 and O_2 are stored in compressed form adjacent to the satellite buildings or in the mine unit areas.

Header house and main trunkline instrumentation and control for the Smith Ranch satellites are similar to that described in Section 3.6.1.4.

3.6.3 North Butte Remote Satellite[5]

3.6.3.1 General Facility Layout

The surface facilities at the North Butte Remote Satellite will include the wellheads, header houses, buried pipelines, overhead and buried power lines, facilities access roads, deep disposal wells, surge ponds and the satellite IX building. The satellite building is located in the NE¼ Section 24, T44N, R75W. The building occupies approximately 2,378 meters^2 (25,600 feet^2) and is designed to operate with a maximum flow of **22,709** liters/minute (6,000 gallons/minute) during operations. Mineral processing and water treatment facilities will be located at the satellite facility shown on **Figure 1.10**. The water treatment facilities include the surge ponds, also shown **on Figure 1.10**. The detailed design and design report for the surge ponds are provided in **Appendix D, North Butte Surge Pond Design**.

Pipelines and power lines follow access roads. **Figure 1.10** depicts the proposed locations of main and secondary access roads. Additional detail and wellfield access roads for Mine Unit No. 1 are shown on **Figure 3.35, Primary and Secondary Access Road Construction**. As shown on **Figure 3.35** power lines and pipelines will run along opposite sides of the access road . Power lines will be constructed to meet current codes for wildlife protection. Pipelines within the mine unit wellfields and from the header houses to the main collection and distribution lines will nominally be 20 centimeters (8 inches) in diameter or smaller. The main collection and distribution pipelines will nominally be up to 61 centimeters (24 inches) in diameter. The main pipeline corridor will house up to eight lines to facilitate water handling, treatment, recycling, and groundwater restoration. The location of the satellite facility is shown on **Figure 1.10**.

---

[5] The design, construction and operation of the North Butte Satellite was amended into License SUA-1548 with ORC/SERP 10/12-2, approved February 2013.

3.6.3.2 Ion Exchange/Lixiviant Makeup Circuit

The IX/lixiviant makeup circuit for the North Butte Remote Satellite is described in Section 3.6.1.2, except that the uranium bearing solution is piped to the North Butte Remote Satellite.

3.6.3.3 Wastewater Management

The four primary process wastewater streams for North Butte are the same as that for the Smith Ranch satellites.

All of these waste streams will be combined and treated in the satellite as follows:

1. Filtration to remove suspended solids;
2. Disposal via a Class I UIC injection well(s).

In addition to the disposal wells, two surge ponds will be installed to assist in the wastewater disposal. **Figure 3.36, North Butte Wastewater Treatment Schematic** provides a schematic describing wastewater treatment at the North Butte Remote Satellite.

Wastewater disposal at the North Butte Remote Satellite currently consists of Class I UIC injection wells. As production and restoration progresses at a site, additional disposal capacity may be necessary. Cameco projects these needs on an annual basis by updating the water balance and surety estimate to take into account activities that have occurred during the year and operations that are planned for the coming year. Additional wastewater disposal facility decisions are made dependent upon the results of these annual updates. Additional disposal capacity at North Butte may be created through the permitting of additional deep disposal wells, land application facilities and possibly solar evaporation ponds. Other technologies may also be considered such as enhanced evaporation techniques, enhanced water treatment and recycling or other methodologies.

Class I Injection Wells

Cameco has an existing Class I UIC permit for two deep disposal wells. Currently, (January 2012) Cameco is drilling one test well at the North Butte Remote Satellite in preparation for installing the two disposal wells[6]. The North Butte Remote Satellite will ultimately have four Class I UIC wells. The installation of these wells will be staged to be installed as needed for operation and restoration requirements. The proposed location of these wells is shown on **Figure 1.10**.

The instrumentation and control system of the well will minimize adverse effects of injection fluid spills to the environment by limiting the amount of fluid released and providing immediate indicators of potential well integrity issues. Each disposal well will be equipped with a high pressure shutoff switch on the injection tubing to prevent operation of the injection pump at pressures greater than the limiting surface injection pressure. Each well will be equipped with a low pressure shut-down switch on the surface injection line that will deactivate the injection pump in the event of a surface leak. Finally, each installation will include a high/low pressure shut down switch with a pressure sensor on the tubing/casing annulus. This switch will stop the injection pump in the event of either a tubing leak or a casing, packer or wellhead leak.

Back-up for the automatic emergency shut down systems will include local displays and instrumentation metering in the satellite control room and at the wellhead building. Disposal well systems will be inspected once per shift**. Figure 1.10** shows the disposal well equipment layout within the satellite. In addition to the disposal wells, two surge ponds will be installed to assist in the wastewater disposal. **Figure 3.36**

[6] As of 2014, one Class I UIC disposal well is in operation at the North Butte Remote Satellite

provides a flow chart for the wastewater disposal system and **Figure 3.37, North Butte Disposal Well Building Layout** describes the disposal well building layout.

Surge Ponds

The North Butte Remote Satellite design includes the construction of a surge pond to contain wastewater from the satellite facility. The overall pond dimensions will be approximately 85 meters by 104 meters (280 feet by 340 feet) and will be divided into two cells. The cell bottoms will have approximate dimensions of 15 meters by 37 meters (50 feet by 120 feet) and the pond side slopes will be constructed at 3:1. The majority of the pond will be below grade and the second cell will provide redundancy. The pond location is shown on **Figure 1.10**. Pond design details, the geotechnical investigation and final design report are provided in **Appendix D**. Additional information, including operations and maintenance recommendations and closure requirements are included in the same attachment. The ponds will have a double synthetic liner with a leak detection system between the two liners. The upper liner will consist of a 1.5-mm (60-mil) HDPE liner, and the lower liner will consist of 1-mm (40-mil) HDPE. Underlying the lowest synthetic liner will be 1 meter (3 feet) of compacted clay. The leak detection system will consist of a perforated 5-centimeter (2-inch) diameter collection pipe system with a sump (well) as presented on the design drawings (**Appendix D**). The sumps will be monitored daily for the presence of fluid as long as the ponds are in use.

The design of the ponds has met the guidance provided in NRC Regulatory Guide 3.11, "Design, Construction and Inspection of Embankment Retention Systems at Uranium Recovery Facilities" and the standards provided in 10 CFR Part 40, Appendix A, Criterion 5(A). The standards and requirements referenced above apply to tailings impoundments, and some of the requirements are not applicable to the design of surge ponds.

Evaluation criteria for selection of the liner system included:

1. The liner material's physical and chemical inertness to the materials to be stored in the ponds;
2. The top liner's physical and chemical inertness to ultra violet exposure; and
3. Method of placement, seaming requirements and puncture resistance.

Surge Pond Probable Maximum Flood Hydrologic Analysis

According to the NRC Regulatory Guide 3.11: "*If impoundments are designed to contain only direct precipitation that falls into the reservoir area, a single occurrence of the 6-hour probable maximum precipitation (PMP) may be used to determine storage capacity and freeboard requirements. If the tailings retention system has some external drainage area, and hydraulic structures (such as diversion channels) are needed to safely divert the probable maximum flood (PMF), the peak PMF inflows and runoff used to design such structures should be determined in accordance with the suggested flood design criteria in NUREG-1623, 'Design of Erosion Protection for Long-Term Stabilization'"*.

The surge pond will be constructed on top of a ridge as shown in **Figure 1.10**. To site the surge pond at an elevation high enough to be protected from the PMF, a model was created routing the PMP through each of the two adjacent drainages. Cameco has allowed for 1.5 meters (5 feet) of freeboard in accordance with the design report and design considerations presented in **Appendix D**. Using the Hydrometeorological Report No. 55A (Hansen et al., 1988), the 6-hour PMP was identified for the North Butte license area as 48 centimeters (19 inches).

The HydroCAD model was used to predict flood flows throughout the North Butte permit area and was also used to evaluate the hydrology and hydraulics in the vicinity of surge ponds. The model generates hydrographs for individual basin areas, and hydrographs are routed downstream through channels and/or reservoirs. Multiple sub-areas can also be modeled within a given watershed model.

HydroCAD uses the Soil Conservation Service runoff curve number calculation method to predict flood flow. A curve number of 76 was used for the upper portions of several of the basins, in particular those that abut the North Butte, where outcrop or thin soils visible on aerial imagery suggest lower infiltration rates. An average curve number of 70 was used in the lower, downstream sub-basin areas where outcrop was not visible and/or well drained soils are indicated. The predicted discharges conservatively exclude storage within the several stock ponds in the basin, even though these ponds likely would retain a portion of predicted runoff.

Based on the difference between the existing land surface relief and the calculated PMF flood stage for the two drainages west and east of the surge pond, the natural topography should pass the flow associated with a PMP. No diversions will be required. **Table 3-9, PMP Hydrologic Analysis** shows the results of the HydroCAD modeling including the calculated flood stage in each of the drainages. **Table 3-9** also lists the approximate topographic relief between each drainage invert and the existing land surface grade at the location of the surge pond.

3.6.3.4 Remote Satellite Plant Equipment, Instrumentation and Controls

The North Butte Remote Satellite building will house IX columns, water treatment equipment, resin transfer facilities, pumps for injection of lixiviant, disposal well equipment, RO units and bioremediation materials for groundwater restoration, a laboratory area, offices, and an employee break room. The IX system consists of ten fixed bed IX vessels. The IX vessels will be operated as four sets of two vessels in series with two vessels available for restoration. WDEQ Permit Application, Figure OP-13 shows the equipment layout for the proposed satellite building. CO_2 and O_2 will be stored in compressed form adjacent to the building or in the mine unit areas. Header house and main trunkline instrumentation and control for the North Butte Remote Satellite are similar to that described in Section 3.6.1.4.

3.6.4 Gas Hills Remote Satellite

3.6.4.1 General Facility Layout

The surface facilities at the Gas Hills Remote Satellite will include the wellheads, header houses, buried pipelines, pump stations, overhead and buried power lines, facilities access roads and the satellite IX buildings, which includes the Carol Shop, designated as the Carol Shop Satellite Building. Mineral processing and water treatment facilities will be located at the Carol Shop Satellite Building (SW1/4, Section 33, T33N, R89W) and Gas Hills Alternative Satellite Building shown on **Figures 1.11** and **1.12**. During production operations, this facility will have a capacity of approximately 51,095 liters/minute (13,500 gallons/minute) for both the Carol Shop (34,063 liters/minute or 9,000 gallons/minute) and Alternative Satellite (**17,032** liters/minute or 4,500 gallons/minute). The final product from Gas Hills will be loaded IX resin or yellowcake slurry, which will be transported to the Highland CPF. The yellowcake slurry will only be produced at the Carol Shop.

The water treatment facilities will include the evaporation ponds, shown on **Figures 1.11** and **1.12**. The design and details for the evaporation ponds are provided in **Appendix E, Gas Hills Evaporation Pond Design.** Cameco is also evaluating the efficiency of deep disposal injection for the wastewater.

Due to the different elevations of the wellfields and the distant satellite facilities, several injection composite (IC) pump stations, called IC Boosters, will be required. Preliminary engineering work indicates that IC Booster No. 1 will be designed for a peak operating flow of 34,020 liters/minute (9,000 gallons/minute) and provide a pressure increase of 0.76 MPa (110 psig). IC Booster No. 2 will be designed for a peak operating flow of 26,460 liters/minute (7,000 gallons/minute) and provide a pressure increase of 0.41 MPa (60 psig). IC Booster No. 3 will be designed for a peak operating flow of 26,460 liters/minute (7,000 gallons/minute) and provide a pressure increase of 0.41 MPa (60 psig). Preliminary schematics of these booster stations are included as **Figure 3.38, Pump Station No. 1 – Typical Layout** and **Figure 3.39, Pump Station No. 2 and No. 3 – Typical Layout**. The final design of the booster stations, and their actual locations, will be determined during the detailed engineering for each mine unit. Approximate locations of these booster stations are shown on **Figures 1.11** and **1.12**.

Pipeline and power lines will follow access roads wherever possible. **Figures 1.11 and 1.12** depict the proposed locations of main and secondary access roads. Additional detail and wellfield access roads for Mine Unit No.1 are shown on **Figures 3.16** and **3.17**. Pipelines within the mine unit wellfields and from the header house to the main collection and distribution lines will typically be 20 centimeters (8 inches) in diameter or smaller. The main collection and distribution pipelines will typically be up to 61 centimeters (24 inches) in diameter. The main pipeline corridor will house up to eight lines to facilitate water handling, treatment, recycling, and groundwater restoration.

3.6.4.2 Uranium Recovery Process

Ion Exchange/Lixiviant Makeup Circuit

The IX/lixiviant makeup circuit for the Gas Hills Remote Satellite is described in Section 3.6.1.2, except that the uranium-bearing solution is piped to the Carol Shop or Alternative Gas Hills Remote Satellites.

Resin Loading/Elution Circuit

The resin loading/elution circuit will be the same as described above for the Smith Ranch satellites and the North Butte Remote Satellite.

Precipitation Circuit

The rich eluate containing the uranium will be routed to tankage for temporary storage ahead of the batch or continuous precipitation circuit. To initiate the precipitation cycle, hydrochloric or sulfuric acid will be added to the uranium-bearing solution to convert the uranyl carbonate present in the solution to uranyl chloride or uranyl sulfate, both soluble species for precipitation. Hydrogen peroxide and sodium hydroxide will then be added to the acidified eluate to precipitate the uranium as uranyl peroxide or sodium diuranate. The addition of hydrogen peroxide lowers the pH of the solution and optimizes crystal growth and settling. Sodium hydroxide adjusts pH. The uranium precipitate will then be allowed to settle. The uranium depleted supernate solution is removed and stored for re-use in future elutions as lean eluate are disposed via evaporation ponds or deep well injection. Sodium chloride and sodium carbonate will be added to the lean eluate as needed for reconstitution.

Precipitate Dewatering, Filtration and Transport

The resulting slurry from the elution/precipitation circuit will be transferred to a storage vessel where the uranium will continue to precipitate and consolidate by gravity. The precipitated and thickened yellowcake slurry will be filter pressed to remove soluble contaminants and then dewatered prior to packaging. The dewatered yellowcake slurry product will be placed into DOT approved containers and transported to the Highland CPF in exclusive-use DOT-authorized transport vehicles.

3.6.4.3 Wastewater Management

There will be four primary process wastewater streams for Gas Hills, similar to other Smith Ranch SUA-1548 Project satellites. All of these waste streams will be combined and treated in the Carol Shop satellite as follows:

1. Filtration to remove suspended solids;
2. Volume reduction using RO, ultra-filtration, nano-filtration, elecrodialysis reversal, thermal concentration, and/or a combination of the above methods to reduce the volume as needed;
3. Solar evaporation of the reject concentrated fluid in evaporation ponds, which may include limited evaporation sprayers or forced evaporation and crystallization of the solids in solution; and
4. Reinjection of reject concentrated fluid via a deep disposal well (pending permit approval).

Wastewater disposal at the Gas Hills Remote Satellite site consists of solar evaporation ponds and potentially Class I UIC injection wells. As production and restoration progresses at the site, additional disposal capacity may be necessary. Cameco projects these needs on an annual basis by updating the water balance and surety estimate to take into account activities that have occurred during the year and operations that are planned for the coming year. Additional wastewater disposal facility decisions are made dependent upon the results of these annual updates. Additional disposal capacity at the Gas Hills Remote Satellite may be created through the permitting of additional solar evaporation ponds, UIC Class I deep disposal wells or land application. Other technologies may also be considered such as enhanced evaporation techniques, enhanced water treatment and recycling or other methodologies.

Evaporation Ponds

As previously described, the Carol Shop Satellite Building will house the final water treatment facilities for the Project. The two evaporation ponds (**Figure 1.11)** will be constructed for the disposal of bleed and process fluids during the first phase of development. The design and technical specifications, geotechnical engineering study, operations and maintenance plan and closure plan for Ponds 1 and 2 are provided in **Appendix E. Figure 1.11** shows the locations of four additional evaporation ponds, but the evaporation pond design has not been completed for Ponds 3, 4, 5 and 6. Cameco intends to use deep disposal well technology as the primary means of wastewater disposal. Cameco will be drilling two test holes (2012) to evaluate the efficacy of deep disposal wells at the Gas Hills Remote Satellite. If these wells are successful, Cameco may not construct Ponds 3, 4, 5 and 6. If construction is proposed, detailed designs of these facilities will be presented to the NRC in advance of construction.

The water treatment plan provides sufficient capacity to store all of the waste fluids described above. The ponds have been designed with freeboard capacity exceeding the designed operating levels, such that each pond has sufficient capacity to hold the combined anticipated operating volume of both ponds. This is necessary to allow evacuation of one pond into another in the event that a pond requires servicing. The pond capacity will allow for increase in the waste streams and for precipitation, and for decreases due to solar evaporation. Pond design will isolate ponds from surface water input.

Ponds 1 and 2 will have an active surface area of approximately 2 hectares (5 acres). The combined storage capacity of the evaporation ponds is approximately 27,137 meters^3 (22 acre-feet), with a normal operating freeboard of 1.5 meters (5 feet).

Design of Evaporation Ponds

The basic design criteria for the evaporation ponds will comply with the standards provided in 40 CFR 264.221 and will, as a minimum, include the following:

1. Excavated materials from the pond will be used to construct berms which will isolate the ponds from the surrounding surface drainage and increase the pond capacity to provide for freeboard and storage of additional direct precipitation.
2. The ponds will have a primary synthetic liner consisting of a AGRU HDPE Drain Liner™, or equivalent, with a typical thickness of 1.5 mm (60 mils). This type of geomembrane is produced with a series of studs on one side. The studs have a typical asperity height of 3.7 mm (145 mils). The studs provide a gap between the primary and secondary geomembrane resulting in in a geosynthetic drainage layer.
3. Underlying the primary HDPE Drain Liner™ will be a secondary liner of 1 mm (30-mil) PVC or an equivalent material. Together, the primary and secondary liners provide a synthetic porous media for the leak detection system. Under a confining load of 718 kPa (15,000 psf), manufacturer testing indicates a transmissivity of this layer ranges from 2E-3 to 1E-2 m^2/sec. The expected load for the liner is 24 kPa (500 psf), and the transmissivity of the system should far exceed 3E-4 m^2/sec or greater specified under 40 CFR 264.221(c) (2)(ii). A piping network consisting of perforated drain pipes will be constructed between the primary and secondary liners. The perforated piping will connect to a solid conveyance line and ultimately to a leak detection well where fluid can be collected and sampled. Each pond will have two perforated drain pipes and two leak detection wells.
4. The leak detection piping will be installed at a nominal 0.5% grade and will flow under gravity to the leak detection well. The bottom of each pond will be sloped at a minimum of 1% grade to the leak detection piping.
5. To minimize the migration of pond fluids into the subsurface should the secondary liner leak, the underlying surface of the pond will be constructed with at least 0.91 meters (3 feet) of compacted soil material having an hydraulic conductivity of no more than 1E-7 cm/sec (4E-8 in/sec).
6. The leak detection system will be constructed of materials that are chemically resistant to the pond fluids, and of sufficient strength and thickness to prevent collapse under the pressure exerted by the overlying fluids.

Design Capacity

The two evaporation ponds are designed with sufficient capacity such that one pond can contain the combined maximum operating capacity of both ponds and allow for a minimum emergency freeboard of 0.5 meters (1.6 feet). The Gas Hills Remote Satellite water balance (see **Table 3-10, Gas Hills Water Balance**) details the production schedule and pond water accumulation estimates. Forced evaporation equipment equivalent to 245,000 $meters^3$ (199 acre-feet) per year of disposal capacity will be added at the beginning of operational Year 5. Beginning in operational Year 7, an additional equivalent of 245,000 $meters^3$ (199 acre-feet) of disposal capacity will be added by the installation of additional forced evaporation equipment. As additional disposal capacity is required, Cameco will prepare and submit final pond designs and/or information pertaining to the deep disposal wells in advance of the demand for this evaporation capacity.

Forced evaporation and crystallization has been used for many years at power plants across the U.S. to treat and recycle saturated wastewaters using a distillation and crystallization process. The evaporator system heats the wastewater feed to the boiling point. The steam is then allowed to cool resulting in a condensate of distilled water. The waste brine generated by the evaporator is transferred to the crystallizer where it is heated to drive off residual moisture and reduce it to a dry solid which can be removed and stored for disposal as **a** solid 11e.(2) byproduct material. Based on the current water balance, it is estimated that during peak operational periods, the forced evaporation process could generate as much as 3,500 meters^3 (4,600 yards^3) of solid byproduct material per year.

Evaporation Ponds 1 and 2 have been designed to operate during normal operations with a storage capacity of 13,500 meters^3 (11 acre-feet) per pond or a combined capacity of 27,000 meters^3 (22 acre-feet). The approximate total capacity of each pond is 32,070 meters^3 (26 acre-feet), and the combined approximate capacity is 64,140 meters^3 (52 acre-feet). Allowing for a 0.6 meter (2 feet) maximum freeboard, the available storage capacity for each pond is approximately 49,340 meters^3 (20 acre-feet) with a combined capacity of 49,340 meters^3 (40 acre-feet). This additional capacity will contain wind and wave action and storage in the event of a high intensity precipitation event. It will also provide for the evacuation of the contents of one pond into the other in the event that a pond is taken out of service for repairs and/or removal of solids.

The maximum cumulative project storage requirements are projected to be when Mine Unit No. 2 begins active restoration. The additional ponds or deep disposal wells will be constructed earlier than needed to provide surge capacity for planned maintenance of water treatment equipment and other unforeseen operational problems. The proposed operation of the ponds will provide redundancy in the case of a liner leak. Pond 1 or 2, operating at the normal operational level, will have sufficient storage capacity for the contents of both ponds. The ponds are designed for the worst-case scenario of a leak at the lowest point of the liner in one pond, requiring total evacuation of one pond into the other. The normal operational capacity for one pond is approximately 13,500 meters^3 (11 acre-feet). In the event of a leak, one pond will hold approximately 27,140 meters^3 (22 acre-feet) required to hold the contents of both ponds with sufficient freeboard capacity (under normal wind conditions).

Freeboard capacity is based on estimated wave height and direct precipitation, as follows (English units were maintained for consistency with cited reference):

1. Wave Height: A site-specific comparison of wind data to the regional NOAA reporting stations. Based on this comparison, the long-term wind data for Casper, Wyoming, Natrona County Airport is the most representative source of long-term wind data. The data shows that peak average monthly wind speeds occur during the months of December and January averaging approximately 33.8 kilometers/hour (21 miles/hour). If the ponds were full, the maximum fetch (the diagonal measurement of the ponds) is approximately 113 meters (370 feet) or 0.1 kilometers (0.07 mile). Based on these conditions, the significant wave height calculates (after Linsley et al., 1992) as:

   Wave Height = (0.034) wind velocity (21.2 miles/hour)$^{1.06}$

   Fetch (0.07 mile)$^{0.47}$ = 0.08 meters (0.25 feet).

If the same calculation were made for wind at 97 kilometers/hour (60 miles/hour), or three times the average, the resultant wave height would be 0.23 meters (0.75 feet).

2. Direct Precipitation: The 6-hour PMP event is estimated at 30 centimeters (12 inches) of rainfall. The maximum pond surface area is approximately 0.8 hectare (2 acres). Thus, a PMP event would add approximately 2,500 meters^3 (2 acre-feet) of water to the pond. The addition of 2,500 meters^3 (2 acre-feet) of water from a PMP storm would result in an increase in water level of approximately 0.3 meters (1 foot).

In summary, the combination of design freeboard, direct precipitation and wave action, would require a minimum freeboard of approximately 0.5 meters (1.6 feet) for average wind speeds and approximately 0.6 meters (2 feet) with winds at 97 kilometers/hour (60 miles/hour). The combination of events necessary for the ponds to reach the emergency freeboard would include (a) both ponds operating at maximum capacity, (b) the occurrence of a PMP rainfall event, and (c) simultaneous winds in excess of 97 kilometers/hour (60 miles/hour). Since this combination of events is very unlikely, and there is a small effective fetch length for the build-up of wind, the design capacity provides an adequate margin of safety with respect to storage capacity and wave action.

To divert surface runoff that could cause overtopping and erosion of the ponds away from the evaporation ponds, the design of several drainage diversion ditches, one drainage control berm, and the Carol Shop Road has been modified. The design addresses the diversion of surface water runoff away from the evaporation ponds as discussed later in this TR.

Dam Stability Analysis

The State of Wyoming Safety of Dam Regulations apply to dams with either impoundment structures in excess of 7.6 meters (25 feet) in height or capacities in excess of 62,000 meters^3 (50 acre-feet). The proposed ponds will have above-grade embankment heights less than 7.6 meters (25 feet) and individual operating capacities less than 62,000 meters^3 (50 acre-feet), and will, therefore be exempt from the Safety of Dams Regulations.

In accordance with Regulatory Guide 3.11 (NRC, [2008]), a stability analysis for Ponds 1 and 2 is provided in **Appendix E**. The analysis concludes that the pond slopes, both interior and exterior, will be stable in the post-construction condition and the steady-state seepage condition.

Construction Methods

During construction, site inspection quality control testing will be completed under the direction of a professional engineer registered in the State of Wyoming and experienced in similar construction requirements and/or methods. Construction and testing methods will adhere to the most recent version of ASTM procedures and/or manufacturer's recommendations. Synthetic liner specifications, including installation details, seaming details, anchoring procedures, and quality assurance/quality control (QA/QC) Procedures, will be submitted to LQD for review prior to pond construction. The basic construction sequence will be in accordance with WQD Rules & Regulations Chapter 11, Part C. Technical specifications for the construction of the ponds are provided in **Appendix E**.

The design of all of the ponds incorporates a local balance of earthwork cut and fills for each pair of ponds. Available topsoil will be salvaged and stockpiled locally. Approximately 6,650 meters^3 (8,700 yards^3) of excess material will be generated during the construction of the two ponds. During reclamation, the berm material will be used as backfill to restore the ponds to their approximate original contours, and stockpiled topsoil will be replaced.

Prior to designing the evaporation pond, 13 geotechnical borings were drilled in the proposed location of the ponds. The depth of the borings ranged from approximately 5 to 11 meters (15 to 37 feet) below grade. Samples were collected to determine in-place density, size gradation, Atterberg limits, soils classification, presence or absence of shallow groundwater, and moisture density relationships. Shallow groundwater was not encountered in any boring. The complete geotechnical engineering study is provided in **Appendix E**.

Inspection and Maintenance

The evaporation ponds will be visually inspected daily for normal operation and condition of ancillary features. Ancillary features include the exposed liner above the water surface, the berm, fences and diversion and/or storm runoff control measures. In addition, the leak detection manhole will be visually inspected daily, and the sump pump will be tested at least once every two weeks. These inspections will be documented and maintained on site. If flow from the leak detection sump pump is observed, the water will be sampled and analyzed for chloride, bicarbonate and conductivity. Should the analysis indicate that a pond is leaking, a verification sample will be collected within 24 hours of receipt of the first analysis results. If the analytical results of the verification sample verify that the pond is leaking, the NRC and LQD will be notified by telephone within 24 hours of verification. Within 5 days of the verbal notification, a written report will be submitted to NRC and LQD. The report will include analytical data and describe mitigation actions and the results of those actions. Once every seven days during the leak and for two weeks following completion of repairs, water will be sampled from the leak detection sump and analyzed for chloride and conductivity. Once per month while the pond is leaking, water will be sampled from the leak detection sump and analyzed for the suite of parameters contained in LQD Guideline 4, Reference Document 10, Table 2.

Once a leak has been verified and reported, the contents of the leaking pond will be transferred into another pond or ponds, and an investigation will be conducted to determine the source of the leak. This investigation will include inspection of the manhole and individual drain line clean out systems. When the source of the leak has been identified, appropriate actions will be taken to repair damage to the system.

Once the pond liner has been repaired and tested, the agencies will be notified verbally or in writing (via a letter or e-mail) that the pond has been repaired and is being put back into service. A final report describing all remedial and repair activities will be provided to the agencies within 60 days after repairs have been completed.

Diversion Hydrology

The design addresses the diversion of surface water runoff away from the evaporation ponds. NRC Regulatory Guide 3.11 recommends that "there shall be no release of process solids or fluids from the evaporation ponds." To address this guidance, the NRC recommended that the designed diversion structures accommodate the PMP event. The PMP is considered the most severe rainfall event probable and is defined by the World Meteorological Organization as "theoretically the greatest depth of precipitation for a given duration that is physically possible over a given storm size area at a particular geographic location."

Since the life of the evaporation pond structures will be less than 30 years, the PMP design is extremely conservative. Cameco has committed to active monitoring and routine inspection of hydrologic and storm water control structures. If a hydrologic structure were damaged, Cameco would repair that structure as part of their ongoing maintenance program.

The design objective is to ensure that there is minimal erosion to the diversion channel or the evaporation pond berms. Channel flow velocities during the passage of the PMF will range from 1.3 to 2.7 meters/second (4.3 to 8.9 feet/second). No riprap protection is proposed or required. Although the PMF velocities could exceed the typical non-erosive velocities of 1.5 meters/second (5 feet/second) or less, the highest channel velocities will occur within the "cut" portion of the diversion channel. The adjacent diversion channel berm will provide PMF freeboard. The evaporation pond process fluids will be isolated from the concentrated flow of the storm by the (1) "cut" diversion channel; (2) diversion channel "compacted" berm; and (3) "compacted" evaporation pond berm. The higher velocity channel flows will not impact the evaporation pond berm. A final design consideration recognizes that the duration of the PMF will be relatively short, and repair of these diversion structures will be performed as soon as practicable following the passage of the PMF or erosion-causing event.

Seven PMF drainages have been shown on **Figure 3.40, PMF Diversions and Evaporation Ponds**. Six of these drainages will require construction of a channel diversion or ditch. The general location of these proposed structures is shown on **Figure 3.40**. Design details as well as hydrologic and hydraulic computations are also shown on **Figure 3.40**. The complete drainage basin boundaries for all seven basins can be found on **Figure 3.40**. The magnitude of the 1-hour PMP was determined using methods described in Hydrometeorological Report No. 55A (HMR-55A, Hansen, et al., 1988) and is estimated to be 23 centimeters (8.9 inches).

PMP runoff hydrology for small basins (those less than 40 hectares or 100 acres) was determined using the Rational Method:

Where:

Q	= PMF peak discharge in cubic feet per second
C	= 1.0
i	= PMP intensity in inches per hour
A	= Drainage basin area in acres

The runoff coefficient, C, was assumed to be 1.0, suggesting that there will be no infiltration of rainfall. Smith Ranch WDEQ Permit Addendum OP-1 presents the rainfall intensity curve applicable to the Rational Method calculations for Basins B-1, B-2, B-4, B-5, B-6, and B-7.

Site Location: Gas Hills, Wyoming

Average Site Elevation = 6,800 ft AMSL

Max 12-hr Dew Point = 24 degrees Celsius (75.2 degrees Fahrenheit)

Drainage Basin Size:

Basin 1 =	7.9 hectares (19.5 acres)	$Q_{(pmf)}$ = 15 meters^3/second (520 feet^3/second)
Basin 2 =	37.0 hectares (91.5 acres)	$Q_{(pmf)}$ = 60 meters^3/second (2,125 feet^3/second)
Basin 3 =	613.1 hectares (1,515 acres)	$Q_{(pmf)}$ = 361meters^3/second (12,750 feet^3/second)
Basin 4 =	7.5 hectares (18.5 acres)	$Q_{(pmf)}$ = 17 meters^3/second (590 feet^3/second)
Basin 6 =	8.5 hectares (21.1 acres)	$Q_{(pmf)}$ = 18 meters^3/second (645 feet^3/second)
Basin 7 =	16.7 hectares (41.2 acres)	$Q_{(pmf)}$ = 33 meters^3/second (1,155 feet^3/second)

PMP runoff hydrology for Basin 3 (613.1 hectares) was determined using the USACE Runoff Hydrology computer package (HEC1). To estimate the peak flow associated with the PMP event, a storm distribution was required for the HEC-1 analysis. The Soil Conservation Service Type II rainfall distribution was used for the 6-hour PMP rainfall. A Curve Number of 87.6 was used to describe the runoff characteristics of this well-vegetated native basin. **Appendix F, Gas Hills Drainage Basin Hydrology (HEC-1 Input/Output)** presents the HEC-1 input and output file and the hydrologic computations for Basin B-3.

Basin 1 generates and delivers water to drainage diversion DD-1. Although this basin exhibits no well-defined drainage, water from this slope could affect the berms around Evaporation Ponds 1 and 2. DD-1 is designed to capture and pass the PMF around the constructed evaporation ponds.

Basin 2 generates and delivers water to drainage diversion DD-2, which ultimately delivers runoff to WCC. This is a relatively large (37 hectares or 91.5 acres) drainage area and is characterized by a well-defined ephemeral drainage. The PMF design incorporates construction of a large trapezoidal channel and an adjacent berm to ensure that the PMF does not negatively impact Evaporation Ponds 1 and 2.

There are several existing gullies that will intersect the new DD-1 and DD-2. In some cases, these existing gullies may intersect at sharp angles. Cameco will transition all existing gullies into the diversion channel to reduce erosion during the more frequently occurring runoff events. In a similar manner, Cameco will transition all diversion channels into their receiving waters to ensure a smooth hydraulic entrance condition with minimal adverse impact to the receiving waters.

Cameco proposes to lower the Carol Shop Road in accordance with the plan presented on **Figure 3.40**. This will ensure that (1) WCC meets the above-described PMF design criteria and (2) the Carol Shop Road will not act as a dam diverting WCC flow into the adjacent Evaporation Pond 1 and 2 Basins (Basin B-2). Basin 3 generates and delivers water to WCC, which is a native intermittent stream in the general area of the project. The constructed weir geometry will ensure that the entire PMF will remain within the WCC basin and not adversely affect Evaporation Ponds 1 and 2. Cameco does not propose to divert or reroute WCC. Where the Carol Shop Road crosses WCC, Cameco has replaced existing culverts with new culverts, which are designed to convey the 25-year, 6-hour storm event.

If Evaporation Ponds 3, 4, 5 and 6 are constructed, Cameco proposes a second design to ensure that the waters of WCC will not adversely impact Evaporation Ponds 3, 4, 5 and 6. In the second design, the reconstructed Carol Shop Road will (a) initially act as a dam, (b) later will act as an outflow weir, and (c) finally will probably fail during the course of the PMF. The worst-case condition for WCC is during the period when the road is acting as a weir, and the water surface elevation for the PMF is at its highest. Based on Cameco calculations ($Q = CLH^{3/2}$), the water surface elevation for the PMF at the Carol Shop Road is 2,062 meters (6,765 feet) above mean sea level (AMSL). The toe of the embankment of the closest evaporation pond (northwest corner of Evaporation Pond 3) is 2,068 meters (6,785 feet) AMSL. The toe of the evaporation pond slope is 6.1 meters (20 feet) above the PMF water surface elevation. Since the evaporation ponds are adequately isolated from WCC, no diversion of WCC and no armor protection of the evaporation ponds is required.

Basins 4, 5, and 6 are small basins adjacent to Evaporation Ponds 3, 4, 5 and 6. Although these basins do not exhibit well-defined drainages, water from their adjacent basin slopes could impact the berms around Evaporation Ponds 3 through 6. DD-4, DD-5 and DD-6 are designed to capture and pass the PMF around the constructed evaporation ponds.

There are several existing gullies that will intersect these diversion ditches. As stated above for Basin 2, Cameco will transition all existing gullies into each diversion channel to ensure that there will be minimal erosion during the more frequently occurring runoff events. In a similar manner, Cameco will transition all diversion channels into their receiving waters to ensure a smooth hydraulic entrance condition with minimal adverse impact to the receiving waters.

Basin 7 originates from reclaimed ground to the south of the evaporation ponds. Diversion 7 (DD-7) collects the PMF from this basin and delivers it to an incised gully to the east of Evaporation Pond 6. The construction of DD-7 fully protects the embankment of the evaporation ponds from the PMF.

The pipelines leading from the wastewater treatment facility to the evaporation ponds will be buried a minimum of **1.5 meters** (5 feet) bgs to protect from freezing. To protect the pipeline crossing WCC from channel scour damage, the crossing portion of the creek will be protected with appropriately sized riprap, or the pipe will be run through an appropriately sized carrier pipe encased in concrete. Riprap will be sized to accommodate flows associated with the PMF without damage.

Estimated Quantity of Evaporation Pond Water and Content of Evaporation Solids

Using the estimated Gas Hills lixiviant concentration in Section 3.5.3.1, the Water Balance and Evaporation Pond fluid Inventory (**Table 3-10**) as input data, the amount of TDS in the water was estimated using the RO manufacturer's (Hydranautics, Inc.) design program. The estimate assumes that all of the TDS contained in the treatment reject fluid would become a solid needing to be disposed of offsite. The solids formed by the water treatment process will consist of salts of sodium and calcium dominated by carbonate and sulfate. Radium is expected to be the predominant radionuclide. The TDS concentration of the water treatment concentrate is anticipated to range from a high of 25,000 mg/L to a low of 3,500 mg/L, with an average concentration of 9,500 mg/L.

The high TDS water resulting from wastewater treatment will be sent exclusively to the ponds only during Years 1 through 4. At Year 5 and again at Year 6, forced evaporation/crystallization equipment will be installed which will essentially treat the waste stream to distilled water quality. At that time, the use of the ponds will shift from complete evaporation to surge capacity to provide for in-plant consumption and restoration water makeup as well as excess water disposal capacity for unanticipated operational upsets and equipment problems. The excess volume of treated water that will not be needed for in-plant consumption will be used for restoration water makeup, mine unit hydrologic control, or will be stored in the ponds. The forced evaporation process will remove all of the TDS from the wastewater stream at the treatment facility where it will be stored and periodically transported to and disposed as an 11e.(2) byproduct material at an NRC licensed disposal facility. The solid residue in the ponds resulting from liquid evaporation over the life of the Project will be equivalent to approximately 1.0% of the total working pond volume and will not affect the total pond capacity over the life of the Gas Hills Remote Satellite operations. The water balance (see Section 3.9.3) for the Gas Hills Remote Satellite accounts for the anticipated volume of sludge to be generated over the project life.

Class I Injection Wells

Cameco is investigating the feasibility of a mine wastewater disposal Class I injection well or multiple wells at the Gas Hills site as a disposal supplement to the planned evaporation ponds. If technically feasible, Cameco plans to add wastewater disposal via injection well(s) because (a) injection wells are less costly to operate and reclaim, and (b) there are fewer environmental concerns as compared to evaporation ponds. Injection wells dispose of concentrated process reject fluids underground, thereby eliminating the surface contamination concerns associated with evaporation ponds and greatly reducing the volume of 11e.(2) material that will require over–road hauling to distant permitted disposal facilities.

Cameco has already completed a preliminary geologic siting study that identified three candidate test injection well locations (see **Figures 1.11** and **1.12**). Based on a preliminary review of the currently available site groundwater quality and geologic data, WQD staff agreed that further site well testing and a UIC permit application for this site seem feasible. Two of the sites will be drilled in late 2011 or early 2012[7].

The feasibility of the injection well option is dependent upon favorable injectivity tests, groundwater quality of the receiving formation meeting the requirements for a Class I injection well, and approval of a WDEQ WQD UIC Class I injection permit. If down-hole testing of the initial test well(s) indicates that the

[7] Both test wells have been drilled, but testing and completion have been deferred until at least 2015.

well is suitable for injection, Cameco will proceed with preparation of a UIC permit application. Upon approval of the UIC permit, Cameco will provide a copy of the UIC permit and application to the regulatory agencies. Cameco will obtain the BLM and WSEO permits necessary to operate the proposed injection wells for wastewater disposal.

3.6.4.4 Remote Satellite Plant Equipment, Instrumentation and Controls

Carol Shop Remote Satellite Building

The Carol Shop Remote Satellite building will house IX columns, water treatment equipment, resin transfer facilities, yellowcake slurry facilities, pumps for injection of lixiviant, disposal well equipment, RO units and bioremediation materials for groundwater restoration, a laboratory area, offices, and an employee break room. The IX system consists of 12 fixed bed IX vessels. The IX vessels will be operated as six sets of two vessels in series with two vessels available for restoration. Gas Hills WDEQ Permit Figure OP3-2 shows the equipment layout for the Carol Shop satellite building. Gas Hills WDEQ Permit Table OP-3-1 Typical Tank Designations provides the Carol Shop satellite tank designations and sizes. CO_2 and O_2 will be stored in compressed form adjacent to the building or in the mine unit areas.

The Carol Shop building is approximately 5,294 meters^2 (56,985 feet^2), but only a portion of the building will be used for the ISR operations. Cameco is completing the final engineering design for the Carol Shop and **Figure 3.2** does not show the locations of the ancillary features (e.g., offices, employee breakroom) in the Carol Shop building. The Carol Shop Remote Satellite will be designed to operate with a maximum operating flow of 34,063 liters/minute (9,000 gallons/minute) and will include a central water treatment facility that can be expanded, as needed, to a capacity of approximately 4,542 to 5,677 liters/minute (1,200 to 1,500 gallons/minute) for treating production and restoration wastewater prior to its disposal. The alternative remote satellite building may not be built. In that case, the Carol Shop design will include the capacity to operate with a maximum flow of 51,095 liters/minute (13,500 gallons/minute).

Alternative Remote Satellite Building

An Alternative Remote Satellite facility **may** be installed as **an** IX, resin loading and unloading facility, and future restoration RO at one of the two locations shown on **Figure 1.12**. Bleed and restoration reject fluids from the associated wellfields will be transferred through pipelines to the central water treatment facility at the Carol Shop for treatment and disposal. The satellite will have an installed flow capacity of approximately 17,010 liters/minute (4,500 gallons/minute) of produced fluids. The layout for the Alternative Remote Satellite building is shown on **Figure 3.3**.

Header house and main trunkline instrumentation and control for the Gas Hills Remote Satellite will be similar to that described in Section 3.6.1.4.

Monitoring at booster pump stations will be very similar to header house monitoring. Each station will have leak proof floors and/or basements equipped with sumps and sump pumps. Each booster pump will have the capability of being remotely monitored running/not running, flow, pressure, temperature, voltage, and phase balance. Each pump will have the capability of being started and stopped remotely as well as remote flow adjustment.

3.6.5 Ruth Remote Satellite

3.6.5.1 General Facility Layout

The Ruth Remote Satellite is located about 10 kilometers (6 miles) east of Linch, in T42N, R77W (Johnson County) and consists of portions of Sections 1, 3, 14, 23, 24 and 26. As previously mentioned, all existing facilities at the Ruth Project are non-operational and on stand-by status. Currently, three buildings, two evaporation ponds and three monitoring wells are all that remain on the property. Cameco plans to extract uranium at Ruth within the next 10 years, but an operations plan that details the mine field layout, elution circuit and other details has yet to be developed. In general, the Ruth Remote Satellite will operate similar to the North Butte Remote Satellite, but the process flow rate will be lower at 3,780 liters/minute (1,000 gallons/minute).

3.7 Access Roads

3.7.1 Primary Access Roads

3.7.1.1 Smith Ranch

Smith Ranch is located in the southern Powder River Basin in Converse County. The main office complex and CPP are approximately 27 air kilometers (17 air miles) or 35 road kilometers (22 road miles) northeast of the town of Glenrock and approximately 37 air kilometers (23 air miles) or approximately 40 road kilometers (25 road miles) northwest of Douglas. Access to the site from the intersection of State Highway 93 and State Highway 95 is by Converse County Road 31, also known as the Ross Road. The Reynolds Ranch satellite is accessed via Ross Road. **Figure 1.3** shows the general project location and access to the mining area.

3.7.1.2 North Butte Remote Satellite

The North Butte Remote Satellite can be accessed from State Highway 50 near Savageton. From Highway 50, travel is west and south on Van Buggenum Road, then Christensen Road (approximately 10 kilometers or 6 miles) to an existing oil field road owned by T-Chair Ranch. There are two main access routes to the site that will use the T-Chair Road. To access the site from the northeast side of the permit boundary, travel along the T-Chair Road for approximately 2.1 kilometers (1.3 miles). At that point turn north onto a graveled CBM road and travel approximately 1.2 kilometers (0.75 mile) and turn west onto the Project Access Road. This road begins at a point located in the NE1/4, NE1/4 of Section 19, T44N, R76W. This access road is a combination of existing and new roadway that covers approximately 3 kilometers (2 miles) to the satellite IX facility. This access road is an existing road built by CCI during the initial development of the North Butte orebody. Cameco upgraded this road, which is within the permit boundary.

The access roads are shown on **Figure 1.10**. Road upgrade design documents and easement descriptions are provided in **Appendix G, North Butte Road Design**. Cameco will rehabilitate the existing roads by upgrading the level of service (top width, surfacing and grading). A 6.1-meter (20-foot) top width with approximately 7.6 to 15.2 centimeters (3 to 6 inches) of crushed gravel or scoria were placed on the road surface. The design included hydraulic evaluations to verify the capacity and condition of existing culverts in the road and to provide miscellaneous drainage. The upgrading and new construction of the access roads comply with the landowner's desires, as provided in letters to Cameco and LQD. New sections of road were constructed by blading the top 7.6 to 15.2 centimeters (3 to 6 inches) of soil to each side of the road and constructing a drain ditch on each side with the topsoil windrowed to the outside of each drain. The windrowed topsoil from the construction of the road and the drain was placed in the bottom of the drain and seeded. The typical road construction standard is presented on **Figure 3.35**. Where BMPs or alternate sediment control measures are required to ensure that no topsoil is lost, Cameco will commit to their implementation (see Section 3.8).

3.7.1.3 Gas Hills Remote Satellite

Primary access to the Gas Hills Remote Satellite can be either from Casper or Riverton. From Casper, access is via 80 kilometers (50 miles) of paved highway on US 20/26 to Waltman, then 40 kilometers (25 miles) southwest on unpaved, graded Natrona County Road 321 (also called the Gas Hills Road) to the Fremont County line. From the county line, the gravel road turns private and is locally called Dry Creek Road. Approximately 5 kilometers (3 miles) west of the county line, an unimproved dirt road, locally called the AML Road, turns south for approximately 6 kilometers (4 miles) and ends at the Carol Shop Road, a haul road used by previous conventional mine operators in the area. The Carol Shop Road leads to the Carol Shop complex and provides access to the majority of the site.

From Riverton, access is via 64 kilometers (40 miles) of paved highway on Wyoming State Highway 136, which ends at the Dry Creek Road. Approximately 6 kilometers (4 miles) east of the Highway 136 intersection is the AML Road, which leads to the Carol Shop Road and the Project site.

A ROW for the portion of the Dry Creek Road in the vicinity of the Project is held by Umetco Minerals. A portion of the road also crosses land owned by Philp Sheep Co. The road has been used for public access to the area for many years. Use agreements for the Dry Creek Road have been obtained from Umetco Minerals and Philp Sheep Co.

The AML Road (see **Figure 1.11**) was constructed by the WDEQ/AML program in 1989 to provide access to reclamation projects within and adjacent to the Project site. The road crosses land owned by Philp Sheep Co. and the BLM. A use agreement has been obtained from Philp Sheep Co. for that portion of the road that crosses their property. Prior to Project construction, Cameco will obtain a ROW from BLM for the portion of the AML Road administered by them, in accordance with 43 CFR 2800. Cameco will accept the maintenance and reclamation responsibility for that portion of the AML Road Cameco wishes to use as primary access to the site.

The AML Road and the portion of the Dry Creek Road that will be used for primary access will be upgraded with culverts and gravel surface prior to facilities construction, including proposed road realignments to allow for pond construction. Road upgrades will be in accordance with Fremont County and BLM standards (BLM Manual 9113-Roads and the BLM Gold Book). The upgraded roads will be approximately 7 meters (24 feet) in width and will be graded, drained, surfaced and capable of carrying highway loads. Professional engineering design and construction oversight will be used as necessary. Plans and designs for the upgrades will be submitted to LQD, BLM and Fremont County for review prior to commencement of road construction. As defined below, the BLM designation for these two access roads and the Carol Shop Road is “Local”.

BLM classifies roads into one of two broad categories (The Gold Book, 2007): non-constructed, or constructed. Monitor well ring access roads and access roads from mine unit header houses to individual wells fit the “non-constructed” road category. Non-constructed roads are “primitive” two-track roads or overland route corridors that have no graded or drained surfaces and are typically limited to four-wheel drive or high-clearance vehicles. They can consist of existing or new roads with minor or moderate grading; two-track roads created by direct vehicle use with little or no grading; overland routes within a defined travel corridor leaving no defined roadway beyond crushed vegetation; or any combination of the above. They should not be flat-bladed, and drainage must be maintained to avoid erosion or the creation of a muddy, braided road. They are not intended for use as all-weather access roads. Damage to the surface, such as mud-holes, ruts or washouts must be repaired as soon as possible by grading and/or placement of road base or gravel fill material.

Constructed roads are subdivided into three basic road types: resource, local, or collector roads, depending on expected traffic volume, seasonal or year-round use, soil types, rainfall, topography and construction.

Secondary access roads (from primary access roads to header houses) are a type of resource road. Resource roads are low-volume, single lane roads. They normally have a 3- to 4- meter (12- to 14-foot) travelway and "intervisible turnouts," where approaching drivers have a clear view of the section of road between the two turnouts and can pull off to the side to let the approaching driver pass. They are generally used for dry weather, but may be surfaced, drained, and maintained for all-weather use. These roads connect facilities to collector, local, or other higher-class roads. They serve low average daily traffic and are located on the basis of the specific resource activity need rather than travel efficiency.

Primary access roads (eg., Dry Creek Road, AML Road, and Carol Shop Road) are considered local roads. Local roads may be single-lane or double-lane with travelways 3 to 7 meters (12 to 24 feet) in width and intervisible turnouts. They are normally graded, drained, and surfaced and are capable of carrying highway loads. These roads provide access to large areas and are for various uses. They collect traffic from resource roads or facilities and are connected to collector roads or public highways. The location and standards for these roads are based on both long-term needs and travel efficiency.

Natrona County Road 321 is an example of a collector road. Collector roads are usually double-lane, graded, drained and surfaced, with a 6 to 7 meter (20 to 24 foot) travelway. They serve large land areas and are the major access route into development areas with high average daily traffic rates. They usually connect with public highways or other arterials to form an integrated network of primary travel routes.

Inberg-Miller Engineers prepared two road design reports to upgrade Dry Creek Road, AML Road and the Carol Shop Road: (1) AML Road 7-kilometer (5-mile) Alignment, and (2) Dry Creek Road 12-kilometer (8-mile) Alignment. The AML Road design alignment is from Dry Creek Road to the Carol Shop satellite building and includes the Carol Shop Road previously described in this section. The design documents and easement descriptions are provided in **Appendix H, Gas Hills Road Design**.

3.7.1.4 Ruth Remote Satellite

The Ruth Remote Satellite can be accessed from State Highway 387 between Edgerton and Pine Tree, Wyoming. From the intersection of Highway 192 and 387, travel east 6.8 kilometers (4.2 miles) to a gravel road, which bears north 7 kilometers (4 miles) to the site. The gravel road roughly follows the Dry Fork of the Powder River drainage.

3.7.2 Secondary Access Roads

A series of roads will be constructed along and within the mine units to provide access for drill rigs, pump pulling units, maintenance vehicles, etc. These roads will connect with Primary Access Roads and will be designed and constructed in such a manner so as to minimize the amount of land disturbance. Road designs have not yet been developed for this remote satellite location.

3.8 Construction Considerations

3.8.1 General Consideration

Smith Ranch and North Butte are operational whereas the Reynolds Ranch Satellite, Gas Hills, and Ruth Remote Satellites have not yet been developed (as of March 2015). The topsoil management and erosion control methods employed at each facility are similar, but facility-specific requirements exist and are detailed where appropriate in the following sections. Mine delineation will be ongoing at each facility and the most current BMP will be employed. Fugitive dust emissions may also be an issue during construction as well as during operations.

3.8.2 Erosion Control Methods

Cameco has a Large General Industrial permit to discharge storm water at both the Smith Ranch and North Butte sites under the Wyoming Pollutant Discharge Elimination System (WYPDES) regulations administered by the WDEQ/WQD. The Gas Hills site currently has a construction storm water permit which will be transferred to an industrial permit once operations commence. Storm Water Pollution Prevention Plans (SWPPPs) will be developed and **storm water** permits will be obtained for the remote satellites prior to beginning construction activities.

As required by the general industrial permit, a SWPPP has been developed and is maintained on file at the Project offices along with a copy of the approved storm water permit. The SWPPP identifies (a) potential pollutants that may leave the site during storm water runoff and (b) potential BMPs to eliminate or minimize pollutants in storm water runoff. The SWPPP will be modified when a change in design, construction, operation or maintenance changes the potential for the discharge of pollutants into waters of the state.

The storm water discharge permit also requires routine inspections of disturbed areas and sediment control structures. Inspections of ongoing construction activities are conducted at least weekly. Once construction activities are complete, and during operations, inspections are conducted monthly and within 24 hours of a rain or snowmelt event exceeding 13 millimeters (0.05 inch). All inspections are documented, and BMP damage will be repaired as soon as possible after it occurs. Areas where final stabilization has been achieved will be documented and omitted from future inspections.

Culverts will be the main hydrologic control installed during the development of access roads (see Section 3.5). Installation of culverts where drainages intersect roads eliminates erosion or sedimentation problems related to vehicle traffic. Culverts will maintain existing site drainage conditions. Culvert design includes providing adequate capacity for both water and sediment yield. Culvert design criteria are based on LQD Guideline No. 8, which factors the design life of the facility or structure with hydrologic return period or flood frequency probability. Culvert slope will be adequate (greater than 2%) to convey sediment through the culvert. Inlets and outlets will be protected as needed.

On a local scale, surface drainage will be directed away from or under facilities, roads and topsoil stockpiles using shallow ditches, culverts and/or berms. As delineation drilling and mine unit development proceeds, lands adjacent to surface waters and/or wetland areas will be protected by the installation of appropriate silt fencing or other appropriate sediment control measures as outlined in the Smith Ranch SWPPP.

Cameco strives to minimize disturbance of the areal extent of a mine unit during construction. Construction and operations will be planned and implemented to minimize sedimentation and erosion. Preservation of existing vegetation and sequencing the construction activities in progressive phases limits the amount of surface being disturbed at one time. During mine unit development planning, a traffic pattern is established whereby access to each well and header house is via delineated routes. Whenever possible, pipe and power line installation occur directly adjacent to access roads. Topsoil and subsoil material from drill mud pits is stockpiled in common areas away from the active drilling area. These actions limit the overall surface disturbance footprint during the mine unit construction phase of the operation. Where possible, vegetative buffer strips are maintained between drill sites and between the disturbed area and drainages.

Standard mine unit construction and normal revegetation procedures and vegetative buffer strips may not always provide adequate erosion/sediment control of a disturbed area. Example conditions include construction operations adjacent to a drainage channel, on steep terrain or locations where vegetative buffer strips cannot be maintained. In these instances, additional sediment control measures may be required.

In such cases, BMPs will be implemented to minimize the pollutants in storm water discharged from the mine unit and processing facilities sites. BMPs fall into three general groups: erosion controls, sedimentation controls, and temporary controls. These controls are intended to handle the 2-year, 24-hour storm event of 3.0 to 3.6 centimeters (1.2 to 1.4 inches) expected in this area. The appropriate uses of these controls are summarized in Table 3-18, Erosion and Sediment Control Table. Typical BMP examples and installation methods are shown on Figure 3.41, Typical Sediment Control Installation & Methods.

For short-term disturbances with erosion potential, such as stockpiling soil excavated from mud pits during drilling operations, Cameco will implement BMPs guided by Table 3-18 and Figure 3.41. Slope barriers will be placed on the downhill side of the mud pit borrow stockpile to ensure that sedimentation does not occur on native ground. Slope barriers may consist of wattles, toe ditches, berms or hay bales.

Stormwater runoff control is an important part of erosion and sediment control. At the Smith Ranch CPP, runoff is directed to closed catchment basins by overland flow, diversion ditches, and drainage pipes (see Figure 3.18). Other sediment controls at the CPP and Satellite facilities include check dams, rip-rap rock barriers, wattles, silt fencing, and vegetation. TR Figure 3.18.1, Smith Ranch Erosion Control SWPPP Map, and Figure 3.18.2, North Butte SWPPP Map, identify and show the location of BMPs currently in place at Smith Ranch and North Butte, respectively. Within the mine unit pattern areas, grading, ditch checks, wing ditches, culverts, wattles, silt fencing, erosion blankets/mats, seeding/hay mulching, rip-rap rock, gabions, and toe ditches/sediment traps are used to control runoff. Hazardous and non-hazardous materials are stored within bermed areas without drains.

Fuel storage areas are managed to prevent off-site drainage to or from the area. All petroleum products stored at the site are contained in approved and appropriately labeled above-ground containers. Secondary containment is accomplished by berming and/or ditching the perimeter of the entire fuel storage area. No solid materials (e.g. drilling materials) or liquids (e.g. petroleum products) will be discharged to drainages within the Project sites.

Purge water from monitor wells is discharged towards diversion structures to prevent run-on to disturbed areas. Discharges from mine unit aquifer pump tests are either contained in tanks or are disposed in accordance with a temporary WYPDES discharge permit. When water is disposed on site in accordance with a temporary WYPDES discharge permit, it is conveyed away from disturbed areas using straw bale dams, conveyance channels or other control methods.

Temporary erosion protection is especially important for graded slopes, ditches, berms and soil stockpiles. For such areas where construction activities have temporarily ceased for an extended period of time, temporary soil stabilization measures are implemented. These measures may include surface roughening, cover crop planting, mulching, erosion control blankets, etc.

All BMPs used during construction activities will be properly selected, installed and maintained in accordance with the manufacturer's specifications and good engineering practices (see Figure 3.41). All structures will be built to withstand and function properly during precipitation events up to a 2-year, 24-hour storm event**.**

3.8.3 Topsoil Management

Where stockpiling of topsoil and subsoil is necessary, LQD Rules and Regulations Chapter 11, Section 4(a)(iii) stipulate that procedures required in Chapter 3, Section 2(c)(i) through (iii) be used to ensure the protection of topsoil and subsoil from excessive compaction, degradation, and wind and water erosion.

These regulations require that Cameco perform ISR activities in a manner that minimizes topsoil damage and sediment loss to wind and water erosion. Should surface drainage require diversion around an operating area, such diversions will be constructed with erosion control using accepted design standards. Similarly, culverts, which pass below disturbed areas including roads, will be protected. LQD Noncoal Rules and Regulations, Guideline No. 4 Reference Document 6 provides guidance for the management of topsoil and subsoil resources at ISR operations. The LQD Guideline No. 4 stresses that the ISR operator limit areas of disturbance during mine unit delineation, construction and operation by minimizing temporary access roads and segregating topsoil and subsoil materials during excavation activities including mud pit, pipeline, and mine unit pattern construction. Although topsoil and subsoil are generally not stripped and stockpiled for the entire mine unit area, soil salvage in specific mine unit pattern areas where traffic is concentrated may be necessary in site-specific situations.

3.8.4 Surface Water Diversions

Surface water diversions are constructed as necessary to divert water around buildings, ponds, and other structures as required to protect facilities and minimize erosion and sedimentation. Diversion structures will be constructed in accordance with accepted BMPs and standard engineering practices.

3.8.5 Fugitive Dust Control

Cameco does not have specific fugitive dust control plans for construction or operations activities. The WDEQ/Air Quality Division (AQD) does not require specific plans and/or permits for fugitive dust control for large-scale construction projects, as the entire state of Wyoming is within an "attainment area" with respect to PM_{10} emissions. As a general rule, abatement measures for dust are required on the primary, secondary and temporary wellfield roads when a visible plume of dust extends more than 91 meters (300 feet) from the source with an estimated opacity exceeding 20% (objects partially obscured). Dust from unpaved roads is not only a nuisance but creates a safety hazard by reducing the driver's visibility.

Water application using water trucks is Cameco's preferred short-term method for controlling fugitive dust emissions during facility construction and wellfield installation. Watering provides short-term reductions in dust generation. Depending on surface evaporation rates, regular light watering has proven to be more effective than less frequent, heavy watering. Water for dust control is obtained from facility wells and is of potable quality. Cameco minimizes water runoff containing mud and silt that can cause damage to streams and other resources.

Cameco does not currently use chemical agents for dust control treatment but may use chemical treatments in the future if water only is not sufficient. Before using chemical agents, Cameco will first evaluate potentially negative environmental consequences of applying salts, including harm to plants, animals, and water quality.

Several chemical treatments are available that improve water dust control properties (also called a palliative). Salts such as calcium chloride and magnesium chloride have been used for many years to control dust with the secondary benefit of stabilizing the road surface, thereby reducing gravel loss from the road surface and associated maintenance. Some studies show that magnesium chloride is more cost effective than calcium chloride. Calcium chloride comes in flakes or pellets and is mixed with water to be applied by a water truck.

Another treatment is an organic derivative of pulp and paper processing, lignosulfonate, also called lignin. Unlike brines, the lignin is mechanically incorporated into the gravel using the same equipment used for maintaining the road. The chemical binds the small gravel particles together, and the result is less dust. Lignin can leach during heavy rain, but not as much as the salt treatments. Lignin-treated surfaces may become slippery when wet and brittle when dry; potholes may form. The treatment retains its effectiveness during dry spells. Lignin treatment may be more expensive than the brines because it has to be incorporated into the road material. The treatment life varies for all these chemicals according to traffic and precipitation.

Other dust suppressants include polymers, vegetable oil and petroleum products. Polymers bind the small gravel particles like lignin but do not leach. Surfaces treated with polymers may be difficult to maintain and are usually more expensive than competitive treatments. There are proprietary petroleum resin products on the market that are non-toxic, not water-soluble and have the benefit of stabilizing the road for reduced maintenance cost. These products are sprayed on the road surface much like the process of chip and seal on an asphalt road. The dust control/stabilizer treatments do not contain asphalt and are not harmful to the environment, according to the manufacturers. Cameco does not use dust suppressants that are petroleum-based, such as cutback asphalt or used motor oil.

3.8.6 Construction Quality Assurance Plan

Cameco will develop a construction quality assurance plan that addresses all aspects of constructing surface facilities. The plan will include:

1. A description of the responsibilities and authorities of key personnel, including the level of experience and training;
2. A description of the required level of experience, training, and duties of the contractor, the contractor's employees, and the quality assurance inspectors;
3. A description of the testing protocols for each major phase of construction, including the frequency of inspections, field testing, and sampling for laboratory testing;
4. The sampling and field testing procedures and the equipment to be used;
5. The calibration of field testing equipment;
6. The laboratory procedures to be used; and
7. Documentation to be maintained.

3.9 Project Schedule and Water Balance

Project schedules and water balances have been developed for each of the SUA-1548 Project facilities. The following general assumptions apply to all SUA-1548 license areas, and specific assumptions for the individual facilities are provided in the further discussions.

1. The groundwater sweep is calculated on the volume of water withdrawn from the formation.
2. The eight pore volumes of the RO treatment were calculated on the volume of permeate injected not the volume of water withdrawn from the formation.
3. The recovery on the RO units is 80%.
4. The pore volumes are based on 2010/2011 approved surety estimates.
5. Future production is accounted for in the water balance.
6. The operational time is 360 days per year or 98.6%.

The production water balances detailed on **Table 3-10, Table 3-11, Smith Ranch Water Balance, Table 3-12, Reynolds Ranch Water Balance, Table 3-13, Highland Water Balance**, and **Table 3-14, North Butte Water Balance** show the sequencing of the development and restoration of the individual mine units.

Anticipated production flows, disposal requirements and capacity are also detailed in the aforementioned tables. The actual production schedule for each facility is dependent upon several factors, including mine unit flows, production rates and economics.

Groundwater restoration will occur concurrently with mining throughout the life of the Project. The groundwater restoration portion of the schedule is designed to achieve the fastest restoration possible, given the ability of the aquifer to yield water. After groundwater restoration and stability have been achieved in a mine unit and regulatory concurrence has been granted, approximately one to two years are typically needed to decommission and reclaim the mine unit surface and ancillary buildings and equipment. Although production and restoration schedules will vary from what has been provided herein, the schedules, water balance and surety bonds for each active production site are revised on an annual basis to include revised forecasts of production and restoration flows, required equipment and the estimated costs to maintain production and restoration activities through the coming year. The required capacity to perform production and restoration activities will be maintained through this annual water balance and surety estimate update process.

3.9.1 Smith Ranch and Satellites

The estimated project and restoration schedules for Smith Ranch, Highland and Reynolds Ranch, presented in **Tables 3-11, 3-12,** and **3-13** are based on an average annual production rate of 907 metric tons (1,000 tons) of uranium. The assumptions for the Smith Ranch water balance include the following:

1. Reynolds Ranch production will be processed at the Smith Ranch CPP.
2. Production bleed is 1%.
3. A mine unit control bleed of 76 liters/minute (20 gallons/minute) was included in the water balance for use anywhere onsite. The control bleed is a provision for excursion control.
4. Groundwater sweep is used for RO make-up water in the water balance. A provision was included for up to a 5% bleed to be used during the RO phase for hydraulic control.
5. Disposal capacity is maintained for the life of the project.
6. Deep disposal well disposal volumes are the most recent volumes to date from the mine.
7. The water balance assumes that a 1,890 liters/minute (500 gallons/minute) [feed] RO unit will be installed at Smith Ranch in 2028.
8. A 945 liters/minute (250 gallons/minute) [feed] RO unit will be added at Smith Ranch satellite SR2 in 2029, and an additional 1,890 liters/minute (500 gallons/minute) [feed] will be installed at SR2 in 2032 for the restoration of Mine Units 9 and 10.
9. Restoration of Mine Units 9 and 10 will need to be concurrent because they are in the same sand unit.

Cameco also plans to process IX resin at the Highland CPF beginning in 2013. **Table 3-13** provides an estimate of the annual processing rates, number of elutions, disposal capacities and water consumption for the Highland CPF.

3.9.2 North Butte Remote Satellite

The estimated project operations and reclamation schedule (**Table 3-14)** are based on an initial annual production rate of 227 metric tons (250 tons) of uranium per year, to be increased to the maximum sustainable production rate currently estimated to be approximately 680 metric tons (750 tons) of uranium per year. The North Butte water balance assumes the following:

1. Production bleed is 1%.
2. Two deep disposal wells will be installed at the beginning of mining, and a third deep disposal well will be installed at the start of restoration. A fourth well will be installed as needed. The disposal capacity of each well was estimated at 189 liters/minute (50 gallons/minute).
3. The water balance assumes a 2,268 liters/minute (600 gallons/minute) [feed] RO unit.

3.9.3 Gas Hills Remote Satellite

The estimated project and restoration schedules for Gas Hills (**Table 3-10)** are based on an average annual production rate of 907 metric tons (1,000 tons) of uranium. The Gas Hills water balance assumes the following:

1. Production bleed is 1%.
2. Initially, two evaporation ponds will be installed, and additional ponds will be constructed as needed. Up to six evaporation ponds will be constructed for a total pond capacity of 180,000 meters^3 (146 acre-feet).
3. Using evaporation ponds only, although Cameco is evaluating using deep disposal wells at Gas Hills.
4. Evaporation rate for the first four ponds is 23,000 meters^3 (19 acre-feet) per year, and 42,000 meters^3 (34 acre-feet) per year for all of the ponds.
5. Cumulative sludge in the evaporation ponds was conservatively calculated to the TDS of the water evaporated from the ponds.

Mine unit development scheduling will also reduce the potential for flare near abandoned mine workings or other areas of high TDS groundwater. The portion of the production pattern area located nearest the mine workings will be developed last. This may result in a shorter production life for the patterns nearest the mine workings before restoration of the wellfield begins. Although the short production life may reduce ultimate recovery from the ore zone, it will result in a lower potential for excursions from the production areas or incursions of high TDS groundwater from the mine workings.

Groundwater zones previously affected by historic mining activities or naturally degraded groundwater outside the mine unit monitor well ring will affect the restoration activities. Groundwater restoration activities will be designed to avoid drawing such water towards or into the wellfield pattern area.

3.9.4 Ruth Remote Satellite

A project schedule and water balance has not been developed for the Ruth Remote Satellite, currently in stand-by status. When it is completed it will be submitted to NRC for review and approval.

3.10 Potential Impacts of Operations on Surrounding Waters

Cameco has contingency plans and spill response equipment necessary to respond to spills and/or releases of process fluids from valve, pipe, or tank failures; evaporation pond liner tears and transportation accidents. A review of these plans and procedures with regard to operations during the last 10 years indicates that

Cameco has addressed contingencies for all of the types of spills that have occurred, including reasonably expected system failures. The list of appropriate plant and corporate personnel who must be notified in the event of specific types of failures is current. Spill and/or release notification requirements in the NRC license, regulations and other permits are current, including agencies and other points of contact.

3.10.1 Spills

3.10.1.1 Summary of Spills and Releases

This section summarizes (a) releases under License SUA-1548 since the previous license renewal submitted November 15, 1999, and (b) potential environmental effects of the releases. Liquid spills which enter "Waters of the State," liquid spills in excess of 1,600 liters (420 gallons), or any spill comprised of lixiviant, pregnant liquid, acid, solvent, process wastewater or a similar stream that threatens to enter Waters of the State are reported to the WDEQ LQD and the NRC. "Waters of the State" include playas, wetlands, streams, rivers, lakes, dry draws (ephemeral drainages), etc. The releases reported to the NRC since the previous license submittals are summarized in **Table 3-15, Summary of Spills and Releases**.

A total of 94 reportable releases have occurred at Smith Ranch since the previous license renewal, totaling approximately 3.3M liters (865,800 gallons). The volume released represents approximately 0.001% of the total volume of fluid circulated since the previous license renewal. Approximately 50% of spills involved injection fluids, which have low uranium concentrations averaging approximately 2 mg/L. Approximately 40% of the spills involved production fluids, with uranium concentrations ranging from <1 to 149.7 mg/L and averaging approximately 20 mg/L. Spills and releases of deep disposal fluids, restoration fluids, and treated process water make up a small percentage (approximately 10%) of the total number of spills. Approximately 82% of spills resulted from mechanical and equipment failures, such as failed fittings, joints, flanges, and unions of pipelines, with 18% of spills resulting from human error.

Based on release investigations and associated sampling, none of the releases during the past 10 years resulted in surface water contamination. Routine groundwater monitoring of overlying aquifers indicates that none of the releases have resulted in groundwater contamination.

While all releases are thoroughly investigated, PRI created a Spill Committee in 1999 to assess actions that could be taken to prevent future releases. This committee was formed to investigate all releases, determine the cause, recommend corrective actions, and evaluate procedures, training and equipment being used. Cameco's Spill Committee currently meets periodically or after a release to discuss corrective actions, status of previously assigned actions, and preventative measures to minimize the potential for a fluid release from the Smith Ranch operations.

Corrective actions resulting from Spill Committee reviews have included:

- Installing leak detection system at the wellheads that has evolved to electronic surveillance tied into the associated satellite's computer monitor with alarms.
- Daily inspection of all wellfields and header houses.
- Removing unions from service when repairs or maintenance are conducted on a wellhead or header house.
- Installing bellholes for maintenance access to buried pipelines. Bellholes are oversized culverts large enough for a work crew to access all connections and are fitted with early warning detection systems.

- Replacing all like components within a wellhead or header house when one component of a wellhead or header house is found to be faulty to reduce the chance for releases.
- Replacing all wetted fixtures at a wellhead every five years, coincident with the required five-year MIT of all injection wells.
- Requiring water sampling staff to visually inspect wellheads in the vicinity of monitor wells being sampled as part of their routine sampling duties. There were 17,000 wellheads visually inspected in 2009, with 96 potential problems noted and corrective actions taken.
- Replacing pop-off valves that failed to reset with newer versions.
- Installing an asbestos-free (green) gasket in all new Production/Injection lines.
- Replacing gaskets with either red-rubber or asbestos-free gaskets upon initiating groundwater restoration.
- Repeatedly replacing and testing well hose connections until a more robust version was found.
- Changing gaskets from paper to neoprene.
- Replacing brass with stainless steel fittings to minimize corrosion.

Upon detecting a release, site personnel have responded as soon as possible to contain and stop the release. Actions taken include isolating the pipeline or shutting down the well, header house, wellfield, or plant, as necessary. Released fluids can be recovered with a vacuum truck and disposed of via deep well injection at the satellites or CPP, if the fluids have not already soaked into the soil. Mitigation measures have included soil removal and securing the affected area with perimeter fencing and/or hurricane fencing.

As directed by the Radiation Safety Officer (RSO) on a case-by-case basis, gamma surveys were conducted and soil samples collected from affected areas. Gamma surveys of soils affected by releases during the past 10 years indicated no immediate requirement for corrective action. Cameco's de-commissioning file contains reports of all releases both reportable and non-reportable, a map, sample results and radiological survey data, as applicable. All release sites will be re-evaluated during the decommissioning of the wellfield to ensure that applicable decommissioning standards are met.

3.10.1.2 Evaluation of Potential Impacts from Spills

According to the "Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities" (NUREG-1910), impacts to soils from spills could range from small to large in the short-term, depending on the volume of soil affected by the spill. However, NUREG-1910 states that, because of the required immediate responses, spill recovery actions, and routine monitoring programs, impacts from spills are temporary and overall long-term impact to soils are expected to be small. Due to the small quantity of fluid involved, the small extent of the spill, and the low precipitation rate and ephemeral nature of surface water at the site, the spills recorded in **Table 3-15** are expected to have minimal long-term effects.

Smith Ranch spill and/or release impacts from surface facilities and equipment on shallow aquifers are a major concern, as these aquifers are important sources of agricultural water in surrounding areas. The surface water monitoring program described in Section 5.10 monitors potential impacts to surface water. Samples from the surface water monitoring locations exhibit a decrease in uranium (nat) and Ra-226 concentrations since the last license renewal in 2001.

The largest spill occurred in June 2007 and involved a spill of 750,300 liters (198,500 gallons) of injection fluids resulting from human error. Post-release radiological survey results, soil and vegetation sampling results, and groundwater from wells installed to test the shallow aquifer indicated no immediate or long-term environmental effects, including no effect within the shallow aquifer.

In stock ponds along drainages near active mine units, monitoring results show that measured concentrations of natural uranium and Ra-226 are all below the effluent concentration limits (ECLs) from 10 CFR 20, Appendix B. Some stock ponds are supplied from wells with windmills, and shallow windmill wells sampled in the past 10 years report concentrations of uranium (nat) and Ra-226 below the ECLs, with one exception. Well GW-5 is located in an area with shallow natural uranium mineralization, resulting in naturally high uranium concentrations that exceed the ECL. Uranium and radium concentrations are naturally elevated in the vicinity of the site and may vary spatially depending on proximity to naturally occurring uranium mineralization and level of oxidation.

3.10.1.3 Spill History Summary

Most spills and/or releases at Smith Ranch have been associated with piping/fittings. Other potential activities that could result in spills and/or releases include transportation, evaporation pond storage, or land application of treated wastewater. BMP and Spill Committee review of spills at Smith Ranch have resulted in leak detection upgrades to existing systems identified above. These in conjunction with Project (SUA-1548) operational procedures including detection and response to leaks and spills (e.g., soil cleanup), monitoring of treated wastewater, and surveys of potentially affected soils help limit the magnitude of overall affects to soils.

3.10.2 Excursion, Incident Investigation or Root Cause Analysis, and Resultant Cleanup History or Status

3.10.2.1 Wellfield Excursions

This reviews and summarizes Smith Ranch SUA-1548 license areas wellfield excursions reported for the period since the previous license renewal (submitted November 15, 1999). It also provides an investigation into the causes of the excursions, corrective actions as necessary, the status of each, and conclusions as to the overall effect of the excursions.

Various facility activities and operations potentially can impact groundwater, for example, if ISR leaching solutions flow away from wellfields during production and/or restoration pumping. The Environmental Monitoring Program at the Smith Ranch SUA-1548 license areas (presented in Section 5.10) is conducted to verify that groundwater excursions are detected in a timely fashion to prevent degradation of groundwater quality outside of the mine unit wellfields. The mine units at Smith Ranch are shown on **Figures 1.4** through **1.8.**

A migration of production fluids into the overlying or underlying aquifers and/or detected at the monitor well ring is termed an excursion. Excursions are indicated by groundwater monitoring data when two or more excursion indicator parameters (alkalinity, chloride, and specific conductivity) exceed the established baseline UCLs. If an excursion is first indicated by routine monitoring results, a second sample is collected within 24 hours of the original analytical result to confirm the excursion. If the second sample does confirm an excursion, Cameco notifies NRC and WDEQ in accordance with the license, and the same well is sampled at least every seven days to closely monitor the UCL parameters and uranium. If the second sample does not confirm an excursion, a third sample is collected within 24 hours of the second to again test the apparent excursion. If the third sample confirms an excursion, Cameco notifies the appropriate regulatory agencies, and additional samples are collected at least every seven days until the sample excursion parameter(s) no longer exceeds the UCL. Excursion events do not necessarily result in environmental impacts but can be indicators of the unintended movement of production fluids.

Mine unit excursions during the license renewal period November 15, 1999 through March 31, 2011 are summarized below. Section 5.10.3 describes the groundwater monitoring program. The completion zone for the given monitor well is denoted by the prefix (see Section 3.5.1.2) of the well ID. For example, BM-42 indicates a monitoring ring well in mine unit B completed in the ore zone. Monitor wells installed in the older mine units at Smith Ranch are denoted with a U (upper) or D (deep) in the well ID.

Mine Unit 1

There were no excursions from MU 1, as evidenced by groundwater analytical results below the UCL concentrations throughout the license renewal period November 15, 1999 through March 31, 2011.

Mine Unit 2

No excursions occurred from this mine unit during the past license period. Groundwater collected on September 1, 2006 from monitoring well MD-208 completed in the underlying aquifer reported two excursion parameters exceeding the UCLs. Samples collected September 5, 2006 from this same well did not confirm the original result.

Mine Unit 3

Groundwater collected on September 30, 2008 from monitoring well MD-306 completed in the underlying aquifer reported two excursion parameters exceeding the UCLs. The original sample was re-analyzed the same day. Results of the analysis indicated the concentrations above the UCLs were due to laboratory error, not an excursion. No other MU-3 monitoring results have indicated an excursion or apparent excursion during the license renewal period.

Mine Unit 4 and 4A

Groundwater collected on September 3, 2004 from well M-428 reported an excursion parameter exceeding the UCL. A follow-up groundwater sample collected September 8, 2004 reported only one excursion parameter exceeding its UCL. Since September 8, 2004, excursion parameters concentrations have been below the UCLs.

Mine Unit 9

There were no excursions from MU 9, as evidenced by groundwater analytical results below the approved UCLs during the license renewal period.

Mine Unit 15 and 15A

There were no excursions from MU 15 or MU 15A, as evidenced by groundwater analytical results below the approved UCLs during the license renewal period.

Mine Unit A

Groundwater restoration of MU A was conducted from July 1991 to October 1998 and was approved by WDEQ on November 23, 2003 and by NRC on June 19, 2005. Groundwater monitoring at MU A was not conducted during the license renewal period because restoration was completed and approved in June 2005. Monitoring wells were plugged between March and May 2005.

Mine Unit B

Starting on November 5, 2002, groundwater collected from Well BM-42 (**Figure 1.4**) reported excursion parameters and uranium concentrations exceeding the UCLs. At that time, MU B was undergoing restoration (which began in July 1991). On March 31, 2008, the LQD approved groundwater restoration of MU B based on Class of Use criteria. Groundwater was sampled from BM-42 approximately every seven days from November 2002 until January 14, 2011 when, after failing its MIT, the original BM-42 was plugged and abandoned and replaced with a new well. Groundwater collected from the newly installed replacement well did not exhibit excursion, and the new well was consequently removed from excursion status.

Mine Unit C

At MU C, one apparent excursion and three confirmed excursions occurred during the license renewal period. Groundwater collected on September 4, 2008 from well CM-14 reported excursion parameters exceeding UCLs. Confirmation samples were not immediately collected from the well. Groundwater collected in November 2008 during the next routine scheduled sampling event did not exhibit excursions. WDEQ was notified of the missed confirmation sampling event.

Excursions were confirmed in groundwater collected from four wells within MU C: CM-15, CM-32, CM-33 and CM-38 (**Figure 1.5**). While on excursion status, these wells were sampled approximately every seven days for excursion parameters and uranium. The confirmed excursions are discussed below:

- Groundwater collected from Well CM-32 on July 3, 2007 reported an excursion parameter exceeding the UCL, which was confirmed by a second sample collected July 6, 2007. Groundwater collected from July 2007 through October 20, 2009 reported two or more parameters exceeding the UCL concentrations.
- Groundwater collected from Well CM-33 on February 22, 2008 reported excursion parameters exceeding the UCL, which was confirmed by samples collected February 22 and 25, 2008. Concentrations of two UCL parameters exceeded the UCLs through May 20, 2008. Samples collected from June 3, 2008 through October 6, 2009 did not report excursions.
- Groundwater collected on November 18, 2008 from Well CM-15 reported excursion parameters exceeding the UCLs, as confirmed by samples collected on November 19, 2008. From November 19, 2008 through September 22, 2009, two UCL parameters exceeded the UCLs.
- Groundwater collected from Well CM-38 on June 14, 2010 reported excursion parameters exceeding the UCLs, as confirmed by samples collected on July 20 and 27, 2010. Groundwater samples collected since July 2010 have not reported excursion parameters exceeding the UCLs.

Cameco Resources is in the process of analyzing historical data and evaluating methods to better control the groundwater gradient in MU C. At the time of these excursions, MU C was in restoration. Wells CM-32 and CM-33 are located within 274 meters (900 feet) of former underground mine workings. During 1991, it was determined that production fluids from the 50-Sand production zone within MU C had entered the abandoned underground workings. Following the excursion at CM-32 in 2007, Cameco began pumping seven wells associated with nearby header house C-22 to control the excursion by drawing the groundwater back into the wellfield. In response to the excursion at CM-33 in 2008, Cameco re-balanced the wellfield in an attempt to mitigate the excursion.

Mine Unit D

During the license renewal period, groundwater samples from monitoring wells DM-1, DM-16 and DM-24 reported apparent excursions, but confirmation sampling showed that the wells were not on excursion. However, excursions have been confirmed at three wells within the wellfield: DM-3, DM-9, and DM-10 (**Figure 1.5)**. These excursions are summarized below:

- Groundwater collected from Well DM-9 on November 5, 2001 reported excursion parameters exceeding UCLs, as confirmed by samples collected on November 6, 2001. From November 2001 through February 2004, excursions were reported at this well, with few exceptions. However, an excursion has not been reported by groundwater from this well since February 24, 2004.
- Groundwater collected from Well DM-3 on January 21, 2002 reported excursion parameters exceeding UCLs, as confirmed by samples collected on January 22, 2002. Excursions were reported from January 2002 through May 2009, with few exceptions. On September 8, 2009, another apparent excursion was reported for well DM-3; however, confirmation sampling showed no excursion. This well was on excursion status throughout 2010, but was removed from excursion status in the summer of 2011.
- Groundwater collected from Well DM-10 on March 20, 2002 reported excursion parameters exceeding UCLs, as confirmed by samples collected on March 21, 2002. From March 2002 through April 2005, one or more parameters exceeded the UCL concentrations. From May 2, 2005 through August 4, 2008, no excursions were reported by this well. However, concentrations of two UCL parameters again exceeded the UCLs on June 3 and 6, 2011, and the well is currently being monitored weekly.

Excursions at Well DM-3 are attributed to abandoned underground workings in the area. As discussed in the section above for MU C, production fluids have entered the underground workings, which extend to the 40-Sand production zone at MU D. Excursions can indicate an over-injection of lixiviant; however, at the time of some of the excursions at DM-3, there was a lack of injection in the MU, which further suggests that underground mine workings are the cause.

Excursions at wells DM-9 and DM-10 are also related to the abandoned underground mine workings and, like the excursion at DM-3, they occurred when there was a lack of injection in the MU. These wells are located south of the abandoned mine workings and northeast of MU D-Extension (**Figure 1.5**), which started production in May 2001. The excursions are thought to have been caused by water-level drawdown in the D-Extension wellfield and resulting changes in the potentiometric surface of the 40-Sand, inducing fluids to migrate from the abandoned mine workings (or nearby wellfield pattern area) towards wells DM-9 and DM-10. Corrective actions were taken following these excursions to alter the groundwater flow paths in the area of concern.

Mine Unit E

Samples collected from well ET-1 in the first quarter of 2006 reported excursion parameters exceeding the UCLs. However, well ET-1 is a “trend” well used only to indicate water quality trends in the wellfield, not for compliance monitoring. No regulatory excursions have occurred from MU E.

Mine Unit F

Results from the July 7, 2009 sampling event for well FM-8 indicated an apparent excursion; however, as stated on the notification letter to WDEQ on July 27, 2009, results from July 7, 2009 were likely inaccurate because evacuation of one casing volume did not provide representative formation fluid within the casing.

Therefore, confirmation samples were not collected. The investigation found that a casing joint had failed at 46 meters (150 feet) depth, and the well was abandoned on August 14, 2009. A replacement monitoring well was installed and completed on August 4, 2009, and subsequent groundwater monitoring results have indicated no further excursions. No other apparent or confirmed excursions have occurred from MU F.

Mine Unit H

One confirmed excursion has occurred from MU H during the license renewal period. Groundwater samples initially collected from well HM-20 (**Figure 1.4**) on January 12, 2010 indicated an excursion, with confirmation samples collected on January 13, 2010. In response to the excursion, injection and production pumping rates were adjusted to increase the bleed rate to approximately 76 liters/minute (20 gallons/minute). Subsequent groundwater samples collected from this well have reported no excursion parameter exceeding the UCLs.

Mine Unit I

During the license renewal period, one apparent excursion occurred from MU I and three excursions were confirmed. Well IM-11 appeared to be on excursion status on May 1, 2007. However, the elevated concentrations were likely caused by over-pumping the monitoring well prior to sample collection (11 casing volumes were purged prior to sampling). Due to this suspected cause, confirmation sampling was delayed until May 11, 2007 to allow well recovery. Confirmation sampling showed that the concentrations were below the UCLs. Since May 11, 2007, sampling results have been below UCLs.

Excursions have been confirmed at three wells within MU I: IM-10, IM-14, and IM-8. The locations of these wells are shown on **Figure 1.4**. These excursions are summarized below:

- Well IM-10 went on excursion on February 11, 2009, with confirmation sampling conducted on February 13, 2009. Results from sampling on March 3, 2009 showed the excursion was resolved. Since that time, no additional excursions have occurred from well IM-10.
- Well IM-14 went on excursion status following sampling on March 27, 2009, with confirmation sampling on March 30, 2009. The excursion was resolved in April 2009 based on sampling results that were below the UCLs.
- Well IM-8 went on excursion on April 14, 2009, with confirmation sampling conducted on April 15, 2009. The well has been on and off excursion status several times between the April 14, 2009 excursion and September 1, 2009, when the excursion was resolved.

In response to the excursions at monitoring wells IM-10, IM-14, and IM-8, Cameco shut off the injection wells in the vicinity of the excursions and reduced the pumping rates in other nearby wells. Cameco is developing a groundwater flow model of the mine unit to help determine optimal pumping and injection rates to prevent excursions in the future.

Mine Unit J

At MU J, monitoring results at wells JMO-009, JMO-013, and JMO-015 are affected by their very low yield. During each sampling event, these wells are pumped dry, which oxygenates the water and ultimately the sampled formation, causing fluctuations in alkalinity. At JMO-013, the pumping off had occasionally resulted in concentrations of two excursion parameters (alkalinity and conductivity) exceeding the UCLs and at JMO-009, pumping off resulted in one occasion in which two excursion parameters exceeded the UCLs. A proposal to revise UCLs for JMO-009, JMO-013 and JMO-015 wells, because of low water yield, was submitted to LQD on November 15, 2007. Following LQD review and approval (May 13, 2010), these wells were placed on a normal twice monthly sampling schedule with new UCLs. Water levels continue to be monitored with pressure transducers due to the potential for communication between this aquifer and the production zone. Well JMO-014 is monitored on a weekly basis for water level only, as it does not contain enough water to sample.

Other than UCL exceedances described above for low-yielding wells JMO-009 and JMO-013, no other sample results have indicated an excursion or apparent excursion at this MU.

Mine Unit K

Analytical results have indicated that sampling parameters were below the approved UCLs and there were no excursions in MU K during this license renewal period.

3.10.2.2 Summary and Impacts of Excursions

Since the previous license renewal submittal in November 1999, approximately 1,000 wells have been monitored for excursion parameters, most of which have been sampled twice a month with 10 days between sampling events. Of those wells, excursions have been confirmed at only twelve wells, located at only five of the 16 MUs: MU B, MU C, MU D, MU H, and MU I. These excursions are horizontal excursions that have occurred within the production zone aquifer at monitoring wells installed in a "ring" around the production zone. Since the previous license renewal submittal, no excursions have occurred in the overlying and underlying aquifers. Of the twelve confirmed excursions, eight excursions lasted more than 60 days. These excursions occurred from the following monitoring wells: BM-42 (MU B), CM-32 (MU C), CM-33 (MU C), CM-15 (MU C), DM-9 (MU D), DM-3 (MU D), DM-10 (MUD), and IM-8 (MU I).

Following detection of an excursion, actions are immediately taken to mitigate potential migration of production fluids. These actions include immediately shutting off the injection wells in the vicinity of the excursion, thereby drawing in production fluids and creating a negative hydraulic gradient. The negative hydraulic gradient, or cone of depression, prevents further migration of production fluids.

Excursions at a Restored Wellfield

Concentrations of excursion parameters at well BM-42 within MU B are below the UCLs. The restoration is complete at the MU and the water quality at the excursion well was returned to its previous WDEQ Class of Use. Restoration at MU B is awaiting approval from the NRC **of an ACL application**. According to the NRC "*Staff Assessment of Groundwater Impacts from Previously Licensed In-Situ Uranium Recovery Facilities*" (Miller, 2009), of the eleven approved wellfield restorations for the three ISR facilities evaluated, all restorations had levels of one or more parameters above the baseline (pre-operational) levels. Despite not returning concentrations of all parameters to baseline conditions, the NRC states that groundwater affects from the NRC-approved restoration sites do not pose a threat to human health or the environment.

Excursions Related to Underground Mine Workings

Abandoned TVA underground mine workings are known to exist in the area near MU "C" and MU "D", as shown on **Figure 1.5**. The underground mine workings extend into the 40-Sand production zone of MU "D" and the 50-Sand production zone of MU C. During 1991, it was determined that production fluids from MU C entered the abandoned underground workings. The production fluids in the underground mine workings have affected the groundwater quality and led to long-term excursions at wells CM-32 and CM-33 within MU C and well DM-3 and DM-10 within MU D.

In November 1992, the WDEQ approved a permit revision to include the mine workings in the MU C production zone. Additional wells were installed to monitor the potential movement of production fluids within and surrounding the mine workings. This group of eleven monitoring wells will be sampled during the restoration and stability periods to assess the progress of groundwater restoration in the underground workings. Since restoration began in 1997 at MUC, most of the additional monitoring wells show a decreasing trend for conductivity, chloride, and bicarbonate. Monitoring well CM-33 is no longer on excursion status. Following complete restoration of MU C and MU D, no impacts are expected from production fluid in the underground mine workings.

Excursions Controlled by Corrective Actions

During operations, a negative hydraulic gradient is expected to be maintained so that groundwater flow is toward the production zone from the edges of the wellfield. If a negative gradient is not maintained, horizontal excursions can occur and lead to the spread of production fluids in the production zone aquifer, beyond the mineralized zone (NUREG-1910, Chapter 4). This imbalance of pumping and injection is likely the cause of excursions at wells DM-9 and DM-10 at MU D and well IM-8 at MU I. These excursions were controlled through corrective measures. Corrective measures have consisted of optimizing the injection and production pumping rates to balance flows in the wellfields. The corrective measures have resulted in the wells being taken off excursion status and therefore these excursions are expected to have no environmental impact.

Well CM-15 at MU C went on excursion status during the restoration period. The exact cause of this excursion is not known. Even though well CM-15 is farther from the underground mine workings than wells CM-32 and CM-33, where excursions have also been reported, the excursion at CM-15 may also be attributed to the underground workings. Another possibility is that a natural hydrologic sink may exist in the area of well CM-15. Regardless of the cause, the excursion was corrected by turning off nearby injection wells and over-pumping the closest production wells, thereby drawing solutions back towards the center of the wellfield, away from the monitoring wells. Corrective actions were effective at reducing the conductivity readings and chloride concentrations and the well has been taken off excursion status.

Conclusion

Cameco has operated its Smith Ranch Project (SUA-1548) in a manner to limit the number of excursions to a very small number relative to the number of mine units operated and the number of wells monitored. As discussed in the NRC's "*Staff Assessment of Groundwater Impacts from Previously Licensed In-Situ Uranium Recovery Facilities*" (Miller, 2009), the number of excursions reported and the duration of the excursions at Smith Ranch constitute a small percentage of the total number of samples analyzed. For example, at the Smith Ranch site, approximately 1,000 wells have been sampled and analyzed twice a month for excursion parameters since the previous license renewal in 1999, compared to confirmed excursions of 12 wells (1% of the wells). Approximately 240,000 monitor well samples have been analyzed for excursion parameters, of which 12 wells have been confirmed to be on excursion status. Only 5 of the 16 mine units that are operational or in restoration have had excursions during the license renewal period. The above mentioned NRC staff assessment report on groundwater impacts states that for most excursion events, the licensees were able to control and reverse the excursions through pumping and extraction at nearby wells. The excursions have not resulted in environmental impacts. This has been true at Smith Ranch in that Cameco has been able to successfully mitigate the effect of the limited number of excursions through corrective actions such as rebalancing of nearby wells.

3.10.3 Pond Leaks

This section provides a summary of storage pond leak events occurring at the Smith Ranch-Highland operation since the previous license submittal and associated design and/or operational changes to reduce the frequency of leak events. All storage pond leak events are reported to the LQD and the NRC.

3.10.3.1 East and West Storage Ponds

A total of 14 leaks have occurred from the East and West Storage Ponds since the previous license submittal (see **Table 3-16, Summary of East and West Storage Pond Leaks**). Upon detecting a leak, site personnel have responded as soon as possible by taking actions to stop and contain the leak. Typical actions include lowering of pond water (freeboard) levels to prevent additional inflow to the secondary containment/leak detection system, recovery of pond leakage from the secondary containment system, isolation of the area of the leak and repair of the liner breach. Once all repairs have been made, water levels are raised to test the integrity of the primary liner prior to resuming operation of the storage pond.

Based on the leak event investigations and associated corrective actions, leak events since the previous license submittal have been limited to minor breaches (e.g., small holes and/or tears) to the primary liner of the pond containment system. As part of the corrective action process associated with these events, several design and/or operational changes have occurred to reduce the frequency of pond leakage. These changes include:

- Installation of pumps in each pond to supplement the need for transfer hoses and prevent leaks caused by the camlock end of transfer hoses (1999);
- Use of higher grade patch kits during liner repair, consisting of HH-66 vinyl cement and vinyl laminated fabric or equivalent materials (starting 2000);
- New liner installations on the West Pond (2004) and East Pond (2008); and
- Fencing upgrades (2009) to restrict wildlife (deer) access.

Since replacement of the primary liner in 2004, the West Pond has performed well with no leaks occurring since that time. The East Pond, which had the primary liner replaced in 2008, has continued to experience leaks in consecutive years since 2008. While these leaks from the East Pond have been limited to minor breaches (holes and/or tears) in the primary liner, Cameco continues to evaluate the performance of the liner system and potential design and/or operational changes to reduce the frequency of leak events in the future.

3.10.3.2 Purge Storage Reservoir 2

This section describes information pertaining to Cameco's investigation activities to evaluate seepage from PSR-2 and potential impacts to the surrounding groundwater. In response to NRC Unresolved Item 040-08964/0801-03 identified by NRC inspectors during the March 2008 inspection, Cameco committed to installing four monitor wells to determine whether or not PSR-2 was leaking into the groundwater. The following discussions summarize the 2009 investigation activities and Cameco's plans to further investigate potential impacts to the surrounding aquifer.

Background

PSR-2 is located north of Wellfield C, approximately 0.8 kilometers (0.5 miles) north-northeast of Satellite 2 of Cameco's Highland Operation. It was originally constructed in 1979 for use by TVA as a wastewater settling pond prior to discharge in accordance with a National Pollutant Discharge Elimination System permit. In 1994, PRI took over operations of the area and PSR-2 was refurbished and permitted as a storage pond for a wastewater land-application facility. While the PSR-2 facility was designed to prevent adverse effects to shallow groundwater, it was not designed to be completely impermeable and was not subject to the design criteria of Regulatory Guide 3.11 in 1994. This was acknowledged by the NRC in their technical evaluation report on the PSR-2 facility (NRC, 1994).

PSR-2 temporarily stores wastewater from Satellite No. 2 and Satellite No. 3 after the water has been treated for uranium, radium and selenium removal and before the water is disposed via land application at Irrigator No. 2. Waste streams feeding PSR-2 consist of wellfield purge and groundwater restoration waters (wellfield bleed, groundwater sweep, and RO concentrate). According to information submitted by PRI for the 1994 Permit, the wastewater met the WDEQ Class of Use limitations for Class III groundwater, except for selenium (WDEQ Water Quality Rules and Regulations, Chapter 8, Section 4(d), Cameco Resources, 2009). The WDEQ Class III (livestock) limit for selenium is 0.05 mg/L, which is also the limit for Class I (domestic) waters.

The selenium concentration has been monitored since 1995 at Irrigator #2, which draws its water from PSR-2. Concentrations of selenium began decreasing in approximately 2000 and were less than 0.5 mg/L since that time except for a period during 2006 and 2007. As of September 23, 2009, a Selenium Treatment Facility has been in operation at a location southwest of Satellite No. 2. Since that time selenium concentrations have decreased (Cameco Resources, 2010) with the addition of treated water with selenium concentrations less than 0.05 mg/L as shown in measurements conducted from Irrigator #2 in 2010.

Groundwater Monitoring

The 1994 Permit (Permit No. 93-410, *Satellite #2 Wastewater Holding Pond and Land Application Facility)* required the construction of two shallow monitoring wells, known as the East and South shallow wells. The East and South wells were completed to depths of approximately 3 and 4.5 meters (10 and 15 feet) bgs, respectively. Baseline monitoring of these wells was not required; however, the wells have been routinely monitored since their installation.

Due to concerns of water potentially leaking from PSR-2, Cameco installed four new shallow monitoring wells in July 2009. Two of the new wells were installed next to the existing East and South wells (MW-4S and MW-3S, respectively). The other two wells were installed north (MW-2S) and west (MW-1S) of the reservoir.

Groundwater did not accumulate in boreholes during drilling at each of the four well locations. According to Cameco (2009), each boring was dry when drilled and was then terminated at a depth of approximately 15 meters (50 feet) in a gray shale. Wells were completed with a 6-meter (20-foot) screen section, from 9 to 15 meters (29 to 49 feet) bgs. After installation of wells MW-1S through MW-4S was completed, water accumulated in these wells. The wells were developed using pumps on September 10, 2009. All of the wells pumped dry after removal of one casing volume of water at an approximate pumping rate of 8 to 11 liters/minute (2 to 3 gallons/minute) (Cameco Resources, 2009). It was not clear from the available lithologic data whether the screened intervals from these four wells intersect a continuous permeable sand zone.

Based on water level data collected after installation of these four new wells, the groundwater flow direction in this shallow zone was assumed to be to the south-southeast (Cameco Resources, 2009). However, this direction is heavily influenced by the presence of PSR-2 and may not be indicative of regional groundwater flow directions around PSR-2. The groundwater encountered in the shallow monitoring wells is considered to be perched and laterally discontinuous. The uppermost, continuous water-bearing zone is postulated to be at a depth of at least approximately 15 to 18 meters (50 to 60 feet) below grade based upon a review of historic hydrogeologic data from wells and borings completed in the area of PSR-2.

Groundwater samples were for four quarters from the four new monitoring wells (MW-1S through MW-4S) and the two existing wells just after their initial development in September 2009. Analytical results are summarized in **Table 3-17, Groundwater Sampling Results for Monitor Wells near PSR-2**.

Selenium analytical results are summarized in **Table 3-17**. The South Well and Well MW-1S reported the highest selenium concentrations. Samples from well MW-3S, located south of PSR-2, and from well MW-4S, located east of PSR-2 reported selenium concentrations exceeding the WDEQ Class III limit of 0.05 mg/L. These analytical results suggest that selenium concentrations in groundwater are elevated in the shallow sediments surrounding the reservoir, except in areas located upgradient (north) of the reservoir.

Installation of Additional Groundwater Monitor Wells

Cameco will further investigate and evaluate seepage from PSR-2. Aquifer testing will be conducted at existing monitor wells near PSR-2. Groundwater velocities and the potential impacts from PSR-2 will be estimated using the hydraulic conductivity, hydraulic gradient and an estimated porosity. The estimated velocity and potential extent of affect will be used to select locations for additional monitor wells. The groundwater investigation plan was discussed with the NRC during the August 29 through September 1, 2011 inspection, and in a letter to Cameco from the NRC found the plan acceptable (NRC, 2011). Once the investigation is completed, Cameco will determine if the groundwater in the lower sandstone has been impacted by seepage at PSR-2.

Corrective Action Plan

A Corrective Action Plan to monitor, mitigate, and remediate potential seepage from the Purge Storage Reservoir 2 (PSR-2) has been developed and was submitted to the NRC on November 9, 2015 (ADAMS Accession Number ML15317A079). The NRC has provided concurrence with respect to corrective actions presented within the plan and Cameco has fully implemented those. NRC staff periodically reviews the status of corrective actions during their annual inspections.

3.10.4 UIC Deep Injection Wells

3.10.4.1 Potential for Interaction between UIC Deep Disposal Wells and Oil and Gas Development

As stated in ER Section 2.1.4.2, existing and proposed UIC deep disposal wells at Smith Ranch and the North Butte Remote Satellite are, or will be, completed in the Teckla, Teapot and/or Parkman (TTP) sandstones at depths ranging from approximately 2,743 to 3,048 meters (9,000 to 10,000 feet). Although these three sandstone units produce economic quantities of oil and gas within portions of the Powder River Basin, no wells within Smith Ranch or North Butte have produced economic quantities of hydrocarbons. Oil and gas are typically present in stratigraphic traps where they are stored in a porous sand that is laterally confined, or trapped, by non-porous sands and vertically confined by clays and shales. To substantiate this, Cameco reviewed the WOGCC records to identify developed and undeveloped oil and gas reserves within or near the Smith Ranch and North Butte sites. The records search for developed reserves at Smith Ranch indicated that three wells located within the Smith Ranch license area contained uneconomic quantities of hydrocarbons and were plugged and abandoned shortly after installation. All other producing wells are approximately 1.5 kilometers (1 mile) or more from the license boundary. Review of the records for North Butte indicated that there are no wells in production from the TTP within or near the North Butte Remote Satellite license boundary. As for undeveloped reserves, the WOGCC record search indicated that there are no known planned wells in the TTP within or near the Smith Ranch and North Butte license boundaries.

There is minimal risk that oil and gas wells will capture injected fluids or that UIC injection wells will restrict the development of oil and gas reserves within 1.5 kilometers (1 mile) of the Smith Ranch or North Butte license boundaries. Within the Powder River Basin TTP, vertical oil and gas wells are typically drilled one per 16.2 hectares (40 acres), while horizontal wells are drilled one well per 130 hectares (320 acres). These wells may not all intersect the same reservoir trap, as they are typically stratigraphically controlled and discontinuous. The UIC deep injection wells typically are not completed within economical oil and gas reservoirs. There are no active or planned production wells within 1.5 kilometers (1 mile) of the Smith Ranch and North Butte license boundaries. Therefore, the risk is minimal that oil and gas development will restrict the installation and use of UIC injection wells.

The Gas Hills Remote Satellite Facility is located within the Wind River Basin. Planned UIC disposal wells at this project site target the Flathead Sandstone at depths of 1,050 meters (3,446 feet) and 1,561 meters (5,120 feet). Although the Flathead Formation can contain hydrocarbons, to date their quantity has been uneconomic. A search of the WOGCC records indicate that there are no active or planned production wells within the Flathead Sandstone within or near the Gas Hills license area. Because of the geologic nature of oil and gas reservoir formation, and the fact that there are no planned or active oil and gas wells within the Flathead sandstone in the Wind River Basin, and the fact that there are no active or planned production wells within 1.5 kilometers (1 mile) of the Gas Hills license boundary, there is minimal risk that oil and gas wells will capture injected fluids or that UIC injection wells will restrict the development of oil and gas reserves within or near each site. Likewise, the risk is minimal that oil and gas development will restrict the installation and use of UIC injection wells.

3.10.4.2 Natural and Manmade Migratory Pathways

Improperly abandoned or sealed wells, casing or grouting failures may potentially allow injected fluids to affect groundwater in other aquifers. Federal and state UIC regulations recognize this potential and require that each UIC applicant investigate this potential as part of the permit application process. In Wyoming, each WDEQ UIC application requires an Area of Review analysis which includes an investigation and identification of potential migratory pathways that may be caused by existing or plugged and abandoned wellbore or other artificial penetration. The regulations also require that the applicant include a corrective action plan to address identified improperly completed or plugged and abandoned wells within the Area of Review. For the UIC well sites permitted to date at Smith Ranch-Highland, North Butte and Gas Hills, no potential migratory pathway problems requiring contingency or corrective action plans have been identified.

To minimize the potential of the injection well itself causing migratory pathway problems due to poor installation practices, the regulations require that the operator use standard reservoir engineering practices to design and construct the well. All engineering schematics and subsurface construction details must be approved by the agency prior to approval of the permit. There must be at least two layers of concentric casing and cement with the outer casing cemented to the surface. Testing must be performed during drilling and construction of the well to ensure that there is no vertical migration of fluids. Prior to operating the well, it is tested internally and externally for mechanical integrity. These tests are repeated at least once every five years. Continuous monitoring of the well during well operation also minimizes the potential of the well itself creating contamination problems via migratory pathways.

Due to the discontinuous nature and low natural permeability of the injection targets at the Smith Ranch Project sites, it is anticipated that hydraulic fracturing will be required as part of the injection well construction at all sites in order to provide adequate wellbore injectivity. Hydraulic fracturing is a well stimulation process that involves the pressurized injection of fluids into the targeted injection zone of a wellbore. The pressure of the injected fluid exceeds the rock strength of the geologic formation resulting in the opening of new or the enlargement of existing fractures in the rock. As the formation is fractured, a "propping agent" such as sand is pumped into the fractures to keep them from closing as the pumping pressure is released. It has been shown that the propagation of fractures due to hydraulic fracturing does not necessarily create fractures that penetrate beyond the zone of injection thereby creating pathways for migration of fluids into shallower sources of groundwater.

At Smith Ranch-Highland and North Butte sites, the targeted injection zone is within the TTP formations. The TTP confining units consist of marine shales that limit vertical fracture growth during hydraulic fracturing. The Type Log for the North Butte well location indicates that approximately 120 meters (400 feet) of shale exists above the Teckla separating it from the lowermost underground source of drinking water (USDW) (the Fox Hills Sandstone). The Type Log for Smith Ranch-Highland indicates approximately 180 meters (600 feet) of shale above the Teckla separating it from the lowermost USDW, which again is the Fox Hills Sandstone. Approximately 243.8 meters (800 feet) of shale separate the base of the Parkman from the next underlying porous formation, the Sussex Sandstone.

Data from historical fracture stimulations of the TTP in the Powder River Basin indicate that the effective fracture lengths are quite small. In fact, they are so small that pressure transient analyses on most of these deep disposal wells do not identify a propped hydraulic fracture by diagnostic linear flow and result in a diagnostic radial flow and homogenous reservoir. The required annual pressure falloff tests (APFT) document this behavior. The wells investigated are listed below with their APFT results:

- Morton 1-20: radial, homogenous reservoir with no boundaries
- Vollman 33-27: radial, homogenous reservoir with no boundaries
- SRHUP 6: radial, homogenous reservoir with a single boundary
- SRHUP 9: homogenous reservoir with parallel boundaries
- SRHUP 10: radial, homogenous reservoir with a single boundary
- SR DDW1: radial composite reservoir
- SR DDW2: radial, homogenous reservoir with no boundaries
- North Butte BY 2: vertical well with finite conductivity fracture

For stimulations currently being performed in the TTP, data indicates that fracture height does not exceed 15 meters (50 feet) above or below the porous sandy interval. A total fracture height of less than 90 meters (300 feet) is the typical industry well design. Current hydraulic fracture stimulation in the Cretaceous sands of the Powder River Basin (which includes the TTP) result in horizontal fracture half-lengths ranging from 90 to 180 meters (300 to 600 feet) with 150 meters (500 feet) being a common design criterion (WOGCC Dockets 89-2012, 208-2012, and 251-2012).

Specifically, the recent completion and stimulation of North Butte BY 2, the deep disposal well at the North Butte project, provided pressure transient test analysis results that describe the propped hydraulic fracture placed in that well. The analysis indicated (a) no vertical fracture growth outside of the completed sand (i.e., effective fracture height equals the perforated height, so there was no additional contributing fracture height), and (b) a propped fracture with a fracture half-length of 65 meters (212 feet). Therefore, the hydraulic fracture stimulations used on the deep disposal wells, both historical and modern do not create fractures that would allow communication with shallower, fresh water aquifers.

The Smith Ranch and North Butte sites are located in areas with no identified faults. Thus, the propped fractures cannot be connected to naturally occurring fault systems.

Prior to drilling Cameco's Gas Hills Test Wells DDW 1 and DDW 2, there were only two historical Flathead Sandstone penetrations in the Gas Hills area, and both of those wells were plugged and abandoned with no completion in the Flathead Sandstone. WOGCC records indicate no oil production from wells completed in the Flathead Sandstone in the state. There are two Flathead Sandstone wells from which water samples have been collected (one in the Hannah Basin, and the other in the Bighorn Basin).

Because of the cementation of this sandstone in the Gas Hills area, Cameco anticipates that hydraulic fracturing will be required to obtain adequate injectivity. There is very little published information on hydraulic fracturing in the Flathead Sandstone in the Wind River Basin. Cameco is unaware of any design or modeling that has predicted fracture height or vertical fracture half-length extent in the Flathead. Although there is identified faulting in the Wind River Basin and within the Gas Hills Project site, there is little geologic data available showing that the faults could extend into the Flathead.

Therefore, Cameco will need to consider the distance between an existing fault and the disposal well when preparing the propped hydraulic fracture design. In choosing the locations for DDW 1 and 2, maximizing the distance from the faults was a major consideration. Although not required by the Class I non-hazardous waste well regulations, design and planning of disposal wells at the Gas Hills site will include a geologic structural analysis to show that the area of influence of the disposal well is free of vertically transmissive faults and fractures.

3.10.4.3 Induced Seismicity

It has long been known that many human activities are capable of inducing earthquakes under certain conditions including impoundment of reservoirs, surface and underground mining, withdrawal of fluids and gas from the subsurface, and injection of fluids into underground formations (Ellsworth, 2013). Seismic activity caused by human activities related to fluid injection into or extraction from the earth is caused by a significant change in rock pore pressure and/or a change in stresses taking place in the presence of (1) faults with specific properties and orientations, and (2) a critical state of stress in the rocks (NAS, 2012). Although research is still being carried out on the detailed causes of induced seismicity, many reports published by government and private entities are available and provide preliminary results of studies conducted to date on the effects of injecting wastewater into deep geologic formations. The UIC National Technical Workgroup was tasked by the EPA in 2012 to develop a report providing practical tools to address the potential for injection-induced seismicity. A draft report was released in November 2012. The report concluded that in order for an induced seismic event to occur due to wastewater injection activities, the injection must take place under conditions of high injection flow and pressure and in proximity to an already stressed fault that is contacted by the injected fluid via a geologic pathway that allows the increased pressure to communicate with the fault. The National Technical Workgroup also concluded that, because injection-induced seismicity is complex and is dependent on a combination of site geology as well as geophysical and reservoir characteristics, basic petroleum reservoir engineering practices coupled with geologic investigation can provide the means to better understand reservoir and fault characteristics. This information can then be used to identify potential induced seismic concerns that can then be minimized through proper well placement and operation (EPA, 2012). The factors affecting the potential for injection activities to generate felt seismic events that can be incorporated into the injection well planning process include:

- Injection flow rate;
- Volume and temperature of the injected fluids;

- Pore pressure;
- Reservoir permeability;
- Fault existence, properties and location;
- Crustal stress conditions;
- Distance of the fault from the injection point; and
- Length of time over which injection takes place (GWREF, 2013).

From the literature research performed, it is evident that the consensus of both the industrial and regulatory communities is that although injection wells do have some potential for inducing seismicity in areas where local faults are susceptible, there have been very few felt (magnitude 3.0 or greater) induced events reported as caused by or likely related to injection well activity (NAS, 2012). Local risks can be assessed using available geologic information to manage identifiable hazards, so that if induced seismicity is suspected to become an issue, operating threshold conditions can be adjusted to keep seismicity at low, non-damaging levels (EPA,2012).

Smith Ranch-Highland and North Butte Sites

Case et al, 2002 has described the seismological characteristics for Campbell and Converse Counties, Wyoming, which describes no known exposed active faults with surface expression in these counties. Historically the Powder River Basin has not been a seismically active region. As Campbell and Converse Counties are in a Zone 0 to Zone 1 area with peak acceleration of 0 to 10%, the chance of seismic activity in the basin is minimal. At the Smith Ranch-Highland site, geological investigations by Exxon, Kerr-McGee and Cameco over the past 30 to 40 years have not identified major faults or folds in the bedrock within the license area (Cameco, 2013). There have been no reports of seismic activity in the area of the existing disposal wells during the past 27 years of operation at the Smith Ranch site. Because (a) there are no identified faults in the area of interest around the disposal wells, and (b) Cameco controls the injection flow and pressure so as to not adversely affect the reservoir being injected into, the risk of seismic events being induced by Cameco's injection well operations is considered minimal.

A similar structural situation exists at the North Butte site. In fact, there is less structure apparent at North Butte because of its close proximity to the center of the Powder River Basin. Faulting within the license boundary at North Butte has not been identified either by field observation or drill hole log correlation. Therefore, similar to Smith Ranch-Highland, it is determined that the risk of induced seismicity caused by injection wells will be minimal here as well.

Gas Hills Remote Satellite Site

Case et al, 2002 describes the seismological characteristics for Fremont County, Wyoming. The Case report states there are "two known active fault systems and one suspected active fault system with a surficial expression within the county boundary."

The South Granite Mountain fault system is composed of faults that border the northern flanks of the Seminoe Mountains, Ferris Mountain, Green Mountain, and Crooks Mountain. The largest earthquake that a portion of the fault could produce would be a magnitude 6.86 earthquake. The Gas Hills DDW #1 and the Gas Hills DDW #2 are located approximately 40 kilometers (25 miles) north of this fault system.

The Stanger Creek fault system is located near Boysen Reservoir. The largest earthquake modeled for this system is a magnitude 6.75. The Gas Hills DDW #1 and the Gas Hills DDW #2 are located approximately 80 kilometers (50 miles) southeast of this fault system.

The Cedar Ridge/Dry Fork fault system is theorized to be inactive based on available evidence. The Gas Hills DDW #1 and the Gas Hills DDW #2 are located approximately 80 kilometers (50 miles) south of this fault system.

All of Fremont County lies within Seismic Zone 1. The UBC correlation is that Zone 1 has an effective peak acceleration of 5 to 10% g. An earthquake event could cause slight damage to structures.

Locally, within the Gas Hills license boundary, there are several mapped faults located in proximity to the three proposed disposal wells. For proposed DDW #1, faults include the Buss Fault (approximately 520 meters or 1,700 feet southeast), the Bountiful Fault (approximately 1,070 meters or 3,500 feet southeast) and the UPZ Fault (approximately 1,525 meters or 5,000 feet south). For proposed DDW #2 location, faults include the Lucky Mc Fault (approximately 120 meters or 400 feet south) and the Jasper Fault (approximately 550 meters or 1,800 feet south). For proposed DDW #3, faults include the North Thunderbird Fault (approximately 1,160 meters or 3,800 feet north), the South Thunderbird Fault (approximately 790 meters or 2,600 feet north) and the Buss Fault (approximately 1,525 meters or 5,000 feet south). With the exception of the Lucky Mc Fault near proposed DDW #2, the remainder of the faults are located far enough from the point of injection that affects will be unlikely. However, as part of the disposal well development plan, Cameco will analyze the probability of injected fluids reaching the faults and whether the faults are likely suspects for induced seismic events. Operational plans will be developed to ensure that injection rates and pressures do not exceed that which would trigger a seismic event.

3.11 References

Avian Power Line Interaction Committee. 2006. Raptor Protection on Power Lines-State of the Art in 2006.[?]

Cameco Resources. November 18, 2009. Monitoring Plan for Purge Storage Reservoir No. 2, Shallow Wells MW-1S, MW-2S, MW-3S, and MW-4S.

Cameco Resources, 2009. Power Resources, Inc. dba Cameco Resources, 2009. Gas Hills ISR WDEQ Permit No. 687.

Cameco Resources, 2015. Smith Ranch-Highland Uranium Project License SUA-1548, Docket No. 40-8964. Smith Ranch-Highland Purge Storage Reservoir No. 2 (PSR-2) Corrective Action Plan. ADAMS Accession No. ML15317A079.

Cameco, 2013. **Power Resources, Inc. dba Cameco Resources Smith Ranch-Highland Uranium Project, Wyoming Department of Environmental Quality - Land Quality Division Permit to Mine No. 633** Appendix D5**.**

Case, J.C./Wyoming Geological Survey, 1986. Earthquakes and related geologic hazards in Wyoming. Public Information Circular No. 26.

Case, J.C., Larsen, L.L., Boyd, C.S., and Cannia, J.C. 1997. Earthquake epicenters and suspected active faults with surficial expression in Wyoming, Wyoming State Geological Survey, Preliminary Hazards Report 97-1.

Case, J.C. Toner, R.N. and Kirkwood, R. 2002. Basic Seismological Characterization for Campbell County, Wyoming, WSGS, http://www.wrds.uwyo.edu/wrds/wsgs/hazards/quakes/seischar/Campbell.pdf.

Case, J.C. Toner, R.N. and Kirkwood, R. 2002. Basic Seismological Characterization for Converse County, Wyoming, WSGS, 14p.

Case, J.C., Toner, R.N., & Kirkwood, R, Wyoming State Geological Survey, (2002). Basic seismological characterization for Fremont County, Wyoming. Retrieved from website: http://www.wrds.uwyo.edu/wrds/wsgs/hazards/quakes/seischar/Fremont.pdf.

Case, J.C., 2000. Probability of Damaging Earthquakes in Wyoming, Wyoming State Geological Survey, Geo-notes No. 67, pp 50-55.

Ellsworth, William L. 2013. Injection-Induced Earthquakes, Science Magazine, www.sciencemag.org.

Frondel, Judith W., Michael Fleischer, and Robert S. Jones. 1967. Glossary of Uranium and Thorium-Bearing Minerals, U.S. Geological Survey Bulletin 1250.

Ground Water Research & Education Foundation (GWREF). 2013. White Paper Summarizing a Special Session on Induced Seismicity, Technology Transfer Session Entitled: Assessing & Managing Risk of Induced Seismicity by Injection, January 22-24, 2013. Hansen, E.M., Fenn, D.D., Schreiner, L.C., Stodt, R.W., and J.F., Miller, 1988, Probable Maximum Precipitation Estimates, United States between the Continental Divide and the 103rd Meridian, Hydrometeorological Report Number 55A, National Weather Service, National Oceanic and Atmospheric Association, U.S. Dept. of Commerce, Silver Spring, MD, 242 pp.

Hazen Research, Inc. 1996. Mineralogical Investigation of Uranium Ore Samples and Leach Residues, report prepared for PRI.

Hubbert and Willis. 1957. AIME Petroleum Transactions, T. P 4597, page 168.

Hydro-Engineering. 1992. Simulation of In Situ Leaching Operation and Ground-Water Hydrology at the North Butte ISL Project.

King, John W. and S. Ralph Austin. May 1966. Some Characteristics of Roll-Type Uranium Deposits at Gas Hills, Wyoming., Mining Engineering Journal, p. 73-80.

Linsley, R. K., Franzini, J. B., Freyberg, D. L., and Tchobanoglous, G. 1992. Water Resources Engineering,4th ed. McGraw-Hill, New York.

Ludwig, Kenneth R. and Richard L. Grauch. 1980. Coexisting Coffinite and Uraninite in Some Sandstone Host Uranium Ores of Wyoming. Economic Geology, v. 75, pp. 296-302.

National Academy of Sciences (NAS). 2012. Induced Seismicity Potential in Energy Technologies.

Neunan, James/Champion Oil. June 1983. Personal communication.

Pinu, Mark/Halliburton Services. May 1983. Personal communication.

Plastic Pipe Institute. 2007. Handbook of Polyethylene Pipe, Second Edition.

U. S. Environmental Protection Agency (EPA). 2012. Draft: Minimizing and Managing Potential Impacts of Induced-Seismicity From Class II Disposal Wells: Practical Approaches.

U. S. Nuclear Regulatory Commission (NRC). November 2008. Regulatory Guide 3.11: Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills.

U.S. Nuclear Regulatory Commission (NRC). 2008. Regulatory Guide 3.13:Design, Construction and Inspection of Embankment Retention Systems at Uranium Recovery Facilities.

U. S. Nuclear Regulatory Commission (NRC). October 15, 2011. Letter to A. Faunce/RSO, Cameco Resources, RE: NRC Inspection Report 040-08964/11-002.

Wyoming Department of Environmental Quality, Land Quality Division. May 2005. Rules and Regulations Chapter 11. Non-Coal In Situ Mining.

Wyoming Department of Environmental Quality, Land Quality Division. 2005. Guideline No. 8: Hydrology.

Wyoming Department of Environmental Quality, Land Quality Division. 2014. Guideline No. 4: In-Situ Mining.

Wyoming State Engineer's Office. 1957. Revised June 2011. Regulations and Instruction Part III, Water Well Minimum Construction Standards, Cheyenne, Wyoming.