TECHNICAL EVALUATION REPORT
CHRISTENSEN RANCH MINE UNITS 2 THROUGH 6 RESTORATION REPORT
URANIUM ONE USA, INC., WILLOW CREEK ISR FACILITY

DATE: October 23, 2012

DOCKET NO.: 040-08502

LICENSEE: Uranium One USA, Inc.

SITE: Willow Creek Christensen Ranch, Wyoming

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SUMMARY AND CONCLUSIONS:

By letter dated March 5, 2008, Cogema Mining Company[1] (Cogema) submitted to the U.S. Nuclear Regulatory Commission (NRC) a package of reports documenting its restoration efforts at the Willow Creek[2] Christensen Ranch Mine Units 2 through 6 (Cogema, 2008c). The package includes a summary report describing activities and settings common to all mine units, and five reports detailing restoration activities for each individual mine unit. In summary, the reports show that the target restoration values were not met for all parameters at the end of the restoration activities for Mine Units 2 through 6. Specifically, the package reports that the levels of up to six constituents (iron, manganese, total dissolved solids (TDS), uranium, selenium and radium-226) at the end of the stabilization monitoring period posed a concern at each of the Mine Units to warrant further evaluation. The further evaluations as reported by the licensee in the restoration package consisted of: (1) a discussion of pre-mining class of use for the aquifer; (2) a discussion on the application of the best practicable technology (BPT), as defined by Wyoming Statutes, in the licensee's restoration efforts; (3) a qualitative analysis of reducing environment conditions that would impede the migration of those parameters from the production zone to the surrounding aquifer; and (4) a quantitative analysis of the decrease in levels of selected constituents based on anticipated dispersion. Based on its further evaluations, Cogema concluded that the levels of the constituents of concern above the restoration target values for Christensen Ranch Mine Units 2 through 6 did not pose a threat to human health or the environment.

The NRC staff reviewed the restoration package and provides an independent review and analysis in this Technical Evaluation Report (TER). The NRC staff concurs with many of the assessments in the reports; however, the staff disagrees with the licensee's assessments on several substantive issues. Consequently, the staff cannot recommend approval of restoration for any of the referenced mine units at this time. The NRC staff recommends that the licensee

[1] Cogema Mining Company was the licensee at the time that the Restoration Report was submitted to the NRC; the current licensee is Uranium One USA, Inc.
[2] The licensee has begun referring to the Irigaray and Christensen Ranch Projects collectively as the Willow Creek In Situ Recovery (ISR) Project.

perform additional evaluation, restoration, and decommissioning at these mine units consistent with requirements of 10 CFR 40.42. The staff expects that the additional evaluation, restoration, and decommissioning will be unique for each mine unit, with some units requiring little additional effort, whereas others require much more effort by the license. The NRC staff's recommendations for each specific mine unit are included in this TER.

INTRODUCTION

By letter dated March 5, 2008, Cogema submitted a report entitled "Wellfield Restoration Report: Christensen Ranch Project: Wyoming" (Restoration Report) to the NRC for review and approval (Cogema, 2008c). The Restoration Report documented Cogema's efforts at restoration of the production aquifers at the Christensen Ranch Mine Units 2 through 6. In February 2009, based on a review of the Restoration Report, the NRC staff sent a request for additional information (RAI) to Cogema (NRC, 2009b). In December 2009, Cogema submitted responses to NRC RAIs (Cogema, 2009a). This TER is staff's completed evaluation of the Restoration Report for Mine Units 2 through 6 at the Willow Creek Christensen Ranch Project, Wyoming.

BACKGROUND

Between 1993 and 2010, Cogema operated a uranium in-situ recovery (ISR) facility at the Irigaray and Christensen Ranch Projects, Johnson and Campbell Counties, Wyoming, under NRC source materials license SUA-1341. Uranium recovery operations for Mine Units 2 through 6 at the Christensen Ranch Project were completed by 2005. In 2009, the license was transferred from Cogema to Uranium One USA, Inc. (NRC, 2009a).

Operations at the Christensen Ranch Project were conducted within five discrete areas designated as Mine Units 2 through 6. The locations of the mine units are shown on Figure 1. Each mine unit is subdivided into three-to-six modules. In the Restoration Report, the licensee described a module as an individual wellfield. Uranium recovery at an individual module may have been sequentially added to a mine unit during operations. Restoration activities may also have been sequentially performed on a module-by-module basis.

Production activities at the Christensen Ranch Project occurred at each mine unit generally within a 2- to 3-year period. Mine Unit 3 (MU-3) was the first mine unit to be brought into production at the Christensen Ranch Project with initial operations dating back to 1989 (prior to Cogema being the licensee). Mine Units 5 and 6 were the last to be brought into production.

Restoration activities at the mine units were performed between 1997 and 2000 after the production activities ceased and continued on a sporadic schedule until 2005. Cogema reports that a 2-year hiatus occurred between the operation and restoration activities only at MU-3, whereas the restoration was conducted immediately following cessation of production activities at all other mine units (Cogema, 2008c).

Restoration activities consisted of a groundwater sweep phase, groundwater treatment phase, and a groundwater recirculation phase. Injection of a reductant (hydrogen sulfide) was included for a short period of time either during groundwater treatment or groundwater recirculation phases for MU-2 through MU-4, and for a short period at selected spots in MU-6. Stability monitoring was conducted for four (4) contiguous quarterly events for each mine unit immediately following completion of the restoration activities.

REGULATORY FRAMEWORK

The NRC staff's evaluation of groundwater restoration is based on the uranium mill regulations in 10 CFR Part 40, Appendix A, which were written primarily for conventional uranium mills and later applied to ISRs. In 2009, Regulatory Issue Summary 2009-05 (RIS 2009-05) stated that 10 CFR Part 40, Appendix A, Criterion 5B standards, are the applicable restoration standards for groundwater at ISR facilities (NRC, 2009c). Prior to 2009, a groundwater "class-of-use" restoration standard, based on the State of Wyoming's groundwater classification system, was considered acceptable. This class-of-use standard was documented in license SUA-1341 for Cogema's Christensen Ranch Project. Therefore, the staff's evaluation of the Cogema Christensen Ranch Restoration report applied the "class-of-use" groundwater restoration standard as it was applicable at the time that this report was submitted.

To clarify this decision, the following section presents the staff's position on RIS 2009-05 and a history behind the acceptance of the class-of-use as an alternative standard.

HISTORICAL PERSPECTIVE OF THE APPLICABLE STANDARDS

Regulatory Based Standards

The applicable regulations for uranium mills are found in 10 CFR Part 40, Appendix A, which is entitled, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by The Extraction or Concentration of Source Material from Ores Processed Primarily for their Source Material Content." In Appendix A, Criterion 5 and Criterion 13 incorporate the groundwater protection standards promulgated by the Environmental Protection Agency (EPA) in 40 CFR Part 192, subparts D and E, which apply during uranium mill operation and prior to closure.

Criterion 5B(5) lists three standards, one of which each hazardous constituent in groundwater must meet at the point of compliance. The standards are:

a) The Commission approved background concentration of that constituent in the ground water;
b) The respective value given in the table in paragraph 5C if the constituent is listed in the table and if the background level of the constituent is below the value listed; or
c) An alternate concentration limit established by the Commission.

As stated in Appendix A, Criterion 5B(6), "[c]onceptually, background concentrations pose no incremental hazards and the drinking water limits in paragraph 5C state acceptable hazards but these two options may not be practically achievable at a specific site." Consequently, the first two standards, the Commission-approved background and drinking water limits in paragraph 5C, are considered the primary goals for the restoration of an ISR production aquifer. Because achieving either of these primary goals may not be practicable for a specific restoration, the third standard, a Commission-established alternate concentration limit (ACL), may be used for a restoration provided the ACLs present no significant hazard, are proposed by a licensee in an application to the Commission, and are approved by the Commission.

The language in the current regulations focuses on conventional mills and not ISR sites because when the regulations were initially written, ISR was an unproven technology. As a

result, the language poses challenges for implementation of the regulations by ISR facilities. The primary challenges are the language used to define (1) the point at which the standards apply, and (2) the set of applicable constituents for which a standard applies.

Criterion 5B(5) states that the standards are applicable at the point of compliance. The point of compliance is defined in the *Introduction* to Appendix A as follows:

> *Point of Compliance* is the site specific location in the uppermost aquifer where the ground-water protection standard must be met.

The uppermost aquifer is defined in the *Introduction* to Appendix A as:

> *Uppermost aquifer* means the geologic formation nearest the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facilities property boundary.

The objective for the point of compliance as defined by Criterion 5B(1) is "to provide the earliest practicable warning that the impoundment is releasing hazardous constituents into the ground water." The current language of the regulations meets this objective for a mill tailings site but not for most ISR sites where the production zone is isolated from the uppermost aquifer. Monitoring in the uppermost aquifer at an ISR site would not meet the stated objective. A general definition of a point of compliance by EPA guidance is that location at which "a facility should monitor groundwater quality and/or achieve specified cleanup levels to meet facility-specific goals" (EPA, 2004). Consequently, the NRC staff applies the groundwater protection standards at ISR sites as follows:

(1) During operations, a detection monitoring program is implemented with the compliance monitoring network consisting of the perimeter ore aquifer monitoring ring, and monitoring wells in the aquifers overlying and underlying ore aquifer; and
(2) During restoration, a compliance monitoring program is implemented with the compliance monitoring network consisting of wells located within the ore zone.

The constituents to be monitored at the point of compliance are hazardous constituents as defined in Criterion 5B(2). Criterion 5B(2) defines a hazardous constituent as follows:

> A constituent becomes a hazardous constituent subject to paragraph 5B(5) only when the constituent meets all three of the following tests:
>
> (a) The constituent is reasonably expected to be in or derived from the byproduct material in the disposal area;
> (b) The constituent has been detected in the ground water in the uppermost aquifer; and
> (c) The constituent is listed in Criterion 13 of 10 CFR Part 40 Appendix A.

ISR sites do not have tailing disposal areas nor is the uppermost aquifer that aquifer which would be first impacted. Consequently, the NRC staff determines that the NRC's regulations are satisfied at ISR sites if:

(a) The constituent is reasonably expected to be in or derived from the byproduct material including the residual lixiviant;
(b) The constituent has been detected in the groundwater in any aquifer immediately surrounding the production zone; and
(c) The constituent is listed in Criterion 13 of this 10 CFR Part 40, Appendix A.

Historical Perspective of the "Class-of-Use" Alternative Standard

In the 1990s, industry questioned NRC's regulatory jurisdiction on the restoration of groundwater within the wellfield as the regulations appeared to be duplicative of those under the EPA-administered Underground Injection Control (UIC) program in 40 CFR Part 146 (Lehrenbaum, et al., 1998). In Staff Requirements Memorandum (SRM)-SECY-99-013, "Recommendations on Ways to Improve the Efficiency of NRC Regulation at in Situ Leach Uranium Recovery Facilities," the Commission affirmed that NRC did have regulatory jurisdiction over groundwater in the wellfield pursuant to the Atomic Energy Act of 1954, as amended (AEA) (NRC, 1999b; NRC, 2000a; NRC, 2000c). However, due to concerns over dual regulation, the staff requested in SECY-03-0186, "Options and Recommendations for NRC Deferring Active Regulation of Ground-Water Protection at In Situ Leach Uranium Extraction Facilities," Commission authorization to rely on the UIC permitting process of EPA-authorized, non-Agreement States as a basis to defer from active NRC regulation in these States (NRC, 2003a). After meeting with Nebraska and Wyoming, two non-Agreement States where NRC-licensed ISRs were in operation, the staff relayed its findings to the Commission in SECY-05-0123, "Status of the Development of Memoranda of Understanding with Nebraska and Wyoming, Regarding the Regulation of Groundwater Protection at Their *In Situ* Leach Uranium Recovery Facilities" (NRC, 2005). The staff found that primary restoration standards of Nebraska and Wyoming's UIC programs under the statutory authority of the Safe Drinking Water Act (SDWA) differed from the primary restoration standards in NRC licenses under the AEA.

The difficulty of utilizing the regulations in Appendix A for groundwater protection led former Commissioner Merrifield to state in COMJSM-06-0001 (NRC, 2006b):

> It is my belief that the manner in which the NRC currently regulates this group of licensees is both complex and unmanageable. While the staff has done its best to regulate ISL licensees through the generally applicable requirements in Part 40 and imposition of license conditions, our failure to promulgate specific regulations for ISLs has resulted in an inconsistent and ineffective regulatory program. We have been attempting to force a square peg into a round hole for years, and I believe we should finally remedy this situation through notice and comment rulemaking….

In SRM-COMJSM-06-0001, "Regulation of Groundwater Protection at In Situ Leach Uranium Extraction Facilities" (NRC, 2006a), the Commission directed the staff to defer active regulation of groundwater protection programs to the EPA or an EPA-authorized State through EPA's underground-injection-control permit program and provide a proposed rule for the Commission to evaluate. During the interim, the staff was directed to:

(1) Pursue memoranda of understanding with Wyoming and Nebraska (both EPA-authorized States for the UIC program and locations of active ISR facilities with a NRC license) such that the states agree to uphold NRC regulations; and

(2) Exercise discretion to allow current licensees to meet State groundwater requirements in lieu of alternative conditions that may exist in their licenses.

Consequently, the groundwater classification or “class-of-use” as a restoration standard was endorsed by the Commission. Most operational ISR licenses contained “class-of-use” as a restoration standard. Active licensees had been notified of this initiative in Regulatory Information Summary (RIS) 2004-09 (NRC, 2004b).

Eventually, the effort to develop a memorandum of understanding between the NRC and the States of Wyoming and Nebraska was discontinued due to differences in the statutory authority for the NRC program under the AEA and the EPA UIC program under the SDWA.

The Commission then directed the staff in SRM-COMSECY-07-0015, “Path Forward For Rulemaking On Groundwater Protection At In Situ Leach Uranium Extraction Facilities,” to resume the rulemaking process for groundwater protection at ISL facilities to conform to 40 CFR Part 192 (NRC, 2007a). The Commission required the staff to:

(1) Engage interested stakeholders through public workshops;
(2) Work closely and cooperatively with EPA;
(3) Remain diligent in working with EPA and appropriate States to establish appropriate standards to protect public health, safety and the environment; and
(4) Reduce and preferably eliminate dual regulation.

Eventually, the proposed rulemaking effort was suspended due to the EPA’s rulemaking effort to revise 40 CFR Part 192 to include requirements for groundwater at ISRs (EPA, 2011).

In RIS 2009-05, “Uranium Recovery Policy Regarding: (1) The Process for Scheduling Licensing Reviews of Applications for New Uranium Recovery Facilities and (2) the Restoration of Groundwater at Licensed Uranium in Situ Recovery Facilities,” the NRC staff recognized that using the groundwater class-of-use, a standard based on the SDWA and EPA UIC program, was inconsistent with the NRC regulations in 10 CFR Part 40, Appendix A and the AEA. The class-of-use groundwater classification as a restoration standard, as discussed in NUREG-1569, was inconsistent with 10 CFR Part 40, Appendix A as well. The class-of-use standard did not meet all of the requirements for an ACL. RIS-2009-05 clarified that the applicable standards for groundwater restoration were those in 10 CFR Part 40, Appendix A, Criterion 5B (i.e., background, values in paragraph 5C, or ACLs) (NRC, 2009c).

Because of the difficulty of regulating groundwater protection at ISR sites due to the lack of specific ISR groundwater regulations in Appendix A, the NRC staff has used license conditions to ensure the protection of groundwater at ISRs. The restoration standards for Mine Units 2 through 6 at the Christensen Ranch Project are governed by the conditions in NRC license SUA-1341 at the time that the Restoration Report was submitted to the NRC on March 5, 2008. At the time the Restoration Report was submitted to the NRC, License SUA-1341, Amendment 12, License Condition 10.16 (NRC, 2007b) stated:

> The licensee shall conduct ground water restoration and post-restoration monitoring as described in Section 6.1 of the approved license application. The primary goal of restoration shall be to return the ground water quality, on a production-unit average, to baseline concentrations on a parameter-by-parameter basis. If the primary goal cannot be achieved, the ground water will, at a minimum, be returned to the pre-mining use category.

Changes to ground water restoration or post-restoration monitoring plans shall be submitted to the NRC for review and approval at least 2 months prior to ground water restoration in a mining unit.

At the time of the previous license renewal on June 30, 1998, NRC had adopted a risk-informed, performance-based (RIPB) licensing approach to ISR facilities (NRC, 1998). License Condition 10.3 in License SUA-1341 includes references to tables listing appropriate baseline concentrations only for Mine Units 2 through 5. These restoration values were carried over from the previous license during the last license renewal on June 30, 1998 (NRC, 1998). A reference to baseline groundwater quality for MU-6 was included in the early versions of the RIPB license, but the reference was removed from the license at the request of the licensee in Amendment No. 4 (NRC, 2001). The baseline concentrations for MU-6 were not included as a license condition but established through the licensee's Safety Evaluation Review Panel (SERP). Consequently, the NRC staff will use the background water quality established in License SUA-1341, Amendment 12, License Condition 10.3 (NRC, 2007b) that states in part:

> The licensee shall establish pre-operational baseline water quality data for all production units. Baseline water quality sampling shall provide representative pre-mining ground water quality data and restoration criteria as described in the approved license application. The data shall be from wells established in the mining zone, the mining zone perimeter, the upper aquifer and the lower aquifer where present, with spacing and locations as specified in the approved license application. The data shall, at a minimum, consist of the sample analyses shown in Table 5.25 of Section 5.8.2.2 of the approved license application.
>
> Baseline ground water quality in previously approved production areas shall be the mean data values (well field average) from the following submittals:

Christensen Ranch	
Unit 3 and Module 2 expansion	December 1, 1988 (Table 2)
Unit 3 expansion and Module 4A expansion	August 8, 1991 (Table 6)
Unit 2 south portion	November 27, 1992 (Table 2)
Unit 2 north portion	April 16, 1992 (Table 2)
Unit 4	April 1, 1994 (Table 6)
Unit 5	February 28, 1995 (Table 7)

As will be discussed in the evaluation findings for Unit 6, NRC will use the baseline as developed by the SERP and approved by the Wyoming Department of Environmental Quality (WDEQ).

For the Restoration Report review, the NRC staff used the restoration standards and baseline water quality at the time the Restoration Report was submitted to the NRC on March 5, 2008. The restoration standards are listed in Materials License SUA-1341, Amendment 12, License Condition 10.16 and the baseline water quality is referenced in License Condition 10.3 (NRC, 2007b). Where the primary restoration goal could not be achieved, the NRC staff used the constituent values listed in the Wyoming pre-mining groundwater class-of-use category as secondary standards in lieu of ACL values.

For Christensen Ranch, the pre-mining class of use of the water was defined by the licensee and WDEQ as Class IV, also known as industrial use (Cogema, 2008; WDEQ, 2005). The NRC staff agrees with this classification. According to Wyoming State Water Quality Rules and Regulations, Chapter 8, Section 4(d)(vii) (C), a discharge into an aquifer containing Class IV groundwater shall not result in it being unfit for its intended use. In addition, under Chapter 8 Section 4(d)(vii)(E) the rules state:

> A discharge into an aquifer with Class IV (a) 1or IV (B) Groundwater of the state shall not result in radioactivity concentrations or amounts which exceed the standards for Class I through III and Special (A) Groundwaters of the State; or in concentrations or amounts which exceed background concentrations of the underground water, whichever is greater, at any place or places of withdrawal or natural flow to the surface.

According to this regulation, the NRC staff concludes that the Class IV restoration standards for all mine units for the radionuclide radium-226 are the Class I, II and III standard of 5 pCi/L or the baseline mean value, whichever is higher. For the radionuclide uranium, Wyoming lists no Class I, II, or III standards, so the NRC staff concludes that the class-of-use standard for uranium is the baseline mean for each mine unit.

REVIEW PROCEDURES

As specific guidance for reviewing restoration reports is not available, the staff based its review of the restoration report on areas of review, review procedures, and acceptance criteria found in other related guidance documents (e.g., NUREG-1569 and NUREG-1620). The review process developed for the restorations under current review is depicted by the flow chart shown on Figure 2. The evaluation consists of the following:

- whether or not the restoration at a specific mine unit achieved the restoration primary goal;
- if the primary goal was not achieved, whether or not the restoration activities are consistent with the application of BPT[3];

[3] Limited guidance is available for staff's interpretation of "not achieving" the primary goal in the case of the class-of-use as a secondary goal. 10 CFR Part 40 Appendix A Criterion 5B(6) specifies that the licensees may request use of an ACL, Criterion 5B(5)(c), but only after demonstrating that Criterion 5B(5)(a) and Criterion 5B(5)(b) are not practicably achievable considering available corrective actions and that the limits are as low as reasonable achievable; however, the class-of-use standard as applied in this case is not an ACL and this regulatory requirement is not applicable. Guidance in NUREG-1569 (NRC, 2003) states that "secondary standards will not be applied so long as restoration continues to result in significant improvement in ground-water quality. The applicant must first attempt to return ground-water quality to primary restoration standards before falling back on secondary restoration standards." Wyoming Guideline No 4 states that the secondary goal of restoration within class of use is applicable if and only if BPT has been demonstrated. Wyoming guideline 4 defines BPT as "a technology based process determined by WDEQ as justifiable in terms of existing performance and achievability (in relation to health and safety) which minimizes, to the extent safe and practicable, disturbances and adverse impacts of the operation on human or animal life, fish, wildlife, plant life and related environmental values."

- whether or not the constituent restoration levels are stable and show no statistically significant increase which could exceed the restoration standard; and
- whether or not impacts from historical excursion events are properly characterized and corrective actions for excursion remediation were satisfactory.

For the stability trend analysis, the NRC staff uses a linear regression analysis of the stability monitoring groundwater data as recommended by the EPA in Chapter 17 of its document entitled, "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance" (EPA, 2009). This analysis uses hypothesis testing to enable the staff to analyze if the slope of a trend line fit through the stability monitoring data is significantly different than zero (null hypothesis). The hypothesis test therefore allows the identification of a statistically significant increasing trend (SSI) in the stability monitoring data.

Specifically, the EPA method used to evaluate the trend involves testing the slope coefficient from a linear regression trend line fit through the stability monitoring data of n points, $y=mx+b$, using a specially constructed Student's t-test. The test evaluates the mean squared error of the residuals, s_e^2, determined from the difference between the measured data values and the linear regression values to determine the standard error, $s_e(m)$, from the slope, m, of the regression line. A t-statistic, t_b, is calculated from the ratio of the slope of the regression line to the standard error, $m/s_e(m)$. This t-statistic is then compared to the Student's t-distribution value, t_{cp}, at a given level of significance, α, with (n-2) degrees of freedom. If the value of $t_b > t_{cp}$, there is a SSI. Otherwise, there is no statistically significant trend. The number of data points, n, used to define the trend affects the value of t_{cp} and thus has a significant impact on whether a statistically significant trend is detected. The NRC staff has determined for a typical ISR setting that at least four monitoring stability data points taken no less than quarterly are required to meet a minimum statistical standard of at least two degrees of freedom (n-2).

This statistical trend analysis was applied to uranium, TDS and radium-226 concentrations for individual compliance wells in each mine unit for which at least four stability measurements were available. The linear regression was done using trend line package in Microsoft Excel. The regression residuals were determined and evaluated for bias. If no bias was found, the linear regression was accepted and the key statistics described above were evaluated. The level of significance for the t-test was chosen to be $\alpha=0.10$ for a 90% confidence.

Details of the staff's evaluation are discussed in the safety evaluation for each mine unit. The evaluation included reviews of data from the restoration reports, annual effluent monitoring reports, excursion monitoring reports and the wellfield data packages prepared by the licensee. For completeness, the trends in the stabilization data are graphically portrayed in Attachment II.

SAFETY EVALUATION

Details of the safety evaluation are discussed below for each mine unit. However, several comments are common to the mine units. For ease of discussion, those comments will be referred to as "general comments" as follows:

Previous NRC staff approvals of restorations that relied on the secondary "class-of-use" goal based their evaluations on the fact that the levels during restoration approached "an asymptotic" trend along with using the best practicable technologies for restoration. This approach is the standard used for this evaluation.

(1) In general, the licensee appears to have made a good faith effort in the restoration activities. This effort is particularly true for the restoration of the first several mine units. The later restorations appear to have been hampered by the large pore volumes associated with the later mine units and by the maximum flow rate capacity for the waste water treatment system, which was ultimately increased from 500 to 1,000 gpm.

(2) The licensee compares the mine unit arithmetic mean after restoration on a parameter-by-parameter basis to a Target Restoration Value (TRV). This comparison is consistent with procedures defined in the license application, assuming that the TRVs used by the licensee are representative of the ***range*** in baseline conditions. The TRVs used by the licensee are derived in part from tables referenced in License Condition 10.3 of the license.

The reported TRVs have been approved by the regulatory agencies (NRC and WDEQ). However, the staff disagrees that the TRVs used by the licensee are representative of baseline conditions for all parameters and, furthermore, License Condition 10.3 specifies that the mean data values listed in those tables (wellfield averages), and not specifically the TRVs used by the licensee, are to be used for baseline (NRC, 2007b).

The TRVs used by the licensee are, in essence, the mean value of the baseline data plus a factor times standard deviation. Use of those TRVs that incorporates a mean plus five standard deviations was questioned by the staff during review of the 1996 license renewal application. At that time, the staff was concerned about the statistical viability of comparing an average for one set of data, in this case the restoration data, to the 99.9999% percentile (mean plus five standard deviations for a normal distribution of data) of another dataset, in this case the baseline data (Cogema, 1996b). In response to the staff's concerns, the licensee committed to performing a statistically viable method for comparison of the restoration to baseline data in the restoration reports but maintained that the tolerance limit approach was still valid (Cogema, 1997). In the later mine unit reports, the licensee calculates a TRV based on the mean plus (3 to 5) times the standard deviation.

The staff acknowledges that the baseline values should reflect variability in the background concentrations. However, a comparison using five standard deviations from the mean may lead to unrealistically elevated concentrations (e.g., a pH value of 13.6 for MU-6). Furthermore, for several constituents, in particular TDS, conductivity and radium-226, the TRVs have been calculated incorrectly by the licensee. The TRVs were calculated using the mean plus the variance rather than the mean plus five standard deviations. Consequently, the licensee has not demonstrated that the TRVs used in the restoration reports are statistically valid for comparison with the restoration wellfield mean value. (For evaluation of health impacts, staff based the evaluation on the mean value. Staff did incorporate the licensee's TRVs as a reference point in the discussion on restoration success because the previous regulatory "approval."

(3) The licensee did not evaluate whether or not the distribution of the restoration data for a wellfield (mine unit) is normal so that statistical averaging may be applied, whether or not "hot spots" exist in the data, or whether or not the number of non-detectable levels is similar to the distribution for the baseline data. Without this evaluation, the staff cannot conclude that the evaluation of impacts from the migration of hot spots as discussed below, for each restoration is acceptable.

(4) The licensee segregated the detailed reports based on mine units. However, the established baseline data, as listed in License Condition 10.3, are segregated as follows:

Mine Unit 2 North;
Mine Unit 2 South;
Mine Unit 3;
Mine Unit 3 Expansion (Module 4a);
Mine Unit 4; and
Mine Unit 5.

The licensee should have adhered to this segregation in the restoration reports but did not provide any justification for doing otherwise. For example, the licensee averaged the baseline data for MU-2 North and MU-2 South for its MU-2 Restoration Report. However, the average should have included a factor for differences in the number of samples in and variance of each dataset. Furthermore, the licensee did not provide rationale for using restoration data in the Restoration Report for MU-4 from three wells that were used for the baseline data analysis for MU-3 Expansion but did not modify the MU-4 baseline data accordingly. The staff's evaluation included a re-calculation of the restoration data for proper comparison of the baseline mean for several mine units.

(5) The licensee relied on qualitative arguments that reducing environments outside of the ore zone will effectively reduce the observed levels to safe levels at the perimeter of the ore zone without providing any quantitative analysis for evaluation by the staff. Furthermore, several of the qualitative arguments appear to be over-simplifications of site conditions. For example, the detection of iron, manganese and a sulfur odor as indicators of reducing conditions is in general correct; however, the detection of uranium at elevated levels in groundwater that has elevated iron and manganese levels is counter to the licensee's argument. Furthermore, the detectable sulfur odor may likely be attributed to the reductant additions and the licensee should address whether or not the effects of the sulfide reductant are local to the well at which the additions were applied or representative of the aquifer. The qualitative arguments by the licensee did not address differences in groundwater quality that will affect the capacity of the aquifer to absorb the trace level constituents (e.g., the abundance of calcium would compete with the absorption of radium or the higher sulfate levels may tend to form soluble complexes with radium, both of which phenomena would increase the mobility of radium). Finally, evaluation of the excursion data at several perimeter wells at MU-5 indicates that it is possible for uranium to migrate from ore zone (or flare) to the perimeter well ring despite the qualitative arguments of reducing conditions suggesting otherwise.

(6) The licensee did not fully evaluate impacts from historical excursions. The staff's evaluation finds that the excursions created two areas of concern which have not been fully addressed by the licensee. First, excursions in the shallow aquifer in the vicinity of the southern area of MU-2 and the northern area of MU-3 indicate an impact greater than a single well. Second, long term excursions extending into the stabilization monitoring period are noted at wells located in areas which separate two mine units or in one case, modules (e.g., between MU-2 South and MU-3, between MU-3 and MU-4, and between MU-5 Module MOD55 and MU-5 Module MOD56[4]). These areas are likely to

[4] The restoration report did not make a distinction for module MOD56; in essence, it was included with MOD55. However, previous mapping submitted by the licensee (e.g., the 2004 Report on the excursion

have been influenced by cones of depression from both mine units/modules at differing times and thus, the long-term excursions are likely residual effects from extensive flaring from one or both mine units/modules.

(7) The licensee reports in Restoration Report, Section 2.3, Groundwater Classifications, Aquifer Exemptions, that all of the mine units' water quality is considered to be Class IV under the WDEQ regulations (WDEQ, 2005). The NRC staff notes that for the EPA aquifer exemption, the State reclassified all of the groundwater in the mine units to Class V (Uranium Commercial) (WDEQ, 1988). The NRC staff has determined that Wyoming State Chapter 8 regulations require that Class V groundwater quality be returned to levels consistent with the pre-mining (Class IV) use, so the reclassification does not affect any change in the Class IV restoration standards used in this review.

These above comments may be referenced as needed in the detailed discussions below.

Mine Unit 2 (Mine Unit 2 North and Mine Unit 2 South)

Geometry, Geology & Hydrogeology

Based on the September 11, 2008, updated surety estimate (Cogema, 2008b), the geometry of the MU-2 is as follows:

Area (acres):	20.43
Thickness (feet):	11
Flare Factor:	1.44
Volume (million cubic feet):	14.1
Porosity:	0.26
Pore Volume (Million gallons):	27.42

MU-2 is comprised of 4 modules, MOD21 through MOD24. Commercial production was initiated at Modules MOD21 through MOD23 in March 1993 and at Module MOD24 in July 1993. A separate wellfield package was submitted for MOD24 with its own baseline quality data. Consequently, this wellfield has been referred to as MU-2 North and the original three modules are referred to as MU-2 South.

Production at MU-2 was from a zone designated as the "K3" sand[5] within the "K" Sandstone. The depth to the top of the K Sandstone at MU-2 is 220 to 300 feet whereas the depth to the K3 sand is 350 to 400 feet. The first overlying aquifer is designated as the "J" Sandstone (or informally referred to as the #1 Sand), which is separated from the K Sandstone by a 130 to 150-foot thick sequence of claystone-mudstone-siltstone. The underlying aquifer is designated as the "L" Sandstone, which is separated from the K Sandstone by a 25 to 50-foot thick sequence of dense claystone and mudstone.

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at well 5MW66) shows that distinction, accordingly, NRC staff concludes that operations at MOD55 were distinct from those at MOD56.

[5] The Restoration Report notes that the production zone was the K3 sand; however, the *Wellfield Data Package: Unit 2 North: Christensen Ranch Project* dated April 1993 states that the production wells used to establish baseline water quality for the production zone are completed in one or more of the upper K2 and middle and lower K3 mineralized intervals.

The potentiometric head gradient reported for the K Sandstone is to the west-northwest with a gradient of 0.01 feet per foot. The transmissivity, saturated thickness and hydraulic conductivity for the MU-2 North production aquifer is approximately 78 square feet per day, 148 feet and 0.52 feet per day, respectively. The transmissivity, saturated thickness and hydraulic conductivity for MU-2 South production aquifer is 133 (51)[6] square feet per day, 195 feet and 0.68 (0.26) feet per day, respectively. The licensee reports that based on pumping test results, MU-2 South has a strong degree of anisotropy to the transmissivity of the production aquifer. Orientation of the major axis of anisotropy is approximately 12 degrees east of north.

History of Operations/Restoration

Production at MU-2 (North & South) was initiated in 1993 and continued until May 1997, at which time restoration activities were initiated. The initial restoration activities consisted of a groundwater sweep phase. The groundwater sweep was conducted at all modules until July 1998. The volume of water associated with the groundwater sweep activities was 2.21 pore volumes (PVs). Following the groundwater sweep and short hiatus, the restoration activities continued at MU-2 with a groundwater treatment phase using reverse osmosis (RO). Groundwater treatment was initiated at MOD21 in October 2000 and the remaining modules in April 2001. The groundwater treatment was concluded by March 2002. A total of 10.8 PVs is associated with the groundwater treatment phase. The final phase of restoration consisted of groundwater recirculation with selected injection of hydrogen sulfide gas as a reductant. This phase of restoration was initiated in April 2003 and concluded in April 2004. The total volume of water associated with the reductant injection/groundwater recirculation phase is 1.4 PVs.

Post-restoration/stabilization monitoring began in April 2004 and concluded in January 2005.

Excursions

During the life of MU-2, three wells were reported on excursion status at various times. The wells consist of:

- One perimeter well monitoring MU-2 North (2MW-108). This well was on excursion status for a short period of time during operations (Cogema, 1996b). The licensee's corrective actions consisted of adjusting the nearby production units. The corrective actions proved successful. However, this well went on excursion status on August 24, 2011, after completion of the stabilization monitoring, and remained on excursion status until January 24, 2012 (Uranium One, 2012a). The licensee did not include a complete confirmatory analysis of the groundwater quality at well 2MW-108 following the corrective action.

- One perimeter well between MU-2 South and MU-3 (2MW-89). This well was on excursion status seven times; initially at the end of operations, once during the hiatus between groundwater sweep and treatment phases of restoration, and six times after stabilization (Uranium One, 2012b; Areva, 2009; Cogema, 2009b; Cogema, 2009d; Cogema, 2009e; Cogema, 2008e; Cogema, 2008f; Cogema, 2000). The well is currently off of excursion status as of the end of the second calendar quarter of 2012. The licensee did not include a complete confirmatory analysis of the groundwater quality at well 2MW-89 following the corrective action.

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[6] The number in parentheses is the value of transmissivity (hydraulic conductivity) along the minor axis to the anisotropy.

- One well in the overlying aquifer located in the southern end of MU-2 South (2MW-68S). The well was on excursion status twice during the reductant injection phase of the restoration activities (Cogema, 2005c; Cogema, 2004b; Cogema, 2004c).

Restoration Results

The groundwater quality in the production zone at the end of operations in MU2 is summarized by the staff in Table 1. The groundwater quality results for MU2 North and South after restoration are shown in Tables 2 and 3, respectively. The licensee states that the BPT, as defined by the WDEQ in Guideline No. 4, In Situ Mining (WDEQ, 2009), was applied to the restoration effort at MU-2. The licensee indicates that the volume of groundwater treated during the restoration efforts (total of 14.35 PVs) exceeds the volumes anticipated in the approved restoration plans. The licensee also indicates that the restoration efforts resulted in the substantial reduction in ionic concentrations at the end of restoration and that the groundwater quality has been restored to the pre-mining class of use (based on Wyoming's classification). Water quality data are presented in both graphical and tabular forms showing temporal variations in the quality of selected constituents during restoration and the stabilization phases. The data are based on wellfield averages on an individual module basis.

The licensee indicates that the primary indicator of success for the restoration efforts is the comparison of the data from the final round of the stability monitoring to the TRVs. The licensee reports that at the end of the stability monitoring the levels for 24 of the 35 constituents included in the monitoring program met or were below the respective TRV. Of the 11 constituents that did not meet the TRVs, five constituents (calcium, magnesium, bicarbonate, alkalinity and silica) do not have a Wyoming Class I standard or National Primary or Secondary Drinking Water Regulations maximum contaminant levels (MCLs), two constituents (arsenic and selenium) had levels that were below the respective Wyoming Class I standard or National Primary Drinking Water Regulations MCLs, and four constituents (iron, manganese, uranium and radium-226) exceeded the respective Wyoming Class I standard, National Primary Drinking Water Regulations MCLs or National Secondary Drinking Water Regulations guidelines. Except for the latter four constituents, the licensee states that levels at the end of stabilization did not pose a potential risk to offsite groundwater quality because either no standards exist or the levels were below the established standards.

For the four constituents that exceeded their National Primary or Secondary Drinking Water Regulations MCLs or guidelines and TRV, the licensee provided an assessment of the potential transport from the production zone through to the boundary of the exempted aquifer (location of the perimeter monitoring wells). The assessment included a quantitative evaluation of time required for groundwater to flow from the wellfield to the perimeter wells and permit [license] boundary, a qualitative evaluation of the geochemistry, in particular reducing conditions of the surrounding aquifers, and a quantitative evaluation of the fate and transport for three of the four constituents. The fate and transport evaluation consisted of the use of a "reduction factor" that was determined from results of numeric modeling performed for the approved Irigaray wellfield restorations. The reduction factor accounted for dispersion but not any absorption. Based on the assessments, the licensee concluded that the levels did not pose unacceptable risks due to reduction in levels and their immobility in groundwater systems under reducing conditions.

In 2009, in response to RAIs, the licensee collected additional groundwater data (Cogema, 2009a). The data consisted of groundwater quality at selected wells along an estimated groundwater flow path through the mine unit. The data includes well locations upgradient,

within and downgradient of the former production aquifer. The licensee cites evidence for a reducing environment by the detectable levels of iron and manganese, low oxidation reduction potential (Eh) and dissolved oxygen levels, and a distinctive sulfide odor detected during sampling at the wells within the former mine unit. The licensee also notes that the additional sampling results at the well which exhibited the maximum uranium concentration within the wellfield at the end of stabilization demonstrates that the uranium concentrations at that well have decreased to levels that are protective, based on the reduction factor analysis and qualitative analysis of the reducing conditions.

<u>*Evaluation Findings*</u>

MU-2 Groundwater Quality at the End of Operations

Table 1 shows the groundwater quality in the production zone at the end of operations as summarized by the staff. The data indicate the following:

1. Of the 35 parameters monitored, nine (9) parameters (Aluminum, Barium, Boron, Cadmium, Chromium, Copper, Lead, Mercury and Molybdenum) were not affected by operations.

2. The 26 parameters affected by the operations are as follows:
    a. concentrations of 21 parameters increased by a factor of 1.2 to 1870 times the background levels;
    b. pH levels decreased from slightly alkaline conditions (baseline) to near neutral conditions; and
    c. the concentrations of two parameters, carbonate and fluoride, decreased below background levels.

Evaluation Step *1 –Restoration Meeting Primary Goals*

Baseline Data

In the Restoration Report (Cogema, 2008c), the licensee compares the levels after restoration shown in Tables 2 and 3 to the established TRV. However, the staff finds the TRVs may not be statistically representative of the range in baseline data as committed to by the licensee (see general comment (2)). Furthermore, for several parameters, the TRV values in that table were calculated incorrectly. Instead of 5 standard deviations, the values listed in the table are based on the mean value plus the variance. The parameters most affected by this error are the TRVs for conductivity, TDS and radium-226. Specifically, the licensee lists a TRV for radium-226 as 214 pCi/L in the Restoration Report. However, in the table referenced by License Condition 10.3, the column of data which the licensee used for TRVs for the other parameters list a value of 100 pCi/L for radium-226. A footnote for the table states that the TRV was set at 100 pCi/L (treatability standard) because the calculated value of 214 exceeded the class-of-use standard of 5 pCi/L. The restoration report reverted back to the high value for the TRV. As discussed earlier, the NRC staff notes the current WY Class IV standard requires radioactive constituents to be restored to background and therefore accepts a TRV for radium-226 of 214 pCi/L.

The licensee combined its evaluation of data for the entire MU-2. However, License Condition 10.3 references baseline quality separately for MU-2 North and MU-2 South (see general comment (4)). Therefore, the staff's evaluation separated the data in accordance with the baseline data as referenced in the license.

Mine Unit 2 North

Wells Used in the Restoration/Baseline Comparison

The baseline and restoration data consisted of eight wells within production zone (TMC, 1993, Cogema, 2008c). Three wells, 2R115-1, 2P110-1 and 2T105-2, used for the post-restoration data differed from wells used in the baseline data. This difference in wells was noted by the licensee. The replacement wells were located 47 to 161 feet from the original wells. Based on typical industry practice, the staff assumes that the replacement wells were needed due to damage (e.g., MIT failure) during the life of a well. The staff finds this information acceptable.

MU-2 North Groundwater Quality after Restoration/Stabilization

Of the 26 parameters affected by operations, the concentrations of 10 parameters did not meet baseline average or the National Primary Drinking Water Regulations MCLs (Table 2). Therefore, the staff's evaluation proceeded to Step 2.

Evaluation Step 2 – Asymptotic Trends and Application of BPT

The licensee states that the levels at the end of restoration/stabilization reflect a significant reduction from levels observed prior to the start of restoration and that the BPT was applied throughout the restoration process (Cogema, 2008c). The licensee presents graphs exhibiting trends in uranium and conductivity versus pore volumes of groundwater treatment that shows an asymptotic decrease for all four modules in MU-2 during restoration. The staff agrees that the licensee did employ the BPT during the restoration of MU2 and that the levels of uranium and conductivity were approaching an asymptotic trend considering practicable corrective actions.

The next step in the evaluation process is Step 2A.

Evaluation Step 2A – Levels Protective of Surrounding USDW

The 10 parameters not meeting the baseline or National Primary Drinking Water Regulations MCLs are segregated into two groups, one group (Group 1) consisting of the constituents TDS, conductivity, calcium, magnesium, bicarbonate and alkalinity.[7] The second group (Group 2) consists of the constituents iron, manganese, uranium and radium-226. For Group 1 constituents, the licensee states that the concentrations do not pose a risk to offsite groundwater quality due to the lack of any established health-risk-based standards (calcium, magnesium, bicarbonate and alkalinity) or that the levels are close to the National Secondary Drinking Water Regulations guidelines (TDS).

For Group 2 constituents, the licensee provided additional analysis on the concentrations anticipated in the future as the constituents migrate from the production aquifer to the surrounding aquifers. The additional analysis consisted of a hydrologic assessment, geochemical assessment and a fate and transport assessment. For the hydrologic assessment,

[7] Cogema did not include TDS or conductivity in this group because of the incorrect TRV used in their analysis. Cogema did discuss that the TDS level was above the Wyoming Class I Standard of 500 milligrams per liter but did state that the concentrations were close to the standard and did not pose a significant risk to offsite groundwater quality.

the licensee estimates that it would take approximately 48 years for groundwater to reach the perimeter well ring (400 feet) and 300 years to reach the permit [license] boundary. For the geochemical assessment, the licensee states that the primary controlling factor is the redox conditions; and in the initial summary report provides factors that qualitatively support reducing conditions in the aquifer. The qualitative assessment is again discussed in the responses to RAIs. Finally, for the fate and transport assessment, the licensee calculates that using a reduction factor of 6, the concentration of iron at the perimeter well ring (400 feet) will be below the National Secondary Drinking Water Regulations standards. However, the concentrations of uranium and manganese will be slightly above the National Primary or Secondary Drinking Water Regulations. For manganese, the licensee states that the standard is not health-based and the levels calculated are only slightly above the guidelines. For the uranium levels calculated, the licensee states that additional retardation will decrease the levels. A fate and transport assessment was not performed for radium because the background levels were relatively high and would not reflect typical values outside of the ore zone.

In general, the staff agrees with the licensee that the constituents of primary concern consist of iron, manganese, uranium and radium-226. However, because TDS levels did exceed the range in baseline levels, the staff finds that TDS should have been included in the additional hydrogeologic, geochemical and fate and transport analyses. The staff agrees, in part, with the licensee's qualitative geochemical assessment that the Group 1 constituents (calcium, magnesium, bicarbonate and alkalinity) do not pose a substantial impact to the surrounding aquifers due to the lack of any established health-risk-based standards. However, in the staff's opinion, the licensee should have prepared a quantitative analysis on the expected levels to quantify the impact to the surrounding aquifers relative to baseline although the staff does not have a regulatory basis to require a quantitative analysis for the Group 1 constituents.

The staff reviewed the hydrologic assessment performed by the licensee and finds it adequate. For the geochemical assessment, the staff agrees with the overall argument that the reducing conditions in and surrounding the production zone will decrease the mobility of the redox-sensitive constituents. However, the arguments were too qualitative, did not include a discussion of several pertinent geochemical aspects (see general comment (5)), and may not be applicable to radium-226.

The staff agrees with the approach of using a retardation factor from existing numerical model efforts in lieu of developing a numeric model specific to this setting provided similar conditions exist between the two settings. In the Restoration Report, the licensee stated that the hydrologic conditions (hydraulic conductivity, hydraulic gradient and porosity) at the Christensen Ranch project were similar to those at the Irigaray ISR operation, which was used for the modeling, but did not provide any details. A summary of the settings compiled by the staff is as follows:

Hydrologic Property	**Irigaray**	**MU-2**
Hydraulic gradient	0.005	0.01
Hydraulic Conductivity (feet per day)	1.0	0.52
Porosity	0.29	0.26
Thickness of ore zone (feet)	21	12
Thickness of aquifer (feet)	100	148
Distance to perimeter well (feet)	400	300
Width of wellfield	700	400

The staff agrees that the hydrologic properties (hydraulic conductivity, hydraulic gradient and porosity) are similar at both settings to allow the reduction factor analysis. However, the thickness of the ore zone, thickness of the aquifer and distance to the perimeter wells differ between settings. The thickness of the ore zone at Christensen Ranch MU-2 is less than that at the Irigaray site, whereas the thickness of the aquifer hosting the ore zone is greater. Both of these factors will tend to increase the dilution (dispersion) leading to a greater reduction factor. The downgradient perimeter wells are located approximately 100 feet closer to the wellfield at Christensen Ranch, which would tend to reduce the reduction factor. Consequently, the staff cannot fully agree with the reduction factor analysis performed by the licensee.

The staff does not agree with the use of TRVs as the baseline values in a reduction factor analysis at the perimeter wells. The TRVs are based on the baseline data within the production aquifer. The objective of the analysis is to determine the impacts to the aquifers surrounding the production aquifer. The baseline values for the perimeter well ring better approximate the baseline values for the surrounding aquifer and thus should have been used in the analysis.

Because of the concerns with the validity of the reduction factor analysis and the lack of a quantitative analysis for TDS, uranium and radium-226, the staff developed a simple numeric modeling effort to evaluate future concentrations of the constituents of concern (i.e., calcium, magnesium, bicarbonate, TDS, iron, manganese, uranium and radium-226) at the perimeter well ring 300 feet from the edge of the injection and production wells (for details on the modeling effort, see Attachment I)). The modeling effort consists of the development of a MODFLOW numeric groundwater flow model coupled with a MT3D fate and transport numeric model (Harbaugh et al., 2000; Zheng, C., 1990). The MODFLOW model was a simple 3-dimensional MODFLOW model with uniform 1-dimensional flow and the MT3D model was simple fate and transport model that incorporated dispersion, radioactive decay (for radium-226), and retardation. Factors included in the models consisted of dilution due to thickness of the aquifer relative to that in the ore zone, actual distance of 300 feet to the downgradient perimeter wells, and background levels for the perimeter downgradient wells.

Based on the staff's calculations, the model-predicted constituent levels at 300 feet downgradient of the MU-2 North are as follows:

Constituent	Concentration (mg/L)
Calcium	12.3
Iron	0.055
Bicarbonate	103
Magnesium	1.05
Manganese	0.023
TDS	422
Uranium	0.027
Radium-226	1.3 pCi/L

For calcium, bicarbonate and magnesium, the model-predicted concentrations are consistent with the range of the baseline concentrations (within 3 standard deviations of the mean background). For iron, manganese and TDS, the model-predicted concentrations are below the respective National Secondary Drinking Water Regulations guidelines and, thus, deemed protective. For uranium and radium-226, the model-predicted concentrations are below the respective National Primary Drinking Water Regulations MCLs and, thus, are protective.

Based on the staff's evaluation of the restoration data, the existing levels for those parameters that did not achieve baseline mean value or MCL, are protective of the surrounding USDWs and are consistent with the class-of-use standard. Therefore, the analysis proceeds to Step 2B.

Evaluation Step 2B - Stability

Based on the staff's stability analysis, a SSI trend was noted in the stability data for the following wells:

Well	Constituent(s)
2S100-2	Uranium and TDS
2T92-2	Uranium and Radium-226
2R115-1	TDS
2T95-1	TDS
2U84-1	TDS

The SSI trends for Mine Unit 2 North for TDS, uranium and radium-226 are shown in Figures 3a, b, and c respectively. In 2009, the licensee reported data from well 2S100-2 (Cogema, 2009a). The uranium and TDS concentrations in the groundwater at well 2S100-2 in 2009 reflect a significant decrease from concentrations reported during the 2004-2005 stability monitoring. Therefore, the SSI determination for well 2S100-2 was considered adequately addressed. The licensee did not report additional analyses for wells 2T92-2, 2R115-1, 2T95-1, or 2U84-1.

The SSI trend in TDS in wells 2R115-1, 2T95-1, or 2U84-1 is not of concern because, although they are significantly increasing and may exceed the TRV, they are far below the WY Class IV standard (Class I, II, III or background TRV) which the staff chose to set at Class II (2000 mg/l). The trend in uranium in well 2T92-2 is of concern as it is above the Class IV standard for radioactive constituents (background TRV) and is increasing. The radium-226 trend in 2T92-2 is also of concern because it is approaching the 214 pCi/L Class IV standard (background TRV) and could surpass it.

Evaluation Step 3B – Proper Corrective Action for Excursions

Well 2MW-108 was on excursion status during operations. The excursion status was short-lived as adjustments to the pumping rates corrected the excursion. Data collected in 2009 are consistent with background levels for that well (Cogema, 2009a), suggesting negligible impacts to the quality due to the prior excursion events. Well 2MW-108 was on excursion status in 2011 and the licensee failed to document the quality following termination of the excursion.

Summary

Based upon the above, the staff concurs that the restoration of MU-2 North is protective of human health and safety and the environment provided that:

(1) SSI trends noted for uranium and radium-226 at well 2T92-2 are shown to be reversed and stabilization is demonstrated.
(2) The licensee provides a confirmatory analysis of the groundwater quality at well 2MW108 subsequent to corrective actions for the 2011 excursion that demonstrates impacts to the aquifer following the 2011

excursion event meet regulatory requirements (groundwater protection criteria).

The staff cannot recommend restoration approval of MU-2 North until the above is completed.

Mine Unit 2 South

Wells Used in the Restoration/Baseline Comparison

The baseline and restoration data consisted of 17 wells within the production zone (TMC, 1992a; Cogema, 2008c). All wells used to obtain post-restoration data are those that were used to establish the baseline data. The staff finds this information is acceptable.

MU-2 South Groundwater Quality after Restoration/Stabilization

Of the 24 parameters affected by the operations, the concentrations of 11 parameters did not meet the baseline or MCL (Table 3). Therefore, the staff's evaluation proceeded to Step 2.

Evaluation Step 2 – Asymptotic Trends and Application of BPT

The licensee states that the levels at the end of restoration/stabilization reflect a significant reduction from levels observed prior to the start of restoration and that the BPT was applied throughout the restoration process. The licensee presents graphs exhibiting trends in uranium and conductivity versus pore volumes of groundwater treatment that shows an asymptotic decrease for all four modules in MU2 during restoration. The staff agrees that the licensee did employ the BPT during the restoration of MU2 and that the levels of uranium and conductivity were approaching an asymptotic trend using practicable corrective actions.

The next step in the evaluation process is Step 2A.

Evaluation Step 2A – Levels Protective of Surrounding USDW

The 11 parameters are divided into two groups, one group (Group 1) consisting of the parameters TDS, conductivity, calcium, magnesium, bicarbonate, silica and alkalinity.[8] The second group (Group 2) consists of iron, manganese, uranium and radium-226. For Group 1 constituents, the licensee states that the concentrations do not pose a risk to offsite groundwater quality due to the lack of any established health-risk-based standards (calcium, magnesium, bicarbonate and alkalinity) or that the levels are close to the National Secondary Drinking Water Regulations guidelines (TDS). For Group 2, the licensee provided additional analysis of the concentrations anticipated for future groundwater quality. The additional analysis consisted of a hydrologic assessment, geochemical assessment, and a fate and transport assessment.

For the hydrologic assessment, the licensee estimates that it would take approximately 48 years for groundwater to reach the perimeter well ring (reported by the licensee to be 400 feet)[9] and

[8] Cogema did not include TDS or conductivity in this group because of the incorrect TRV used in their analysis. Cogema did discuss that the TDS level was above the Wyoming Class I Standard of 500 milligrams per liter but did stated that the concentrations were close to the standard and did not pose a significant risk to offsite groundwater quality.

[9] Staff observes that actual distance to the monitor well ring at Mine Unit 2 South is 300 feet.

300 years to reach the permit [license] boundary. For the geochemical assessment, the licensee states that primary controlling factor is the redox condition; and in the initial summary report provides factors that qualitatively support reducing conditions in the aquifer. Finally, for the fate and transport assessment, the licensee calculates that using a reduction factor of 6, the concentration of iron at the perimeter well ring (reported by the licensee to be 400 feet)[10] will be slightly above the respective National Primary or Secondary Drinking Water Regulations MCLs or guidelines. For manganese, the licensee notes that the standard is not health-based and the levels are only slightly above the standard. For uranium, the licensee states that additional retardation not included in its analysis will decrease the levels to that below the MCL. A fate and transport assessment was not performed by the licensee for radium "because the background levels are relatively high within the ore zone (214 pCi/L) and would not reflect typical values outside of the ore body (Cogema, 2008a).

The staff agrees with the licensee's contention that Group 1 constituent levels do not pose a health-risk but disagrees that the lack of health-risk-based standard does not warrant evaluation of the impacts of those constituents. However, the levels for calcium, magnesium, bicarbonate and TDS are less or approximately equal to those levels at MU-2 North. Because those levels at MU-2 North were determined to be protective based on the staff's evaluation, then the equivalent or lower levels at MU-2 South would be similarly protective. Conductivity is an indicator parameter rather than a constituent of interest and directly related to TDS levels. Therefore, additional evaluation of conductivity levels is not warranted. Alkalinity is a measure of both calcium and bicarbonate which were analyzed for impacts individual; thus, an analysis for alkalinity is not warranted. The staff's analysis will include silica levels.

The staff agrees with the licensee that the parameters of concern consist of iron, manganese, uranium, and radium-226; however, because the silica levels exceed the baseline levels, the staff finds that the additional analysis should include silica as well. The staff agrees with the licensee's hydrologic assessment. For the geochemical assessment, the staff agrees with the overall argument that reducing conditions in and surrounding the production zone will increase the immobilization of the redox-sensitive constituents; however, the arguments were too qualitative and did not include a discussion of all geochemical aspects. For example, while the staff agrees that iron and manganese are good indicators for reducing conditions, the elevated uranium concentrations suggest that other factors beyond simple reduction should be addressed ion the geochemical analysis (e.g., colloidal transport). The licensee failed to include a discussion on changes in pH levels in the production zone, including influences that resulted in a change between field- and laboratory-measured ph levels for the 2009 sampling or the distribution of the data, including any outlier statistical analysis.

The staff agrees with the approach of using a retardation factor from existing numeric model efforts in lieu of developing a numeric model specific to this setting provided similar conditions exist between the two settings. As discussed above (see MU-2 North), the staff determined that several conditions for the settings were different enough to potentially invalidate the retardation factor analysis, thus the staff performed an independent verification of the impacts using groundwater flow and fate and transport modeling.

Based on the staff's calculations, the model-predicted constituent levels at 300 feet downgradient of the MU-2 South are as follows:

[10] ditto

Constituent	Concentration (mg/L)
Iron	0.07
Manganese	0.033
Silica	5.24
Uranium	0.012
Radium-226	1.0 pCi/L

For silica, the model-predicted concentrations are consistent with the range of the baseline concentrations (within 3 standard deviations of the mean background). For iron and manganese, the model-predicted concentrations are below the respective National Secondary Drinking Water Regulations guidelines and thus deemed protective. For uranium and radium-226, the model-predicted concentrations are below the respective National Primary Drinking Water Regulations MCLs and thus are protective.

Based on the staff's evaluation of the restoration data, the existing levels for those parameters that did not achieve baseline mean value or National Primary Drinking Water Regulations MCLs, are protective of the surrounding USDWs and are consistent with the class-of-use standard. Therefore, the analysis proceeds to Step 2B.

Evaluation Step 2B - Stability

Based on the stability analysis, a SSI trend was noted in the stability data for the following wells:

Well	Constituent(s)
2AF34-1	Uranium

The SSI trend for Mine Unit 2 South for uranium in this well is shown in Figure 3c. It is of concern to the staff because it shows that uranium in this well is above the Class IV standard (background TRV) and is increasing.

Evaluation Step 3B – Proper Corrective Action for Excursions

The licensee implied in the Restoration Report that the levels of the excursion indicator parameters indicate that the perimeter ring and overlying and underlying aquifers were not affected by mining solutions during restoration. Perimeter monitoring well 2MW-89 has been on and off excursion status six times since 2008 (Uranium One, 2012b; Areva, 2009; Cogema, 2009c; Cogema, 2008a). The last excursion status was terminated on April 16, 2012 (Uranium One, 2012b). In addition, the staff notes that one well in the overlying aquifer, well MW-68S, had been on excursion status during the reductant addition phase of restoration.

The staff evaluated the setting and found spatial nexus between the wells that were, or have been reported, on excursion. The relations are: (1) well 2MW-89 is located between MU-2 South and MU-3, (2) three (2MW-68S, 3MW-46S, and 3MW-48S) of five wells in the shallow aquifer overlying the southernmost portion of MU-2 South and northernmost of MU-3 have been on excursion either during operations (3MW-48S and 3MW-46S), or during or subsequent to restoration (2MW-68S and 3MW-48S); and (3), established UCLs for two other wells in the shallow aquifer in that area (2MW-70S and 2MW-72S) are extremely high, limiting their potential to detect an excursion.

As discussed below, perimeter ring wells on long-term excursion status are located in areas in which two production units abut. The staff finds that the excursion associated with those wells is likely attributed to enhanced flare emanating from one or both production units due to competing drawdown for each unit. Well 2MW-89 is located in such a setting. Furthermore, staff notes that the documentation by the licensee on the source of the excursions for wells in the overlying aquifer is inconclusive. For example, for the 1991 excursion at well 3MW-48S, the licensee noted that the excursion in the overlying aquifer could be through well completions, exploration boreholes or hydraulic communication between aquifers (TMC, 1992b). The licensee subsequently reported an integrity failure of one nearby production well to 3MW-48S which it replaced. The licensee did not report the source of the excursions at the other two wells in the overlying aquifer.

In TMC (1992a), the licensee noted difficulties with the obtaining baseline in this area. Specifically, the licensee showed that the shallow aquifer at the location of 3MW-48S thins considerably and pinches out in the southernmost area of MU-2. The overlying aquifer in the southernmost portion of MU-2 consists of a series of sand units, each with a limited extent and thickness over a lignite marker bed. As noted at the Irigaray project, a coal seam as the overlying aquifer proved to be inadequate for excursion monitoring (Westinghouse, 1986).

Given this potential source of the historical excursions, the staff has determined that the licensee has failed to characterize the potential impacts to the production zone and shallow aquifer between MU-2 South and MU-3.

<u>Summary</u>

The staff cannot recommend restoration approval of MU-2 South until:

(1) The licensee demonstrates the overlying and production aquifers between MU-2 South and MU-3 are not impacted; and
(2) The licensee demonstrates the SSI trend noted in the uranium concentrations at well 2AF34-1 is reversed and stable.

<u>Mine Unit 3 (MU-3 w/o expansion & MU-3 w/ expansion (Module 4a))</u>

<u>Geometry, Geology & Hydrogeology</u>

Based on the September 11, 2008 updated surety estimate (Cogema, 2008b), the geometry of the MU-3 is as follows:

Area (acres):	18.34
Thickness (feet)	10
Flare Factor;	1.44
Volume (million cubic feet)	11.5
Porosity	0.26
PV (Million gallons)	22.37

MU-3 is comprised of 5 modules, MOD31 through MOD34 and MOD34A. Commercial production was initiated at MU-3 in March 1989, though the mine unit expanded through its early history. Two references are included in License Condition 10.3 for baseline conditions within MU-3; the first reference is for “Unit 3 and Module 2 expansion” dated December 1, 1988, and the second reference is “Unit 3 expansion and Module 4a expansion” dated August 8, 1991.

Modules MOD31 through MOD34 are included in the first reference (designated herein as MU-3 w/o expansion), whereas Module34A is included in the baseline for the latter reference (designated herein as MU-3 expansion). The initial baseline data for MU-3 w/o expansion are presented in Malapai (1988). The initial baseline data for MU-3 expansion are presented in TMC (1991).

Production at MU-3 was from the zone designated as the “K” Sandstone (Cogema, 2008c). The depth to the top of the K Sandstone at MU-3 is 250 to 400 feet. The licensee reported that the ore zone was the “K2” sandstone, but multiple ore horizons within the K Sandstone were common. The first overlying aquifer is designated as the “J” Sandstone, which is separated from the K Sandstone by a 80 to 130-foot thick sequence of claystone-siltstone. The underlying aquifer is designated as the “L” Sandstone, which is separated from the K Sandstone by a 50 to 60-foot thick sequence of dense claystone and shale.

The potentiometric head gradient reported for the K Sandstone is to the northwest with a gradient of 0.01 feet per foot (Cogema, 2008c). The transmissivity, saturated thickness and hydraulic conductivity for MU-3 production aquifer is approximately 56 square feet per day, 162 feet and 0.34 feet per day, respectively.

History of Operations/Restoration

As discussed in the Restoration Report, production at MU-3 was initiated in 1989 at MOD31 with production at the final module, MOD34A beginning in November 1991 (Cogema, 2008c). Operations continued until June 1995. After a short hiatus, a groundwater sweep phase of restoration was initiated at MOD32 in March 1997 and completed at all modules in September 1998. The volume of water associated with the groundwater sweep activities was 1.78 PVs. The next phase of restoration consisted of the groundwater treatment with RO permeate injection. This phase was initiated at MOD31 in February 1998 and at the other modules by August 2002. The groundwater treatment phase was completed by August 2002. A total of 16.44 PVs is associated with the groundwater treatment phase. The final phase of restoration consisted of groundwater recirculation with selected injection of hydrogen sulfide gas as a reductant. This phase of restoration was initiated in February 2004 and concluded in October 2004. The total volume of water associated with the reductant injection/groundwater recirculation phase is 1.57 PVs.

Excursions

During the life of MU-3, the licensee reported that five wells were on excursion status at various times. The wells consist of:

- One perimeter well monitoring the downgradient northwestern perimeter (MW-19). This well was on excursion status for two short periods of time during operations (Cogema, 1996b). The licensee’s corrective actions consisted of adjusting the nearby production units. The corrective actions proved successful to terminate the excursion status.

- Two wells screened in the overlying aquifer in the northeastern portion of MU-3 (MW-46S and MW-48S (Cogema, 1996b; NRC, 2000b; Cogema, 2004c). The wells were on excursion six times, during and at the end of operations, during the hiatus between operation and restoration, and during restoration. The period of time on excursion status extended up to 16 months.

- One perimeter ring monitoring well located in the upgradient region between MU-3 and MU-4 (MW-64). This well was on excursion status during the initial stages of the groundwater sweep.

- One perimeter well that later became an operation well in MU-2 Module 4a (4E6-1; Cogema, 1996b)).

Restoration Results

The groundwater quality in the production zone at the end of operations in MU3 is summarized by the staff in Table 4. The groundwater quality results for MU3 (without module 4A) and MU3 module 4A after restoration are shown in Tables 5 and 6, respectively. The licensee states that the BPT was applied to the restoration effort at MU-3 (Cogema, 2008c). The licensee indicates that the volume of groundwater treated during the restoration efforts (total of 19.8 PVs) exceeded the volumes anticipated in the approved restoration plans. The licensee also indicates that the restoration efforts resulted in a substantial reduction in the concentrations of the constituents of concern at the end of restoration and that the groundwater quality has been restored to the pre-mining Class IV (based on Wyoming's classification). Water quality data are presented in both graphical and tabular forms showing temporal variations in the quality of selected constituents during restoration and the stabilization phases. The data are based on wellfield averages and individual modules.

The licensee indicates that the primary indicator of success for the restoration efforts is the comparison of the data from the final round of the stability monitoring to the TRVs. The licensee reports that at the end of the stability monitoring, the levels for 27 of the 35 constituents included in the monitoring program met or were below the respective TRV. Of the 8 constituents that did not meet the TRVs, five constituents (calcium, magnesium, bicarbonate, alkalinity and silica) do not have a Wyoming Class I standard or National Primary or Secondary Drinking Water MCLs or guidelines. Two constituents (TDS & nitrate) had levels that were below the respective Wyoming Class I standard or the National Primary or Secondary Drinking Water Regulations MCLs or guidelines, and one constituent (manganese) exceeded the National Secondary Drinking Water Regulations MCL. Except for manganese, the licensee states that levels at the end of stabilization did not pose a potential risk to off-site groundwater quality because either no standards exist or the levels were below the established standards.

For the constituent manganese which exceeded the National Secondary Drinking Water Regulations guideline and TRVs, and the constituents, uranium and radium-226, which exceeded the respective National Primary Drinking Water Regulations MCLs but not TRVs, the licensee provided an assessment of the potential transport from the production zone to the boundary of the exempted aquifer (location of the perimeter monitoring wells). The assessment included a quantitative evaluation of time required for groundwater to flow from the wellfield to the perimeter wells and permit [license] boundary, a qualitative evaluation of the geochemistry, in particular, reducing conditions of the surrounding aquifers, and a quantitative evaluation of the fate and transport for manganese. The fate and transport evaluation consisted of the use of a "reduction factor" that was determined from results of numeric modeling performed for the approved Irigaray wellfield restorations. The reduction factor accounted for dispersion but not any absorption. Based on the assessments, the licensee concluded that the levels did not pose unacceptable risks due to reduction in levels and their immobility in groundwater systems under reducing conditions.

In a 2009 response to RAIs, the licensee collected additional groundwater data at MU-3 (Cogema, 2009a). The data consisted of groundwater quality at selected wells along an estimated groundwater flow path through the mine unit. The data includes wells at locations upgradient, within and downgradient of the former production aquifer. The licensee cites evidence for a reducing environment by the detectable levels of iron and manganese, low Eh and dissolved oxygen levels, and a distinctive sulfide odor detected during sampling at the wells within the former mine unit (Cogema, 2009a). The parameters analyzed at selected wells within the production zone consisted of nitrate plus the field-measured parameters.

Evaluation Findings

MU-3 Groundwater Quality at the End of Operations

The quality of the groundwater in the production zone at the end of operations is presented by the staff in Table 4. The data are summarized as follows:

1. Of the 35 parameters monitored, 11 parameters (Aluminum, Barium, Boron, Cadmium, Chromium, Copper, Lead, Mercury, Molybdenum, Nickel, and Zinc) were not affected by operations. The 24 parameters affected by the operations are as follows:

    a. concentrations of 21 parameters increased by a factor of 2 to 2296 times the mean background levels;
    b. pH levels decreased from slightly alkaline conditions (baseline) to near neutral conditions; and
    c. the concentrations of two parameters, carbonate and fluoride, decreased below background levels.

Evaluation Step *1 –Restoration Meeting Primary Goals*

Baseline Data

In the Restoration Report (Cogema, 2008c), the licensee compares the groundwater quality after restoration shown in Tables 5 and 6 to the established TRVs. However, the staff finds the TRVs may not be statistically representative of the range in baseline data as committed to by the licensee (see general comment (2)). Furthermore, for several parameters, the TRV values in that table were calculated incorrectly. Instead of 5 standard deviations, the values listed in the table are based on the mean value plus the variance. The parameters most affected by this error are the TRVs for conductivity, total dissolved solids (TDS) and radium-226. In addition, in the Restoration Report, the licensee lists a TRV for radium-226 as 270.8 pCi/L (Cogema, 2008c). However, in the table referenced by License Condition 10.3, the column of data which the licensee used for TRVs for the other parameters list a value of 100 pCi/L for radium-226. A footnote for the table states that the TRV was set at 100 pCi/L (treatability standard) because the calculated value of 270.8 exceeded the class-of-use standard of 5 pCi/L. The Restoration Report revised the TRV back to the high value. As discussed earlier, the NRC staff notes the current WY Class IV standard requires radioactive constituents to be restored to background and therefore accepts a TRV for radium-226 of 270.8 pCi/L.

The licensee combined its evaluation of data for the entire MU-3. However, License Condition 10.3 references baseline quality separately for (1) MU-3 and Module 2 expansion (December 1, 1988) and (2) Unit 3 expansion and Module 4A expansion (see general comment (4)).

Therefore, the staff's evaluation segregated the data in accordance with the baseline data as referenced in the license.

MU-3 w/o expansion (exclusive of Module 4a)

<u>Wells Used in the Restoration/Baseline Comparison</u>

The baseline and restoration data shown in Table 5 was derived from 16 wells within production zone (Malapai, 1988). One well, 3D12-2, used for the post-restoration data differed from wells used in the baseline data. This difference in wells was not noted by the licensee in the Restoration Report (Cogema, 2008c). The replacement well is approximately 113 feet from the original well location. Based on typical industry practice, the NRC staff assumes that the replacement well was needed due to damage (e.g., MIT failure) during the life of the well. The licensee needs to confirm that this information is correct.

<u>MU-3 w/o expansion Groundwater Quality after Restoration/Stabilization</u>

Of the 24 parameters affected by operations, the concentrations of nine (9) parameters did not meet baseline average or National Primary Drinking Water Regulations MCLs as shown in Table 5. Therefore, the staff's evaluation proceeded to Step 2.

Evaluation Step 2 – Asymptotic Trends and Application of BPT

The licensee states that the levels at the end of restoration/stabilization reflect a significant reduction from levels observed prior to the start of restoration and that the BPT was applied throughout the restoration process (Cogema, 2008c). The licensee presents graphs exhibiting trends in uranium and conductivity versus pore volumes of groundwater treatment that shows an asymptotic decrease for all four modules in MU3 during restoration. The staff agrees that the licensee did employ the BPT during the restoration of MU3 and that the levels of uranium and conductivity were approaching an asymptotic trend using practicable corrective actions.

The next step in the evaluation process is Step 2A.

Evaluation Step 2A – Levels Protective of Surrounding USDW

The nine constituents that did not meet the baseline average or MCL are divided into two groups. One group (Group 1) consists of the constituents TDS, calcium, magnesium, bicarbonate, silica and alkalinity.[11] The second group (Group 2) consists of iron, manganese, uranium and radium-226. For Group 1 constituents, the licensee states that the concentrations do not pose a risk to offsite groundwater quality due to the lack of any established health-risk-based standards (calcium, magnesium, bicarbonate and alkalinity) or that the levels are below the National Secondary Drinking Water Regulations guidelines (TDS). For Group 2 constituents the licensee provided additional analysis of only manganese concentrations anticipated for future groundwater quality. The additional analysis consisted of a hydrologic assessment, geochemical assessment, and a fate and transport assessment. The licensee noted that the uranium and radium-226 concentrations were under the respective TRVs.

[11] Cogema did not include TDS or conductivity in this group because of the incorrect TRV used in their analysis. Cogema did discuss that the TDS level was above the Wyoming Class I Standard of 500 milligrams per liter but did stated that the concentrations were close to the standard and did not pose a significant risk to offsite groundwater quality.

For the hydrologic assessment, the licensee estimates that it would take approximately 48 years for groundwater to reach the perimeter well ring (400 feet) and 300 years to reach the permit [license] boundary. For the geochemical assessment, the licensee states that the primary controlling factor is the redox condition; and in the initial summary report provides factors that qualitatively support reducing conditions in the aquifer. For a fate and transport assessment, the licensee calculates that, using a reduction factor of 6, the predicted maximum manganese concentration at the perimeter well ring (400 feet) will be below the National Secondary Drinking Water Regulations guideline and thus determined to be safe. A fate and transport assessment was not performed for radium because the background levels were relatively high and would not reflect typical values outside of the ore zone.

The staff agrees with the licensee that the constituents of concern consist of manganese but also includes radium-226, iron, calcium, magnesium, bicarbonate, and silica because these compounds exceed the baseline mean plus a statistically valid estimate of the natural variability in the baseline range. The staff agrees with the licensee that uranium levels have returned to baseline because the levels are within 2 standard deviations of the baseline mean.

The staff has no objections to the hydrologic assessment. For the geochemical assessment, the staff agrees with the overall argument that the reducing conditions in and surrounding the production zone will decrease the immobility of the redox-sensitive constituents. However, the licensee's arguments were too qualitative and did not include a discussion of all geochemical aspects. For example, while iron and manganese are good indicators for reducing conditions, the elevated uranium concentrations suggest that other factors beyond simple reduction should be addressed in the geochemical analysis (e.g., colloidal transport). The licensee failed to include a discussion on changes in pH levels in the production zone, including influences that resulted in a change between field- and laboratory-measured pH levels for the 2009 sampling or the distribution of the data, including any outlier statistical analysis.

The staff agrees with the approach of using a retardation factor from existing numeric model efforts in lieu of developing a numeric model specific to this setting provided similar conditions exist between the two settings. In the Restoration Report, the licensee stated that the hydrologic conditions (hydraulic conductivity, hydraulic gradient, and porosity) at the Christensen Ranch project were similar to those at the Irigaray ISR operation, which was used for the modeling but did not provide any details. A summary of the two settings compiled by the NRC staff is as follows:

Hydrologic Property	**Irigaray**	**Christensen Ranch MU-3**
Hydraulic gradient	0.005	0.01
Hydraulic Conductivity (feet per day)	1.0	0.34
Porosity	0.29	0.26
Thickness of ore zone (feet)	21	10
Thickness of aquifer (feet)	100	162
Distance to perimeter well (feet)	400	300
Width of wellfield	700	400

The staff agrees that the hydrologic properties (hydraulic conductivity, hydraulic gradient and porosity) are similar at both settings to allow the reduction factor analysis. However, the thickness of the ore zone, thickness of the aquifer and distance to the perimeter wells differ between settings. The thickness of the ore zone at Christensen Ranch MU-3 is less than that at

the Irigaray site whereas the thickness of the aquifer hosting the ore zone is greater. Both of these factors will tend to increase the dilution (dispersion) leading to a greater reduction factor at Christensen Ranch. The downgradient perimeter wells are located approximately 100 feet closer to the wellfield at Christensen Ranch which would tend to reduce the reduction factor.

In addition, the staff does not agree with the use of TRVs as the baseline values in the reduction factor analysis. The baseline values for the surrounding aquifer or National Primary Drinking Water Regulations MCLs should be used in the impact analysis and not the baseline values for the production aquifer.

Because of the concerns with the validity of the reduction factor analysis and the lack of a quantitative analysis for radium-226, the staff developed a simple numeric modeling effort to evaluate future concentrations of the constituents of concern (i.e., calcium, magnesium, bicarbonate, silica, iron, manganese, and radium-226) at the perimeter well ring 300 feet from the edge of the injection and production wells (for details on the modeling effort, see Attachment I). The modeling effort consists of the development of a MODFLOW numeric groundwater flow model coupled with a MT3D fate and transport numeric model (Harbaugh et al., 2000; Zheng, C., 1990). The MODFLOW model was a simple 3-dimensional MODFLOW model with uniform 1-dimensional flow and the MT3D model was simple fate and transport model that incorporated dispersion, radioactive decay (for radium-226), and retardation. Factors included in the models consisted of dilution due to thickness of the aquifer relative to that in the ore zone, actual distance of 300 feet to the downgradient perimeter wells, and background levels for the perimeter downgradient wells.

Based on the staff's calculations, the model-predicted constituent levels at 300 feet downgradient of the MU-3 are as follows:

Constituent	**Concentration (mg/L)**
Calcium	10.2
Iron	0.042
Bicarbonate	118.5
Magnesium	1.39
Manganese	0.013
Silica	8.96
Radium-226	Baseline

For calcium, bicarbonate, magnesium, and silica, the model-predicted maximum concentrations are consistent with the range of the baseline concentrations (within 3 standard deviations of the mean background). For iron and manganese, the model-predicted maximum concentrations are below the respective National Secondary Drinking Water Regulations guidelines and thus deemed to be protective. For radium-226, the model-predicted maximum concentration would not result in an increase above the existing baseline and thus protective of human health and the environment.

Based on the staff's evaluation of the restoration data, the existing levels for those parameters that did not achieve baseline mean value or MCL are protective of the surrounding USDWs and are consistent with the class-of-use standard. Therefore, the analysis proceeds to Step 2B.

Evaluation Step 2B - Stability

The SSI trends for wells in MU-3 w/o expansion and MU-3 w/ expansion (module 4A) for TDS, uranium and radium-226 are shown in Figures 4a, b, and c respectively. Based on the stability analysis, a SSI trend was noted in the stability data for the following wells in MU-3 w/o expansion:

Well	Constituent(s)
3U58-2	Uranium
3U45-1	Uranium
3D12-1	Uranium
3N25-1	Uranium
3T37-1	Uranium
3T27-1	Uranium
3AC82-1	TDS
3W75-1	TDS, Uranium, Radium-226
3Z87-1	TDS, Radium-226
3V58-2	Uranium

The SSI trend in uranium in two of these wells is of particular concern because one, 3V58-2, has already exceeded the Class IV standard (baseline mean) of 0.0376 mg/l, and another, 3W75-1, has the potential to exceed it. The SSI trend in radium-226 is also of concern because wells 3W75-1 and 3Z87-1, also show potential to exceed the baseline mean Class IV standard of 270.8 pCi/L. The SSI trends in TDS in wells 3AC82-1, 3W75-1 and 3Z87-1 are not of concern because, although they are significantly increasing and are exceeding the TRV, they are far below the WY Class IV standard (Class I, II, III or background TRV) which the staff chose to set at Class II (2000 mg/l).

The licensee addressed the staff's concerns regarding the stability of nitrate and nitrite concentrations during the stability monitoring period by collecting additional data for three wells with the former production zone (i.e., wells 3O37-2, 3T27-1 and 3T37-1) (Cogema, 2009a). However, the 2009 sampling event did not include all parameters at those wells within the production zone. The field-measured [specific] conductivity data indicate a high conductivity at two of three wells (1.578 microsiemen per centimeter (mS/cm) at well 3T37-1 and 1.883 mS/cm at well 3T27-2). For comparison, the reported range in [specific] conductivity during the stability monitoring was 0.55 to 0.679 mS/cm for both wells, the baseline data for [specific] conductivity is 0.674 +/- 0.016 mS/CM. The elevated [specific] conductivity, which is generally directly proportional to TDS, is significantly higher than the levels noted during the stability monitoring period, and the staff is concerned that the high TDS may include increases in all parameters including trace metals.

Evaluation Step 3B – Proper Corrective Action for Excursions

Five wells were on excursion status at one or more times during the life of MU-3. Only one well (3MW-19) that was on excursion status is pertinent to MU-3 w/o expansion. Excursions at the other four wells are discussed elsewhere in this TER. Specifically, excursions at two wells in the shallow aquifer, MW-45S and MW-48S, were addressed in this TER discussion under MU-2 South, and, excursions at two wells, MW-64 and 4E6-1, are discussed in this TER discussion under MU-3 w/ expansion (module 4A).

For well 3MW-19, two excursions occurred during the early production (pre-1993). The excursions were relatively short lived. The termination of excursion status letter dated February 8, 1993, and submitted by Total Minerals Corporation to NRC, included uranium concentrations during the excursion status. The uranium concentrations increased to 2 mg/L during the initial stages of the excursion followed by a significant decrease during the latter stages. Based on the data presented, the staff finds that the corrective actions undertaken to terminate the excursion status were sufficient to protect impacts to the surrounding aquifer.

<u>Summary</u>

The staff cannot recommend restoration approval of MU-3 w/o expansion (exclusive of Module 4A) until:

(1) The licensee confirms that well 3D12-2 used in the restoration, but not in the baseline, was needed to replace a well that has been abandoned.
(2) The elevated conductivity noted in the 2009 sampling and levels of all constituents of concern in wells 3T37-2 and 3T27-2 are adequately demonstrated to be below Class IV standards.
(3) The licensee demonstrates the SSI trend noted in the uranium concentrations at well 3V58-2 is reversed and stable.

MU-3 w/ Expansion (Module 4A)

<u>Wells Used in the Restoration/Baseline Comparison</u>

The baseline data in MU-3 w/expansion (module 4A) consisted of six (6) wells within production zone (TMC, 1991). The licensee did not provide a separate evaluation of the restoration for MU-3 w/ expansion (module 4A). The licensee did use restoration data from three wells in MU-3 w/ expansion in the evaluation of MU-3, and the three remaining wells in the evaluation of MU-4. However, the baseline data for those mine units were not adjusted accordingly.

<u>MU-3 w/ Expansion (Module 4A) Groundwater Quality after Restoration/Stabilization</u>

Of the 24 parameters affected by operations, the concentrations of nine (9) parameters did not meet baseline average or National Primary Drinking Water Regulations MCLs (Table 6). Therefore, the staff's evaluation proceeded to Step 2.

Evaluation Step 2 – Asymptotic Trends and Application of BPT

The licensee states that the levels at the end of restoration/stabilization reflect a significant reduction from levels observed prior to the start of restoration and that the BPT was applied throughout the restoration process. The licensee presents graphs exhibiting trends in uranium (U_3O_8) and conductivity versus pore volumes of groundwater treatment that shows an asymptotic decrease for MU-3 w/expansion (module 4A) during restoration. However, near the end of the groundwater treatment stage, the levels appear to have a slight increasing trend. The staff agrees that the licensee did employ the BPT during the restoration of MU-3 w/expansion (module 4A) and that the levels of uranium and conductivity were approaching an asymptotic trend using practicable corrective actions.

The next step in the evaluation process is Step 2A.

Evaluation Step 2A – Levels Protective of Surrounding USDW

The restoration data for MU-3 w/ expansion (module 4A) did not permit an evaluation by the staff because of noted discrepancies in the distribution of the data set. Of the six wells used for this analysis, data for one well (4E6-1) appeared to be an outlier (or hot spot, see general comment (3)) with elevated constituent levels. However, the data for another well (4H7-1) appeared to be statistically identical to the baseline data for all parameters suggesting that this portion of the MU-3 expansion was never subjected to lixiviant injection. The licensee will have to provide additional information on the viability of any distribution used for statistical analysis of the data. Consequently, the staff cannot conclude that the levels are protective of the surrounding USDW.

Evaluation Step 2B - Stability

The stability of wells in the MU-3 w/ expansion (module 4A) was included in the MU-3 w/o expansion analysis above.

The next step is Step 3A.

Evaluation Step 3A Excursions

Two of the wells (4E6-1 and MW-64) which were reported on excursion status during the life of MU-3 are associated with MU-3 w/ expansion (module 4A). Well 4E6-1 was a temporary well along the perimeter and is not part of the production zone monitoring. Therefore, this excursion is evaluated under the restoration of the ore zone for this module.

Well MW-64 is located between module 4A and MU-4. In the documentation for termination of the excursion status for this well, the licensee provided data on the uranium concentrations. The uranium concentrations were below the detection limits[12]. The levels of all three excursion indicator parameters have been significantly below their respective UCLs since that time. In addition, well MW-64 is located upgradient of the mine unit. Therefore, the staff's evaluation is that the corrective actions taken at the time of the excursion and existing groundwater flow direction are protective of the surrounding USDWs.

Summary

Based upon the above, the staff cannot concur that the restoration of MU-3 w/ expansion (module 4A) is protective of human health and safety and the environment until the licensee:

(1) Provides a statistical evaluation of the restoration data including rationale for outliers and stability analyses.
(2) Demonstrates the SSI trend in uranium and radium-226 in wells 3W75-1 and 3Z87-1 is reversed and stable.

[12] The uranium concentrations were reported as U_3O_8 with a detection level at 0.4 mg/L. The detection levels correspond to a uranium level of 0.113 mg/L.

Mine Unit 4

Geometry, Geology & Hydrogeology

Based on the September 11, 2008 updated surety estimate (Cogema, 2008b), the geometry of the MU-4 is as follows:

Area (acres):	11.71
Thickness (feet)	12.7
Flare Factor;	1.44
Volume (million cubic feet)	10.1
Porosity	0.26
PV (Million gallons)	19.57

As discussed in the Restoration Report, MU-4 is comprised of 3 modules, MOD41 through MOD43. Commercial production was initiated at MU-4 in June 1994, and concluded in August 1997.

Production at MU-4 was from the zone designated as the “K” Sandstone. The depth to the top of the K Sandstone at MU-4 is 300 to 350 feet. The licensee reported that the ore zone was the “K2” or “K3” sandstone; however, multiple ore horizons within the K Sandstone were common. The depth to the top of the ore zone ranges from 300 to 500 feet below grade.

Directly overlying the K Sandstone is a 75-to-100-foot thick sequence of claystone-siltstone, which is intersected by a thin (less than 5-foot thick) coal seam. Underlying the K Sandstone is a 40-to-50 foot thick sequence of dense claystone and shale. The overlying aquifer consists of a group of 5 discontinuous sand units designated as Sand No. 1 (shallowest) through Sand No. 5 (deepest), with Sand No. 3 being most pervasive and often the first sandstone unit overlying the J Sandstone. The licensee reports that these sands are equivalent to the “J” Sandstone. The first “significant” underlying aquifer is the “L” Sandstone, which is found approximately 500-to-600 feet below grade.

The potentiometric head gradient reported for the K Sandstone is to the northwest with a gradient of 0.005 to 0.01 feet per foot. The transmissivity, saturated thickness and hydraulic conductivity for MU4 production aquifer is approximately 91 square feet per day, 180 feet and 0.51 feet per day, respectively.

History of Operations/Restoration

As reported by the licensee, production at MU-4 was initiated in June 1994 at MOD42, August 1994 at MOD43, and December 1994 at MOD41. Operations continued until August 1997. Groundwater sweep phase of the restoration was initiated at all three modules in August 1997 and completed at all modules in July 1998. The volume of water associated with the groundwater sweep activities was 1.93 PVs. After a three year hiatus, the next phase of restoration consisted of the groundwater treatment with RO permeate injection. This phase was initiated at MOD43 in April 2001, and at the other two modules in February-March 2002. The groundwater treatment phase was completed by March 2003. A total of 9.84 PVs is associated with the groundwater treatment phase. Injection of hydrogen sulfide gas as a reductant was initiated during the final stages of the groundwater treatment phase for MOD42 from January 2003 to March 2003. The final phase of restoration consisted of groundwater recirculation to spread the hydrogen sulfide reductant to modules MOD41 and MOD43. This phase of

restoration was initiated in March 2003 and concluded in April 2004. The total volume of water associated with the groundwater recirculation phase is 1.0 PVs.

Excursions

During the life of MU-4, two wells were reported on excursion status at various times. The wells consist of:

- One perimeter well monitoring the downgradient northwestern perimeter (4MW-15). This well was on excursion status for a short period of time during operations. The licensee's corrective actions consisted of adjusting the nearby production units. The corrective actions proved successful to terminate the excursion status.

- One perimeter well between MU-4 and MU-3 w/ expansion (4MW-1). The well was on excursion status multiple times after stabilization, generally once a year for a period of approximately one month (Cogema, 2009c; Cogema, 2008a; Cogema, 2008d; Cogema, 2008e). The corrective actions include pumping from nearby wells (Cogema, 2009c). The well went on excursion again on March 23, 2011. Corrective actions were successful in reversing the excursion by the pumping of one recovery well. 4MW 1 was terminated from excursion status by letter dated July 1, 2011 (Uranium One, 2011).

Restoration Results

The groundwater quality in the production zone at the end of operations in MU-4 is summarized by the staff in Table 7. The groundwater quality results for MU-4 after restoration are shown in Table 8. The licensee states that the BPT was applied to the restoration effort at MU-4. The licensee indicates that the volume of groundwater treated during the restoration efforts (total of 12.8 PVs) exceed the volumes anticipated in the approved restoration plans. The licensee also indicates that the restoration efforts resulted in the substantial reduction in ionic concentrations at the end of restoration and that the groundwater quality has been restored to the pre-mining class of use (based on Wyoming's classification). Water quality data are presented by the licensee in both graphical and tabular forms showing temporal variations in the quality of selected constituents during restoration and the stabilization phases. The data are based on wellfield averages and individual modules.

The licensee indicates that the primary indicator of success for the restoration efforts is the comparison of the data from the final round of the stability monitoring to the TRVs. The licensee reports that at the end of the stability monitoring, the levels for 21 of the 35 constituents included in the monitoring program met or were below the respective TRV. Of the 12 constituents that did not meet the TRVs, six constituents (calcium, magnesium, bicarbonate, alkalinity, sodium and conductivity) do not have a Wyoming Class I standard or MCL, two constituents (chloride and aluminum) had levels that were below the respective Wyoming Class I standard or National Primary Drinking Water Regulations MCLs, and six constituents (TDS, iron, manganese, selenium, uranium and radium-226) exceeded the National Primary Drinking Water Regulations MCLs, Wyoming's standard, or National Secondary Drinking Water Regulations guidelines. Except for the latter constituents, the licensee states that levels at the end of stabilization did not pose a potential risk to offsite groundwater quality because either no standards exist or the levels were below the established standards.

For the constituents that exceed their standard and TRVs, the licensee provided an assessment of the potential transport from the production zone through to the boundary of the exempted

aquifer (location of the perimeter monitoring wells). The assessment included a quantitative evaluation of time required for groundwater to flow from the wellfield to the perimeter wells and permit [license] boundary, a qualitative evaluation of the geochemistry in particular reducing conditions of the surrounding aquifers, and a quantitative evaluation of the fate and transport for constituents of concern. The fate and transport evaluation consisted of the use of a “reduction factor” that was determined from results of numeric modeling performed for the approved Irigaray wellfield restorations. The reduction factor accounted for dispersion but not any absorption. Based on the assessments, the licensee concluded that the levels did not pose unacceptable risks due to reduction in levels and their immobility in groundwater systems under reducing conditions.

In 2009, in response to RAIs, the licensee collected additional groundwater data (Cogema, 2009a). The data consisted of groundwater quality at selected wells along an estimated groundwater flow path through the mine unit. The data includes well locations upgradient, within and downgradient of the former production aquifer. The licensee cites evidence for a reducing environment by the detectable levels of iron and manganese, low Eh and dissolved oxygen levels, and a distinctive sulfide odor detected during sampling at the wells within the former mine unit. The parameters analyzed at selected wells within the production zone consisted of nitrate plus the field-measured parameters.

<u>Evaluation Findings</u>

MU-4 Groundwater Quality at the End of Operations

The quality of the groundwater in the production zone at the end of operations is summarized by the staff on Table 7. The data are summarized as follows:

1. Of the 35 parameters monitored, 11 parameters (Nitrite, Aluminum, Barium, Boron, Cadmium, Chromium, Copper, Lead, Mercury, Molybdenum, and Nickel) were not affected by operations. The 24 parameters affected by the operations are as follows:

    a. concentrations of 21 parameters increased by a factor of 1.3 to 1520 times
    b. the mean background levels
    c. pH levels decreased from slightly alkaline conditions (baseline) to near neutral conditions
    d. and the concentrations of three parameters, carbonate, zinc and fluoride, decreased below background levels.

Evaluation Step *1 –Restoration Meeting Primary Goals*

Baseline Data

In the Restoration Report, the licensee compares the levels after restoration to the established TRVs. Unlike the TRVs reported for MU-2 and MU-3, the TRVs for MU-4 are based on the mean value plus a factor multiplied by the standard deviation (Cogema, 1994), which the NRC staff agrees is a statistically valid approach assuming a normal distribution of data. The factor used for most constituents is between 4 and 5.

Wells Used in the Restoration/Baseline Comparison

The baseline and restoration data consisted of 16 wells within production zone. One well, 4W106-1, used for the post-restoration data, differed from wells used in the baseline data. This difference in wells was noted by the licensee. The replacement well was approximately 85 feet from the original well. The licensee reports that the replacement well was needed due to damage (e.g., MIT failure) during the life of the original well. The staff finds this information is adequate.

MU-4 Groundwater Quality after Restoration/Stabilization

Of the 24 parameters affected by operations, the concentrations of nine (9) parameters did not meet baseline average or National Primary Drinking Water Regulations MCLs (Table 8). Therefore, the staff's evaluation proceeded to Step 2.

Evaluation Step 2 – Asymptotic Trends and Application of BPT

The licensee states that the levels at the end of restoration/stabilization reflect a significant reduction from levels observed prior to the start of restoration and that the BPT was applied throughout the restoration process. The licensee presents graphs exhibiting trends in uranium (U_3O_8) and conductivity versus pore volumes of groundwater treatment that show a linear decrease for two modules (Figure 4-2 (MOD42) and Figure 4-3 (MOD43) in the MU-4 Report in the Restoration Report (Cogema, 2008c), and an increasing trend for one module during restoration (Figure 4-1 (MOD41) in the MU-4 Report in the Restoration Report (Cogema, 2008c)).

The licensee reports the parameter average concentrations post-RO but not the average concentrations post-reductant addition (as was reported in the MU-2 and MU-3 reports). The stability monitoring data are significantly higher than the concentrations reported post-RO and a significant percentage of the post-mining concentrations. Furthermore, though the uranium level at well 4T114-1 has diminished to 6.66 mg/L from the concentration of 16 mg/L during stabilization (2004-2005), the levels of most parameters have remained relatively constant at elevated levels. In addition, the concentration during stability monitoring of 16 mg/L was approximately equal to the post-mining concentration of 17.55 mg/L. Consequently, the staff concludes that the licensee has not adequately demonstrated that its restoration effort at MU4 is consistent with the application of BPT.

The next step in the evaluation process is Step 3A.

Evaluation Step 3A Excursions

Two wells were reported on excursion status. One well, 4MW-15, is located on the northwest downgradient perimeter of the wellfield for approximately 5 months during operations. The licensee reported uranium as U_3O_8 concentrations as high as 1.3 mg/L, or approximately 10 times the maximum baseline value during the event. The uranium concentrations exhibited a significant decreasing trend during termination of excursion status. Since the excursion event, the levels of all excursion indicator parameters have been below their respective UCL. The licensee has not reported uranium concentrations since the termination of the excursion event.

Based on the levels of the excursion indicator parameters, the staff is confident that the corrective actions during the excursion were adequate to protect the impacts to the surrounding

USDW. However, because this well, under static conditions, is downgradient of MU-4 and the impacts to the groundwater at this well included elevation uranium concentrations, the staff has determined that additional analysis should be conducted on this well.

Well 4MW-1 is located between MU4 and MU3. The staff is concerned that the on-going excursions associated with this well are attributed to enhance flaring emanating from one or both production units due to competing drawdown at each unit. The staff has determined that the licensee has failed to characterize the potential impacts to the production zone between Mine Units 3 and 4.

Summary

Based upon the above, the staff cannot concur that the restoration of MU-4 is protective of human health and safety and the environment until the licensee:

(1) Demonstrates that its restoration effort results in parameter levels approaching asymptotic trends using BPT.
(2) Provides confirmatory analyses on the uranium concentrations at monitoring well 4MW-15 that demonstrate the levels are within regulatory requirements (groundwater protection criteria).
(3) Adequately characterizes the impacts to the aquifer in the vicinity of 4MW-1 and those impacts are within regulatory requirements (groundwater protection criteria).
(4) Demonstrates stability of contaminant concentrations by showing no SSI trends during the stability monitoring period once the restoration goals are achieved.

Mine Unit 5 (MU-5)

Geometry, Geology & Hydrogeology

Based on the September 11, 2008, updated surety estimate (Cogema, 2008b), the geometry of the MU-5 is as follows:

Area (acres):	27.8
Thickness (feet)	19.9
Flare Factor;	1.44
Volume (million cubic feet)	38.6
Porosity	0.26
PV (Million gallons)	75.1

As discussed in the Restoration Report, MU-5 is comprised of 5 modules, MOD51 through MOD55. Commercial production was initiated at MU-5 in June 1995 and concluded in March 2000.

Production at MU-5 was from the zone designated as the “K” Sandstone. The depth to the top of the K Sandstone at MU-5 is 250-to-400 feet. The licensee reported that the ore zone was the “K2” or “K3” sandstone; however, multiple ore horizons within the K Sandstone were common. The depth to the top of the ore zone ranges from 300-to-500 feet below grade. The K Sandstone coalesces with the deeper sand (No. 1 Deep Sand) in the northern portions of MU-5.

Directly overlying the K Sandstone is a 40-to-140 foot thick sequence of claystone-siltstone, which is intersected by a thin (less than 5-foot thick) coal seam. Underlying the K Sandstone is a 25-to-90 foot thick sequence of dense claystone and shale.

The licensee did not report information on the overlying or underlying aquifers.

The potentiometric head gradient reported for the K Sandstone is to the northwest with a gradient of 0.005 feet per foot. The transmissivity, saturated thickness and hydraulic conductivity for MU4 production aquifer is approximately 87 square feet per day, 190 feet and 0.47 feet per day, respectively.

History of Operations/Restoration

Production at MU-5 was initiated in June 1995 at MOD51, October 1995 at MOD52, January 1996 at MOD53, April 1996 at MOD54, and August 1996 at MOD55. Operations continued until March 2000. Groundwater sweep phase of the restoration was initiated at module MOD55 in April 2000, and all other modules in July 2000, and completed at all modules in June 2001. The volume of water associated with the groundwater sweep activities was 4.83 PVs. The next phase of restoration consisted of the groundwater treatment with RO permeate injection. This phase was initiated at MOD51 in February 2001 and at the other modules between January and March 2002. The groundwater treatment phase was completed by November 2003. The licensee did not report a total volume with the groundwater treatment phase. The final phase of restoration consisted of groundwater recirculation. The initiation of this phase of restoration was not reported but was concluded in November 2003. The total volume of water associated with the groundwater treatment and groundwater recirculation phases is 5.3 PVs.

The licensee did not report the use of a reductant in the restoration process for this mine unit.

Active uranium recovery operations restarted in Module 52 in 2012. This TER was written and in review when the MOD 52 was returned to service. Therefore, any discussions by the NRC staff pertaining to MOD 52 in this TER are no longer timely.

Excursions

During the life of MU-5, five wells were reported on excursion status at various times. The wells consist of:

- One perimeter well monitoring on the downgradient, central-northwestern side of the MU-5 (5MW-52). This well was on excursion status for a short period of time during operations. The licensee's corrective actions consisted of adjusting the nearby production units. The corrective actions proved successful to terminate the excursion status.

- One perimeter well at monitoring the downgradient northwestern perimeter (5MW-16). The well was on excursion status for less than one month during operations. The corrective actions included pumping from nearby wells.

- One perimeter well monitoring the side gradient southwestern perimeter (5MW-43). This well was on excursion status for a short period of time during restoration (groundwater sweep; Cogema, 2002). The licensee's corrective actions consisted of adjusting the

nearby production units. The corrective actions proved successful to terminate the excursion status.

- One perimeter well monitoring the downgradient northwestern perimeter (5MW-8). This well was on excursion status for a six-month period during restoration (groundwater treatment/recirculation; Cogema, 2003a; Cogema, 2003b). The licensee's corrective actions consisted of adjusting the nearby production units. The corrective actions proved successful to terminate the excursion status. 5MW-8 was again confirmed on excursion status on April 19, 2011. Corrective action began on April 29, 2011 with the pumping of one adjacent recovery well. 5MW8 met the criteria for termination May 31, 2011, and was terminated from excursion status on June 6, 2011 (Uranium One, 2011).

- One perimeter well monitoring the downgradient central-northwestern perimeter (5MW-54). This well was on excursion status for a four month period during restoration (groundwater treatment/recirculation; Cogema, 2003a; Cogema, 2003b). The licensee's corrective actions consisted of adjusting the nearby production units. The corrective actions proved successful to terminate the excursion status.

- One perimeter well monitoring the downgradient central-northwestern perimeter (5MW-66). This well was on excursion status twice for a four-month period during restoration (groundwater treatment/recirculation) and during and after the stabilization period[13] (Cogema, 2009b; Cogema, 2009c; Cogema, 2008a; Cogema, 2008d; Cogema, 2007a; Cogema, 2007b; Cogema, 2006; Cogema, 2005a; Cogema, 2005c; Cogema, 2003b; Cogema, 2002). 5MW-66 remained on excursion status through March, 2011 and was terminated from excursion status on April 19, 2011.

- One perimeter well monitoring the downgradient central-northwestern perimeter (5MW-48). This well was on excursion status twice for two short periods of time during and after the stabilization period (Cogema, 2009c; Cogema, 2008a; Cogema, 2008d; Cogema, 2007a). The licensee's corrective actions consisted of adjusting the nearby production units. The corrective actions proved successful to terminate the excursion status.

Restoration Results

The groundwater quality in the production zone at the end of operations in MU-5 is summarized by the staff in Table 9. The groundwater quality results for MU-5 after restoration are shown in Table 10. The licensee states that the BPT was applied to the restoration effort at MU-5. The licensee indicates that the volume of groundwater treated during the restoration efforts (total of 10.1 PVs) exceed the volumes anticipated in the approved restoration plans. The licensee also indicates that the restoration efforts resulted in the substantial reduction in ionic concentrations at the end of restoration and that the groundwater quality has been restored to the pre-mining class of use (based on Wyoming's classification). Water quality data are presented in both graphical and tabular forms showing temporal variations in the quality of selected constituents during restoration and the stabilization phases. The data are based on wellfield averages and individual modules.

[13] At the request of the licensee, the NRC and Wyoming removed the well from excursion status reporting and monitoring requirements (although the excursion parameter levels would have maintained the excursion status). Quarterly monitoring was required as well as investigations during restoration (Cogema, 2005b).

The licensee indicates that the primary indicator of success for the restoration efforts is the comparison of the data from the final round of the stability monitoring to the TRVs. The licensee reports that at the end of the stability monitoring, the levels for 25 of the 35 constituents included in the monitoring program met or were below the respective TRV. Of the 10 constituents that did not meet the TRVs, four constituents (calcium, magnesium, bicarbonate and alkalinity) do not have a Wyoming Class I standard or MCL, three constituents (arsenic, aluminum and iron) had levels that were below the respective Wyoming Class I standard or the National Primary Drinking Water Regulations MCLs, and three constituents (manganese, selenium and uranium) exceeded the National Primary Drinking Water Regulations MCLs, National Secondary Drinking Water Regulations guidelines or Wyoming's standard. Except for the latter constituents, the licensee states that levels at the end of stabilization did not pose a potential risk to offsite groundwater quality because either no standards exist or the levels were below the established standards.

For the constituents that exceed their standard and TRVs, the licensee provided an assessment of the potential transport from the production zone through to the boundary of the exempted aquifer (location of the perimeter monitoring wells). The assessment included a quantitative evaluation of time required for groundwater to flow from the wellfield to the perimeter wells and permit [license] boundary, a qualitative evaluation of the geochemistry in particular reducing conditions of the surrounding aquifers, and a quantitative evaluation of the fate and transport for constituents of concern. The fate and transport evaluation consisted of the use of a "reduction factor" that was determined from results of numeric modeling performed for the approved Irigaray wellfield restorations. The reduction factor accounted for dispersion but not any absorption. Based on the assessments, the licensee concluded that the levels did not pose unacceptable risks due to reduction in levels and their immobility in groundwater systems under reducing conditions.

In the 2009 response to RAIs, the licensee collected additional groundwater data. The data consisted of groundwater quality at selected wells along an estimated groundwater flow path through the mine unit. The data includes well locations upgradient, within and downgradient of the former production aquifer. The licensee cites evidence for a reducing environment by the detectable levels of iron and manganese, low Eh and dissolved oxygen levels, and a distinctive sulfide odor detected during sampling at the wells within the former mine unit. The licensee cites the decrease in uranium concentrations at well 5BL76-1 from 14.8 mg/L in August 2004 to 12.8 in June 2009 as evidence of stability.

In the 2009 response to RAIs, the licensee also provides data collected at well 5MW-66, which has been on excursion status for an extended period of time. The data show that many constituent concentrations have increased since 2004, most notably uranium and selenium. The licensee argues that the data for 5MW-66 is inconsistent with results for sampling conducted at other locations in MU-5. The licensee indicates that the evidence of reducing conditions at the downgradient wells would retard any migration such that the potential health risk from well 5MW-66 is minimal. In addition, the licensee notes that based on potentiometric head contour mapping and its locations relative to other perimeter wells (5MW-64 and 5MW-68), the transport from 5MW-66 will remain within the boundary of MU-5.

Evaluation Findings

Mine Unit 5 Groundwater Quality at the End of Operations

The quality of the groundwater in the production zone at the end of operations is summarized by the staff in Table 9. The data are summarized as follows:

1. Of the 35 parameters monitored, 11 parameters (Nitrite, Aluminum, Barium, Boron, Cadmium, Chromium, Copper, Lead, Mercury, Molybdenum, and Nickel) were not affected by operations. The 24 parameters affected by the operations are as follows:

    a. concentrations of 20 parameters increased by a factor of 1.2 to 543 times the mean background levels;
    b. pH levels decreased from slightly alkaline conditions (baseline) to near neutral conditions; and
    the concentrations of three parameters, carbonate, zinc and fluoride, decreased below background levels.

Evaluation Step *1 –Restoration Meeting Primary Goals*

Baseline Data

In the Restoration Report, the licensee compares the levels after restoration to the established TRV. Unlike the TRVs reported for MU-2 and MU-3, the TRVs for MU-4 are based on the mean value plus a factor multiplied by the standard deviation which is a statistically valid approach (Cogema, 1995). The factor used for most constituents is between 3.9 and 4.6. The factors used for ammonia, nitrate, selenium, and zinc exceed 4.6.

Wells Used in the Restoration/Baseline Comparison

The baseline and restoration data consisted of 25 wells within production zone. Wells used for the restoration data are those used to establish baseline data. The staff finds this information is adequate.

MU-5 Groundwater Quality after Restoration/Stabilization

Of the 20 constituents with an increased concentrations at the end of operations, the concentrations of 6 constituents calcium, magnesium, bicarbonate, TDS, manganese and uranium) did not meet baseline average, TRVs, or National Primary Drinking Water Regulations MCLs (Table 10). In addition, the distribution of restoration data for several constituents (arsenic, iron, selenium, vanadium and radium-226) suggests that hot spots may exist and the normality of the data should be verified. Therefore, the staff's evaluation proceeded to Step 2.

Evaluation Step 2 – Asymptotic Trends and Application of BPT

The licensee states that the levels at the end of restoration/stabilization reflect a significant reduction from levels observed prior to the start of restoration and that the BPT was applied throughout the restoration process. The licensee presents graphs exhibiting trends in uranium (U_3O_8) and conductivity versus pore volumes of groundwater treatment that show a asymptotic decrease for four modules and a linear decreasing trend for one module during restoration. The licensee reports the parameter average concentrations post-RO, but not the average

concentrations post-reductant addition (as was reported in the MU-2 and MU-3 reports). The stability monitoring data are slightly higher than the concentrations reported post-RO and a decrease from the post-mining concentrations. However, the staff could not fully evaluate the groundwater quality after restoration, given the reported data. The restoration data for one module, module 55, exhibit a dichotomy of data, with one well exhibiting extremely high parameter levels and other wells exhibiting extremely low parameter values. It is difficult to evaluate the data given the distribution of data. The data collected during 2009 exhibit continued elevated levels at well 5BL76-1 in module 55 (Cogema, 2009a).

Therefore, for the reasons indicated in the preceding paragraph, the staff cannot determine whether or not the licensee applied BPT for restoration so that the levels approach an asymptotic trend throughout the entire MU-5. The next step in the evaluation process is Step 3A.

Evaluation Step 3A Excursions

The staff's primary concern regarding excursions is well 5MW-66. The well has been on excursion status throughout most of the post-stabilization period. The data indicate that: (1) the levels of all three excursion indicator parameters exceed their respective UCL by at least 40 percent; (2) the excursion indicator parameter levels continue to exhibit an increasing trend; (3) the pH levels inversely correlate with the excursion indicator parameter levels (i.e., the pH levels decrease from 8.3 to 7.2); (4) groundwater elevations directly correlate with the excursion indicator parameter levels (i.e., the groundwater elevations increased from 4,535 to 4,630 feet above mean sea level); and (5) the parameter levels of most constituents are above baseline levels and have increased since the last analysis in 2004.

The staff's concern is that the above data reflect an impact from mining fluids that continue to affect this well. The licensee's arguments are that the results from well 5MW-66 are inconsistent with sampling results at other locations in MU5, the primary constituents of concern are selenium and uranium, the direction of flow from 5MW-66 is west-northwest between 5MW-66 and 5MW-68 and that the distance to those wells will result in transport from 5MW-66 remaining within the boundary of MU-5, and the reducing conditions within and downgradient of MU-5 will greatly retard the migration of uranium and selenium such that the potential health risk is minimal.

The staff does not agree with the licensee's arguments because the characterization of the impacts has not been fully defined. As observed at previous mine units, long-term excursions are associated with their location, i.e., in areas in which two mine units abut. Monitoring well 5MW-66 is not located between two mine units; however, its location can be described as being between two modules. In fact, the 2004 report on the excursion includes a figure that refers to the northern extension of MU-5 beyond 5MW-66 as module 5-6 (apparently, module 5-6 has been joined to module 5-5). The staff's concern is that the impact at 5MW-66 does not reflect the entire impact if a flare occurred between the modules, a flare which was not restored.

An even more troubling perspective is if the impacts at well MW-66 are attributed to the migration of fluids from mine unit module 5-5, fluids which were subjected to the licensee's restoration. The staff notes that several excursions have been noted at several wells along the downgradient edge of this module (e.g., wells 5MW-52 and 5MW-54 located south of 5MW-66 and wells 5MW-8 and 5MW-16 located north of 5MW-66). If the impacts at 5MW-66 reflect the migration from a restored aquifer, similar impacts may be expected at the downgradient perimeter wells in the future.

The licensee's argument that the transport will remain within the boundaries of MU-5 is questionable. The licensee notes the location of well 5MW-68 relative to 5MW-66, and well 5MW-68 and 5MW-70 are included on the list of perimeter monitoring wells in their Restoration Report, but monitoring at those wells are not included in reports dating at least to 2000 and their locations are not shown on many maps. The licensee must define the perimeter well ring, especially if it is to be the boundary of the exempted aquifer.

Summary

Based upon the above, the staff cannot concur that the restoration of MU-5 is protective of human health and safety and the environment until the licensee:

(1) Demonstrates that its restoration effort is consistent with BPT and results in levels that exhibit an asymptotic trend, especially for module 5-5;
(2) Characterizes the impacts to the aquifer in the vicinity of perimeter well 5MW-66 and the impacts meet the regulatory requirements (groundwater protection criteria); and
(3) Completes restoration at Module 5-2 that is now in production.

Mine Unit 6 (MU-6)

Geometry, Geology & Hydrogeology

Based on the September 11, 2008 updated surety estimate (Cogema, 2008b), the geometry of the MU-6 is as follows:

Area (acres):	46.4
Thickness (feet)	21.8
Flare Factor;	1.44
Volume (million cubic feet)	64.6
Porosity	0.26
PV (Million gallons)	125.61

MU-6 is comprised of 6 modules, MOD61 through MOD66. Commercial production was initiated at MU-6 in January 1997 and concluded in June 2000.

Production at MU-6 was from the zone designated as the "K" Sandstone. The depth to the top of the K Sandstone at MU-6 is 250-to-400 feet and 130 to 200 feet thick. The licensee reported that the ore zone was the "K3" sand, which is located in the lower portion of the K Sandstone. Thickness of the ore zone is between 50 and 60 feet and the depth to the top of the ore zone is approximately 500 feet below grade. The K3 Sand coalesces with the overlying "K2" sand and underlying "K4" sand in portions of the mine unit.

Directly overlying the K Sandstone is a 20-to-120 foot thick sequence of claystone-siltstone. Underlying the K Sandstone is a 20-to-160 foot thick sequence of dense claystone and shale.

The licensee did not report information on the overlying or underlying aquifers.

The potentiometric head gradient reported for the K Sandstone is to the northwest with a gradient of 0.007 feet per foot. The transmissivity, saturated thickness and hydraulic conductivity for MU-6 production aquifer is approximately 84 square feet per day, 55 feet and 1.58 feet per day, respectively.

History of Operations/Restoration

Production at MU-6 was initiated in January 1997 at MOD61 through July 1999, at MOD66. Operations continued until June 2000. Groundwater sweep phase of the restoration was initiated at modules MOD63 and MOD64 in September 2000, modules MOD61 and MOD62 in March 2001, and modules MOD65 and MOD66 in June 2001, and a completed at all modules in February 2003. The volume of water associated with the groundwater sweep activities was 1.5 PVs. The next phase of restoration consisted of the groundwater treatment with RO permeate injection. This phase was initiated at MOD66 in October 2003 and at the other modules by July 2004. The groundwater treatment phase was completed by May 2005. The licensee did not report a total volume with the groundwater treatment phase. The final phase of restoration consisted of groundwater recirculation. The initiation of this phase of restoration was not reported; however, the licensee reported it was concluded in "November 2003" (Cogema, 2008c; Cogema, 2005a), which is inconsistent with the dates reported for groundwater treatment if the recirculation followed treatment. The total volume of water associated with the groundwater treatment and groundwater recirculation phases is 4.5 PVs.

The licensee did not report the use of reductant addition in the restoration process for this mine unit in the Restoration History Section of their Restoration Report. However, in the Restoration Water Quality Section of the Restoration Report, the licensee states that after sampling of designated wells for selected parameters of interest close to the end of the RO phase that more restoration was needed using RO with the reductant addition. The licensee states that during the last pore volume of RO, reductant was circulated through MU6 (April 2005 through May 2005). In its 2009 response, the licensee stated that reductant addition occurred during the final pore volume of restoration at MU-6.

Excursions

During the life of MU-6, three wells were reported on excursion status during operations. The wells consist of:

- One perimeter well monitoring the side-gradient northern perimeter (6MW-46). This well was on excursion status for less than one month during operations. The licensee's corrective actions consisted of adjusting the nearby production units. The corrective actions proved successful to terminate the excursion status.

- One perimeter well monitoring the upgradient northeastern perimeter (6MW-40). The well was on excursion status for less than one month during operations. The corrective actions include pumping from nearby wells.

- One perimeter well monitoring the side-gradient southwestern perimeter (6MW-21). This well was on excursion status for approximately one month during operations. The licensee's corrective actions consisted of adjusting the nearby production units. The corrective actions proved successful to terminate the excursion status.

Restoration Results

The groundwater quality in the production zone at the end of operations in MU6 is summarized by the staff in Table 11. The licensee states that the BPT was applied to the restoration effort at MU-6. The licensee indicates that the restoration efforts resulted in the substantial reduction in ionic concentrations at the end of restoration and that the groundwater quality has been restored to the pre-mining class of use (based on Wyoming's classification). Water quality data are presented in both graphical and tabular forms showing temporal variations in the quality of selected constituents during restoration and the stabilization phases. The data are based on wellfield averages and individual modules.

The licensee indicates that the primary indicator of success for the restoration efforts is the comparison of the data from the final round of the stability monitoring to the TRVs. The licensee reports that at the end of the stability monitoring, the levels for 27 of the 35 constituents included in the monitoring program met or were below the respective TRV. Of the eight constituents that did not meet the TRVs, four constituents (calcium, magnesium, bicarbonate and alkalinity) do not have a Wyoming Class I standard or National Primary Drinking Water Regulations MCLs, one constituent (chloride) had levels that were below the respective Wyoming Class I standard and the National Secondary Drinking Water Regulations guidelines, and three constituents (manganese, selenium and uranium) exceeded the National Primary Drinking Water Regulations MCLs, National Secondary Drinking Water Regulations guidelines, or Wyoming's standard. Except for the latter constituents, the licensee states that levels at the end of stabilization did not pose a potential risk to offsite groundwater quality because either no standards exist or the levels were below the established standards.

For the constituents that exceed the National Primary Drinking Water Regulations MCLs or TRV, the licensee provided an assessment of the potential transport from the production zone through to the boundary of the exempted aquifer (location of the perimeter monitoring wells). The assessment included a quantitative evaluation of time required for groundwater to flow from the wellfield to the perimeter wells and permit [license] boundary, a qualitative evaluation of the geochemistry in particular reducing conditions of the surrounding aquifers, and a quantitative evaluation of the fate and transport for constituents of concern. The fate and transport evaluation consisted of the use of a "reduction factor" that was determined from results of numeric modeling performed for the approved Irigaray wellfield restorations. The reduction factor accounted for dispersion but not any absorption. Based on the assessments, the licensee concluded that the levels did not pose unacceptable risks due to reduction in levels and their immobility in groundwater systems under reducing conditions.

In the 2009 response to RAIs, the licensee collected additional groundwater data. The data consisted of groundwater quality at selected wells along an estimated groundwater flow path through the mine unit. The data includes well locations upgradient, within and downgradient of the former production aquifer. The licensee cites evidence for a reducing environment by the detectable levels of iron and manganese, low Eh and dissolved oxygen levels, and a distinctive sulfide odor detected during sampling at the wells within the former mine unit. The licensee cites the elevated iron and manganese concentrations at well 6M29-1 in 2009 as evidence for stable reducing conditions. The licensee also notes that in 2009, selenium concentrations at well 6M29-1 decreased to below the minimum detection limits and that the uranium concentrations increased. However, the licensee states that increase in uranium concentrations will not pose a risk to public health and safety downgradient of the mine because of the reducing conditions in this area.

Evaluation Findings

MU-6 Groundwater Quality at the End of Operations

The quality of the groundwater in the production zone at the end of operations is summarized by the staff in Table 11. The data are summarized as follows:

1. Of the 35 parameters monitored, 12 parameters (Nitrite, Aluminum, Barium, Boron, Cadmium, Chromium, Copper, Lead, Mercury, Molybdenum, Nickel and Zinc) were not affected by operations. The 23 parameters affected by the operations are as follows:
    a. concentrations of 20 parameters increased by a factor of 2 to 1122 times the mean background levels;
    b. pH levels decreased from slightly alkaline conditions (baseline) to near neutral conditions; and
    c. and the concentrations of two parameters, carbonate and fluoride, decreased below background levels.

Evaluation Step *1 –Restoration Meeting Primary Goals*

The staff cannot independently evaluate the restoration data for this mine unit. First, the baseline for MU-6 was not approved by NRC but through the licensee's SERP. Apparently, License Condition 10.3 did include a reference to the September 1996 MU- 6 Wellfield Package prior to Amendment 4. This reference was removed from the license at the request of the licensee under Amendment 4. The licensee references a December 1996, document for baseline which the staff does not have. Only the September 24, 1996, Wellfield package is in NRC's Agencywide Documents Access and Management System (ADAMS) (Cogema, 1996a).

The Restoration Report discusses that 42 wells were used as the original baseline and 5 wells were added but later dropped at the request of WDEQ because the baseline data was acquired after the operations were initiated. The September 1996, wellfield report also documents 42 wells used in the baseline. However, Table 4-1 of the Restoration Report (Cogema, 2008c) lists 44 wells as the designated restoration wells (42 wells in the September 1996, wellfield package minus three wells (NPOW-2, NPOW-3 and NPPW-1) plus five additional wells (6AG64-2, 6AI63-3, 6AL54-2 and 6AP64-2). To make things more complicated, the laboratory data in Restoration Report, Appendix A, includes 47 wells (3 wells not listed on Table 4-1 (6AF42-1, 6AH40-2 and 6AN47-1) and one slightly different well (6T23-4 for 6T23-3). The staff is not aware of the source of the discrepancies; they may be documented in the unavailable December 1996, report.

Because of these discrepancies, the staff cannot fully evaluate the baseline data. For several parameters, the TRVs used by the licensee differ significantly from values listed in the September 1996 document. The appropriateness of the TRVs is significant for several TRVs (e.g., iron, pH).

The staff cannot fully evaluate whether or not BPT was employed during the restoration process. First, the licensee combines groundwater treatment and recirculation phases. Based on a review of the monthly production reports for 2003 through 2005, it appears that recirculation may have dominated the efforts. If the constituent levels remain elevated, the staff will not be able to approve a restoration if the predominant restoration process was simply recirculation. Second, uranium levels at one well appear to have increased from 9.28 mg/L in

2006 to 12.4 mg/L in 2009. The staff cannot reconcile that BPT have been employed to achieve a level of 12.4 mg/l whereas a level of 12.57 mg/L was reported for post mining average.

Based upon the above, the staff cannot concur that the restoration of MU- 6 is protective of human health and safety and the environment until the licensee:

(1) Provides the staff with data used to define baseline; and
(2) Demonstrates that its restoration effort is consistent with BPT and results in levels that exhibit an asymptotic trend.

SUMMARY

The staff is unable to approve restoration for any of the mine units reported as restored by the licensee in the Restoration Report. The following information or demonstration of restoration is required:

MU-2 North

(1) Demonstrate that the SSI trends for uranium and radium-226 at well 2T92-2 are reversed and stable.
(2) Provide a confirmatory analysis of the groundwater quality at well 2MW108 subsequent to the corrective actions for the 2011 excursion that demonstrates impacts to the aquifer following the 2011 excursion event meet regulatory requirements (groundwater protection criteria).

MU-2 South

(1) Demonstrate that the impacts to the overlying and production aquifers between MU2 South and MU3 meet regulatory requirements;
(2) Demonstrate that the SSI trend noted in the uranium concentrations at well 2AF34-1 is reversed and stable.

MU-3 w/o Expansion

(1) Confirm that the well 3D12-2 used in the restoration, but not in the baseline, was needed to a replace well that has been abandoned;
(2) Demonstrate that the elevated conductivity noted in the 2009 sampling event does not result in levels of all constituents of concern in wells 3T37-2 and 3T27-2 above the applicable standards.
(3) Demonstrate that the SSI trend noted in the uranium concentrations at well 3V58-2 is reversed and stable.

MU-3 w/ Expansion (Module 4A)

(1) Provide a statistical evaluation of the restoration data including rationale for outliers and stability analyses.
(2) Demonstrate that the SSI trend in uranium and radium-226 in wells 3W75-1 and 3Z87-1 is reversed and stable.

MU-4

(1) Demonstrate that its restoration effort results in parameter levels approaching asymptotic trends using BPT.
(2) Provide confirmatory analyses on the uranium concentrations at monitoring well 4MW-15 that demonstrate the levels are within regulatory requirements (groundwater protection criteria).
(3) Adequately characterize the impacts to the aquifer in the vicinity of 4MW-1 and that those impacts are within regulatory requirements (groundwater protection criteria).
(4) Demonstrate stability of contaminant concentrations by showing no SSI trends during the stability monitoring period once the restoration goals are achieved.

MU-5

(1) Demonstrate that their restoration effort is consistent with BPT and results in levels that exhibit an asymptotic trend especially for module 5-5.
(2) Characterize the impacts to the aquifer in the vicinity of perimeter well 5MW-66 and that the impacts meet the regulatory requirements (groundwater protection criteria).
(3) Complete restoration at Module 5-2 that is now in production.

MU-6

(1) Provide the staff with data used to define baseline.
(2) Demonstrate that the restoration effort is consistent with BPT and results in levels that exhibit an asymptotic trend.

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TABLES

Table 1 Parameters affected by the In-situ Operations at Christensen Ranch Mine Unit 2

Parameter	Baseline Mean Value[1]			Post Operations/ Pre-Restoration Quality	Aquifer Affected by Lixiviant[3]	Factor of Increase[4]
	MU2-South	MU2-North	Weighted Average[2]			
Ca	8.61	8.15	8.297	285.8	Yes	34
Mg	0.93	0.53	0.658	53.1	Yes	81
Na	143.82	135.78	138.353	696.4	Yes	5
K	3.17	3.52	3.408	9.4	Yes	3
CO3	5.85	10.91	9.291	1	*	
HCO3	114.7	100.64	105.139	1898.8	Yes	18
SO4	215.51	213.78	214.334	784.1	Yes	4
Cl	9.42	8.87	9.046	122.9	Yes	14
NH4	0.14	0.08	0.099	0.52	Yes	5
NO2 (N)	0.1	0.1	0.100	0.12	Yes	1
NO3 (N)	0.13	0.1	0.110	0.22	Yes	2
F	0.2	0.27	0.248	0.1	*	
SiO2	5	8.4	7.312	12.6	Yes	2
TDS	443	427.25	432.290	3054.6	Yes	7
Cond	650	709.97	690.780	4007.8	Yes	6
Alkalinity	101.66	100	100.531	1484.9	Yes	15
pH	8.8	9.13	9.024	7.51	*	
Al	0.1	0.1	0.100	0.1	No	
As	0.002	0.002	0.002	0.12	Yes	60
Ba	0.1	0.1	0.100	0.1	No	
B	0.1	0.1	0.100	0.1	No	
Cd	0.01	0.01	0.010	0.01	No	
Cr	0.05	0.05	0.050	0.05	No	
Cu	0.01	0.01	0.010	0.01	No	
Fe	0.04	0.05	0.047	0.14	Yes	3
Pb	0.05	0.05	0.050	0.05	No	
Mn	0.01	0.01	0.010	0.66	Yes	66
Hg	0.001	0.001	0.001	0.001	No	
Mo	0.1	0.1	0.100	0.1	No	
Ni	0.05	0.05	0.050	0.12	Yes	2
Se	0.002	0.004	0.003	6.33	Yes	1884
V	0.1	0.1	0.100	0.24	Yes	2
Zn	0.01	0.01	0.010	0.05	Yes	5
U	0.0274	0.041	0.037	11.75	Yes	321
Radium-226	17.2	22.741	20.968	257.7	Yes	12

1 Baseline Mean Source: Wellfield Data Packages
2 Weighted average based on number of wells in each area (8 wells in MU-2 North, 17 wells in MU-2 South)
3 A "*" indicates that the concentration decreased during operations.
4 Factor of increase in the ratio of the concentration in the aquifer at the end of mining to baseline mean.

Table 2 Comparison of Restoration Final Round of Data to Baseline Mean Values for Mine Unit 2 North

Constituent	Baseline Mean Concentration	Round 4 Stability Mean Concentration	Less than Baseline Mean Value	MCL	Does Not Meet Baseline or MCL
Ca	8.15	73.6	No		X
Mg	0.53	7.6	No		X
Na	135.78	109.8	Yes		
K	3.52	1.4	Yes		
CO3	10.91	1	Yes		
HCO3	100.64	330.3	No		X
SO4	213.78	154.4	Yes		
Cl	8.87	7.2[a]	Yes		
NH4	0.08	0.1	Yes - PQL differences		
NO2 (N)	0.1	0.1	Yes		
NO3 (N)	0.1	0.1	Yes		
F	0.27	0.1	Yes		
SiO2	8.4	8.6	Yes - within statistical range		
TDS	427.25	560	No		X
Cond	709.97	821.9	No		X
Alkalinity	100	270.5	No		X
pH	9.13	7.8			
Al	0.1	0.1	Yes		
As	0.002	0.008	No	0.01	
Ba	0.1	0.5	No	2	
B	0.1	0.05	Yes		
Cd	0.01	0.002	Yes		
Cr	0.05	0.01	Yes		
Cu	0.01	0.01	Yes		
Fe	0.05	0.43	No		X
Pb	0.05	0.02	Yes		
Mn	0.01	0.25	No		X
Hg	0.001	0.001	Yes		
Mo	0.1	0.02	Yes		
Ni	0.05	0.01	Yes		
Se	0.004	0.01	No	0.05	
V	0.1	0.1	Yes		
Zn	0.01	0.01	Yes		
U	0.041	0.33[a]	No	0.03	X
Radium-226	22.741	243[a]	No	5	X

[a] Data were determined not to be normally distributed; listed mean value based on a log-normal distribution

Table 3 Comparison of Restoration Final Round of Data to Baseline Mean Values for Mine Unit 2 South

Constituent	Baseline Mean Concentration	Round 4 Stability Mean Concentration	Less than Baseline Mean Value	MCL	Does Not Meet Baseline or MCL
Ca	8.61	58.4	No		X
Mg	0.93	8.1	No		X
Na	143.82	108.9	Yes		
K	3.17	1.5	Yes		
CO3	5.85	1	Yes		
HCO3	114.7	246	No		X
SO4	215.51	185.7	Yes		
Cl	9.42	8.2	Yes		
NH4	0.14	0.1	Yes		
NO2 (N)	0.1	0.1	Yes		
NO3 (N)	0.13	0.1	Yes		
F	0.2	0.11	Yes		
SiO2	5	11.8	No		X
TDS	443	542.9	No		X
Cond	650	778.9	No		X
Alkalinity	101.66	202.4	No		X
pH	8.8	7.74			
Al	0.1	0.1	Yes		
As	0.002	0.009	No	0.01	
Ba	0.1	0.5	No	2	
B	0.1	0.06	Yes		
Cd	0.01	0.002	Yes		
Cr	0.05	0.01	Yes		
Cu	0.01	0.01	Yes		
Fe	0.04	0.64	No		X
Pb	0.05	0.02	Yes		
Mn	0.01	0.38	No		X
Hg	0.001	0.001	Yes		
Mo	0.1	0.02	Yes		
Ni	0.05	0.01	Yes		
Se	0.002	0.01	No	0.05	
V	0.1	0.09	Yes		
Zn	0.01	0.01	Yes		
U	0.0274	0.13	No	0.03	X
Radium-226	17.2	164.3	No	5	X

Table 4 Parameters affected by the In-situ Operations at Christensen Ranch Mine Unit 3

Parameter	Baseline Mean Value[1]			Post Operations/ Pre-Restoration Quality	Aquifer Affected by Lixiviant[3]	Factor of Increase[4]
	MU3 without Module 4a	MU3 Module 4A	Weighted Average[2]			
Ca	7.85	7.81	7.84	325	Yes	41
Mg	0.9	0.67	0.837	60.4	Yes	72
Na	134.69	130.68	133.6	863.1	Yes	6
K	3.52	2.22	3.17	9.7	Yes	3
CO3	6.17	2.36	5.13	0.5	*	
HCO3	108.62	118.36	111.3	2280.4	Yes	20
SO4	198.2	196.25	197.7	909.9	Yes	5
Cl	9.1	8.85	9.032	155.4	Yes	17
NH4	0.07	0.02	0.056	1.14	Yes	20
NO2 (N)	0.01	0.01	0.01	0.1	Yes	10
NO3 (N)	0.04	0.01	0.03	0.1	Yes	3
F	0.21	0.11	0.18	0.1	*	
SiO2	8.33	5.15	7.46	16.2	Yes	2
TDS	411.58	420.17	413.9	3773.7	Yes	9
Cond	681.72	695.92	685.59	4787.9	Yes	5
Alkalinity	99.16	100.43	99.5	1869.3	Yes	19
pH	8.89	8.75	8.85	7.4	*	
Al	<0.1	<0.1	<0.1	0.1	No	
As	0.0026	<.001	0.003	0.02	Yes	8
Ba	<0.1	<0.1	<0.1	0.1	No	
B	<0.1	<0.1	<0.1	0.1	No	
Cd	<0.01	<0.01	<0.01	0.01	No	
Cr	<0.05	<0.05	<0.05	0.05	No	
Cu	0.01	<0.01	0.010	0.01	No	
Fe	0.069	<0.05	0.069	2.81	Yes	41
Pb	<0.05	<0.05	<0.05	0.05	No	
Mn	<0.01	<0.01	<0.01	0.69	Yes	>69
Hg	<0.001	<0.001	<0.001	0.001	No	
Mo	<0.1	<0.1	<0.1	0.1	No	
Ni	<0.05	<0.05	<0.05	0.05	No	
Se	0.00189	<0.001	0.002	4.34	Yes	2296
V	0.102	<0.1	0.102	0.61	Yes	6
Zn	0.0125	<0.01	0.013	0.01	No	
U	0.0752	0.06	0.065	15.58	Yes	240
Radium-226	81.3	16.27	37.080	516.1	Yes	14

[1] Baseline Mean Source: Wellfield Data Packages:
For Module 41, used only three of six wells
[2] Weighted average based on number of wells in each area (16 wells in MU-3, and 6 wells in MU-3 expansion)
[3] A "*" indicates that the concentration decreased during operations.

[4] Factor of increase in the ratio of the concentration in the aquifer at the end of mining to baseline mean.

Table 5 Comparison of Restoration Final Round of Data to Baseline Mean Values for Mine Unit 3 without Module 4A

Constituent	Baseline Mean Concentration	Round 4 Stability Mean Concentration	Less than Baseline Mean Value	MCL	Does Not Meet Baseline or MCL
Ca	7.85	43.9	No		X
Mg	0.9	6.25	No		X
Na	134.69	108	Yes		
K	3.52	1.6	Yes		
CO3	6.17	<5	Yes		
HCO3	108.62	222.6	No		X
SO4	198.2	169.3	Yes		
Cl	9.1	5.56	Yes		
NH4	0.07	0.11	Yes - PQL Differences		
NO2 (N)		*	*	10	
NO3 (N)	0.04	0.05	Yes - PQL Differences		
F	0.21	<0.1	Yes		
SiO2	8.33	16.8	No		X
TDS	411.58	480.6	No		X
Cond	681.72	713.3	Yes - within tolerance levels		
Alkalinity	99.16	181.8	No		X
pH	8.89	7.67			
Al	<0.1	0.1	Yes		
As	0.002609	0.008	Yes - PQL Differences	0.01	
Ba	<0.1	<0.5	Yes - PQL Differences	2	
B	<0.1	0.07	Yes		
Cd	<0.01	0.002	Yes		
Cr	<0.05	0.01	Yes		
Cu	0.010312	0.01	Yes		
Fe	0.069375	0.248	No		X
Pb	<0.05	0.02	Yes		
Mn	<0.01	0.109	No		X
Hg	<0.001	0.001	Yes		
Mo	<0.1	0.02	Yes		
Ni	<0.05	0.01	Yes		
Se	0.00189	0.01	No	0.05	
V	0.101562	0.03	Yes		
Zn	0.0125	0.01	Yes		
U	0.075	0.145	Yes - within tolerance levels	0.03	
Radium-226	81.3	185.2	Yes - within tolerance levels	5	X

* Ammonia detected above PQL only at two wells

[a] value based on a log-normal distribution

Table 6 Comparison of Restoration Final Round of Data to Baseline Mean Values for Mine Unit 3 Module 4A

Parameter	Baseline Mean Concentration	Round 4 Stability Mean Concentration	Meets Baseline Mean Values	MCL	Does Not Meet Baseline Mean or MCL
Ca	7.81	48.8	No		X
Mg	0.67	5.2	No		X
Na	130.68	173.8	No		
K	2.22	2.6	Yes		
CO3	2.36	<5	Yes		
HCO3	118.36	308.6	No		X
SO4	196.25	234.2	No		
Cl	8.85	13.6	No		
NH4	0.02	0.11[a]	Yes - PQL Differences		
NO2 (N)	0.01	0.16[b]	*	10	
NO3 (N)	0.01	0.43[b]	Yes - PQL Differences		
F	0.11	0.1	Yes - within tolerance levels		
SiO2	5.15	12.8	No		X
TDS	420.17	656	No		X
Cond	695.92	896	Yes - within tolerance levels		
Alkalinity	100.43	252.8	No		X
pH	8.75	8	Yes - within tolerance levels		
Al	<0.1	<0.1	Yes		
As	<.001	0.008	Yes - PQL Differences	0.01	
Ba	<0.1	<0.5	Yes - PQL Differences	2	
B	<0.1	0.07	Yes		
Cd	<0.01	<0.002	Yes		
Cr	<0.05	<0.01	Yes		
Cu	<0.01	<0.01	Yes		
Fe	<0.05	0.371	No		X
Pb	<0.05	<0.02	Yes		
Mn	<0.01	0.102	No		X
Hg	<0.001	<0.001	Yes		
Mo	<0.1	<0.02	Yes		
Ni	<0.05	<0.01	Yes		
Se	<0.001	0.0735	No	0.05	X
V	<0.1	0.04	Yes		
Zn	<0.01	<0.01	Yes		
U	0.06	1.07	No	0.03	X
Radium-226	16.27	215.1	No	5	X

[a] Ammonia detected above PQL only at two wells

[b] Distribution of data was not normal; value based on a log-normal distribution

Table 7 Parameters affected by the In-situ Operations at Christensen Ranch Mine Unit 4

Parameter	Baseline Mean Value[1]	Post Operations/ Pre-Restoration Quality	Aquifer Affected by Lixiviant[2]	Factor of Increase[3]
Ca	7.49	320.8	Yes	42.8
Mg	0.755	57.9	Yes	76.7
Na	132.04	690.8	Yes	5.2
K	2.755	12.5	Yes	4.5
CO3	6.354	1	*	
HCO3	109.9	1881.7	Yes	17.1
SO4	198.04	886.3	Yes	4.5
Cl	8.9	176.9	Yes	19.9
NH4	0.1	0.74	Yes	7.4
NO2 (N)	<0.1	0.1	No	
NO3 (N)	0.115	0.15	Yes	1.3
F	0.188	0.1	*	
SiO2	8.465	13.1	Yes	1.5
TDS	426.918	3225.8	Yes	7.6
Cond	701.745	4276.7	Yes	6.1
Alkalinity	100.583	1548.3	Yes	15.4
pH	9.01	7.69	*	
Al	<0.1	0.1	No	
As	0.002	0.11	Yes	55
Ba	<0.1	0.1	No	
B	<0.1	0.1	No	
Cd	<0.01	0.01	No	
Cr	<0.05	0.05	No	
Cu	<0.01	0.01	No	
Fe	0.05	0.22	Yes	4.4
Pb	<0.05	0.05	No	
Mn	<0.01	0.65	Yes	>65
Hg	<0.001	0.001	No	
Mo	<0.1	0.1	No	
Ni	<0.05	0.05	No	
Se	0.002	3.04	Yes	1520
V	<0.1	0.27	Yes	>27
Zn	0.017	0.01	*	
U	0.0348	17.55	Yes	504.3
Radium-226	17.77	286.2	Yes	16.1

[1] Baseline Mean Source: Wellfield Data Package

[2] A "*" indicates that the concentration decreased during operations.

[3] Factor of increase is the ratio of the concentration in the aquifer at the end of mining to baseline mean.

Table 8 Comparison of Restoration Final Round of Data to Baseline Mean Values for Mine Unit 4

Parameter	Baseline Mean Concentration	Round 4 Stability Mean Concentration	Meets Baseline Mean Values	MCL	Does Not Meet Baseline Mean or MCL
Ca	7.49	42.7	No		X
Mg	0.755	9.1	No		X
Na	132.04	227	No		X
K	2.755	3.6	Yes - within Tolerance		
CO3	6.354	1.7	Yes		
HCO3	109.9	446	No		X
SO4	198.04	210.5	Yes - within Tolerance		
Cl	8.9	19.3	No		X
NH4	0.1	0.2	Yes - PQL Differences		
NO2 (N)	<0.1	*	*	10	
NO3 (N)	0.115	0.12	Yes - PQL Differences		
F	0.188	0.12	Yes		
SiO2	8.465	9.3	Yes - within Tolerance		
TDS	426.918	775	No		X
Cond	701.745	1125	No		
Alkalinity	100.583	386.4	No		
pH	9.01	8.01	*		
Al	<0.1	<0.1	Yes		
As	0.002	0.006	Yes - within Tolerance	0.01	
Ba	<0.1	<0.5	Yes - PQL Differences	2	
B	<0.1	<0.06	Yes		
Cd	<0.01	<0.002	Yes		
Cr	<0.05	<0.01	Yes		
Cu	<0.01	<0.01	Yes		
Fe	0.05	0.36	No		Need to determine if hot spots exist in restoration data
Pb	<0.05	<0.02	Yes		
Mn	<0.01	0.14	No		X
Hg	<0.001	<0.001	Yes		
Mo	<0.1	<0.02	Yes		
Ni	<0.05	<0.01	Yes		
Se	0.002	0.208	No	0.05	x
V	<0.1	0.07	Yes		Need to determine if hot spots exist in restoration data
Zn	0.017	<0.01	Yes		
U	0.0348	3.83	No	0.03	Need to determine if hot spots exist in restoration data
Radium-226	17.77	114.1	No	5	X

* Ammonia detected above PQL only at two wells

[a] Validity of the mean value should be verified due to non-detectable levels in dataset

Table 9 Parameters affected by the In-situ Operations at Christensen Ranch Mine Unit 5

Parameter	Baseline Mean Value[1]	Post Operations/ Pre-Restoration Quality	Aquifer Affected by Lixiviant[2]	Factor of Increase[3]
Ca	10.2	267.6	Yes	26.2
Mg	1.371	54.3	Yes	39.6
Na	146.39	598.4	Yes	4.1
K	4.22	12.7	Yes	3.0
CO3	7.255	1	*	
HCO3	123.52	1392.9	Yes	11.3
SO4	215.51	981	Yes	4.6
Cl	7.722	129.4	Yes	16.8
NH4	0.143	0.39	Yes	2.73
NO2 (N)	0.1	0.1	No	
NO3 (N)	0.125	0.11	*	
F	0.184	0.12	*	
SiO2	8.41	10.5	Yes	1.2
TDS	448.14	3074.4	Yes	6.9
Cond	750.38	4047.3	Yes	5.4
Alkalinity	106.649	1143.9	Yes	10.7
pH	8.753	7.63	*	
Al	<0.1	0.1	No	
As	0.002	0.011	Yes	5.5
Ba	<0.1	0.1	No	
B	<0.1	0.1	No	
Cd	<0.01	0.01	No	
Cr	<0.05	0.05	No	
Cu	<0.01	0.01	No	
Fe	0.05	0.55	Yes	11
Pb	<0.05	0.05	No	
Mn	<0.01	0.55	Yes	>55
Hg	<0.001	0.001	No	
Mo	<0.1	0.1	No	
Ni	<0.05	0.05	No	
Se	0.002	0.55	Yes	275
V	0.14	0.22	Yes	1.57
Zn	0.015	0.01	*	
U	0.0232	12.61	Yes	543.5
Radium-226	67.588	475.7	Yes	7.0

1 Baseline Mean Source: Restoration Report

2 A "*" indicates that the concentration decreased during operations.

3 Factor of increase is the ratio of the concentration in the aquifer at the end of mining to baseline mean.

Table 10 Comparison of Round 4 Mean Data to Baseline Mean Values for Mine Uni 5

Parameter	Baseline Mean Concentration	Round 4 Stability Mean Concentration	Meets Baseline Mean Values	MCL	Does Not Meet Baseline Mean or MCL
Ca	10.2	35.6	No		X
Mg	1.37	7.2	No		X
Na	146.4	157	No		
K	4.22	4	Yes		
CO3	7.26	1.2	Yes		
HCO3	123.5	356.6	No		X
SO4	215.5	159	Yes		
Cl	7.72	7.1	Yes		
NH4	0.143	0.1	Yes - PQL Differences		
NO2 (N)		*	*	10	
NO3 (N)	0.125	0.12	Yes - PQL Differences		
F	0.184	0.1	Yes		
SiO2	8.41	7.1	Yes		
TDS	448.1	589.2	No		X
Cond	750.38	944.6	No		
Alkalinity	106.6	293.1	No		
pH	8.75	8.1	*		
Al	<0.1	0.11	Yes - PQL Differences		
As	0.002	0.008	No	0.01	Three values exceed MCL, determine if hot spots exist
Ba	<0.1	0.5	Yes - PQL Differences	2	
B	<0.1	0.07	Yes		
Cd	<0.01	<0.002	Yes		
Cr	<0.05	<0.01	Yes		
Cu	<0.01	<0.01	Yes		
Fe	<0.05	0.1[a]	No		Need to determine if hot spots exist in restoration data
Pb	<0.05	<0.02	Yes		
Mn	<0.01	0.08	No		X
Hg	<0.001	<0.001	Yes		
Mo	<0.1	<0.02	Yes		
Ni	<0.05	<0.02	Yes		
Se	0.002	0.41[a]	No	0.05	Three values exceed MCL, determine if hot spots exist
V	0.14	0.12	Yes		Need to determine if hot spots exist in restoration data
Zn	0.015	0.01	Yes		
U	0.0232	2.05	No	0.03	X
Radium-226	67.6	238	Yes - Meets Approved TRV	5	Need to determine if hot spots exist in restoration data

* Ammonia detected above PQL only at two wells

[a] Validity of the mean value should be verified due to non-detectable levels in datas

Table 11 Parameters affected by the In-situ Operations at Christensen Ranch Mine Unit 6

Parameter	Baseline Mean Value[1]	Post Operations/ Pre-Restoration Quality	Aquifer Affected by Lixiviant[2]	Factor of Increase[3]
Ca	26.28	292.2	Yes	11.1
Mg	4.52	64.6	Yes	14.3
Na	240.4	662.6	Yes	2.8
K	6.21	11.8	Yes	1.9
CO3	4.5	1	*	
HCO3	74.21	1420.4	Yes	19.1
SO4	533.14	1089.1	Yes	2.0
Cl	4.58	120.6	Yes	26.3
NH4	<0.05	0.38	Yes	>7.6
NO2 (N)	<0.05	0.1	No	
NO3 (N)	<0.05	0.17	Yes	>3.4
F	0.14	0.1	*	
SiO2	4.5	12.14	Yes	2.7
TDS	859.84	3292.2	Yes	3.8
Cond	1263.25	4297.2	Yes	3.4
Alkalinity	70.09	1165.2	Yes	16.6
pH	8.59	7.34	*	
Al	<0.05	0.1	No	
As	0.002	0.03	Yes	15
Ba	<0.05	0.1	No	
B	<0.1	0.1	No	
Cd	<0.05	0.01	No	
Cr	<0.05	0.05	No	
Cu	<0.05	0.01	No	
Fe	<0.05	0.7	Yes	>14
Pb	<0.005	0.05	No	
Mn	<0.05	0.61	Yes	>55
Hg	<0.0002	0.001	No	
Mo	<0.05	0.1	No	
Ni	<0.05	0.05	No	
Se	<0.001	1.09	Yes	>1090
V	<0.05	0.49	Yes	>9.8
Zn	<0.01	0.02	No	
U	0.0112	12.57	Yes	1122.3
Radium-226	103.8	526.4	Yes	5.1

[1] Baseline Mean Source: Restoration Re

[2] A "*" indicates that the concentration decreased during operations.

[3] Factor of increase is the ratio of the concentration in the aquifer at the end of mining to baseline mean.

FIGURES

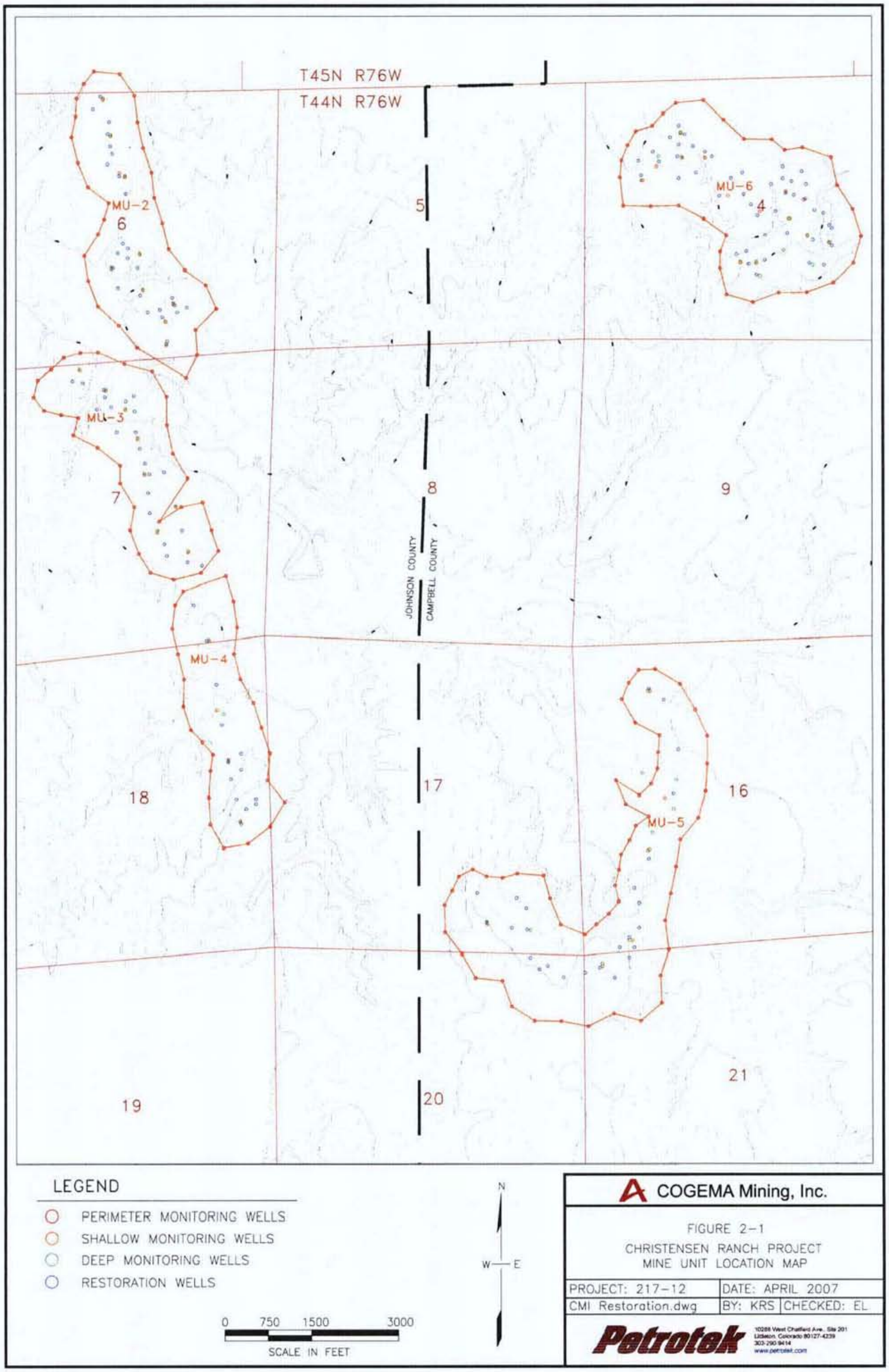

Figure 1 Location of Christensen Ranch Mine Units

Base Map Source: Cogema, 2008C.

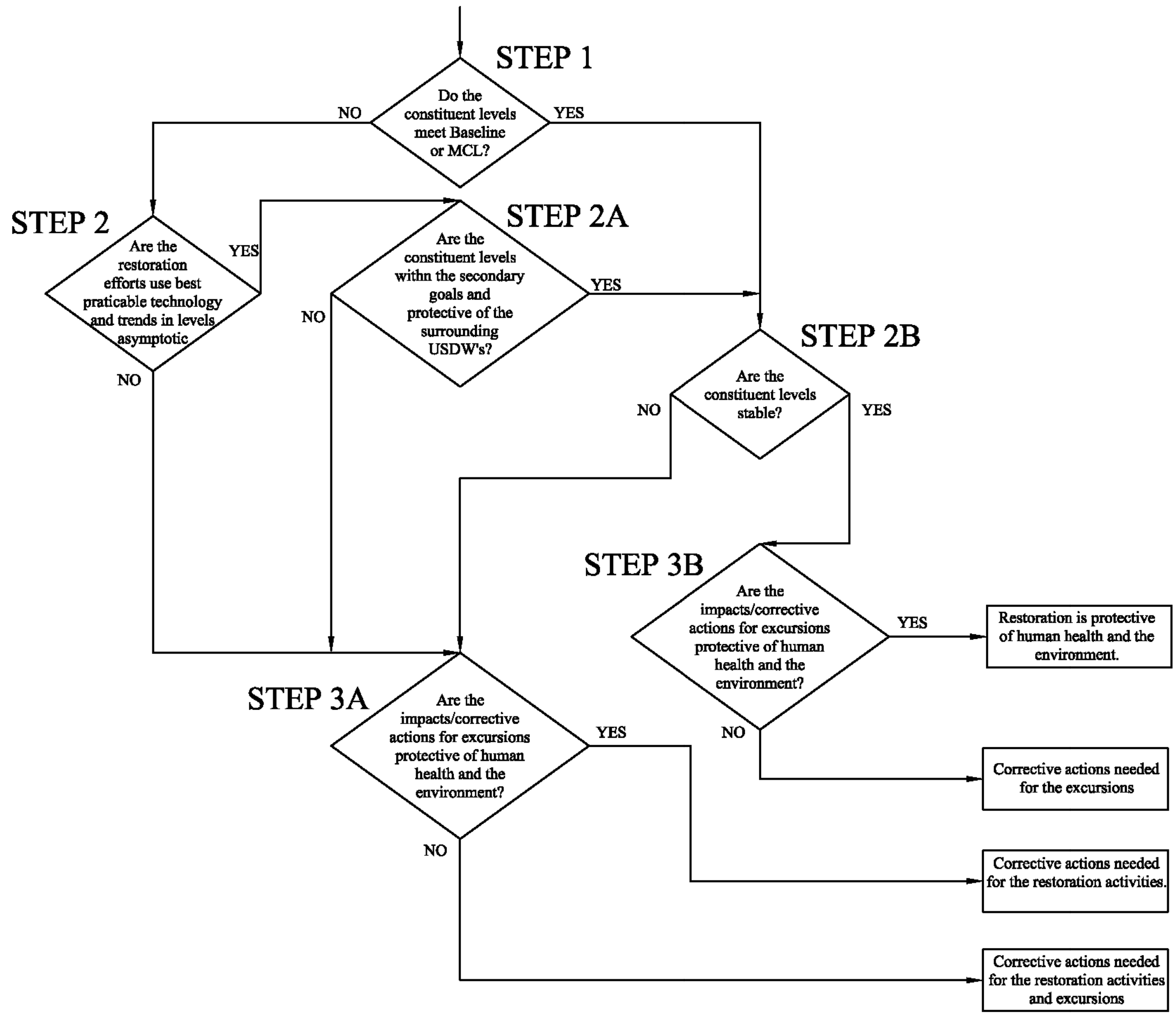

Figure 2. Flow chart depicting staff's review process for evaluation of Cogema's restoration reports.

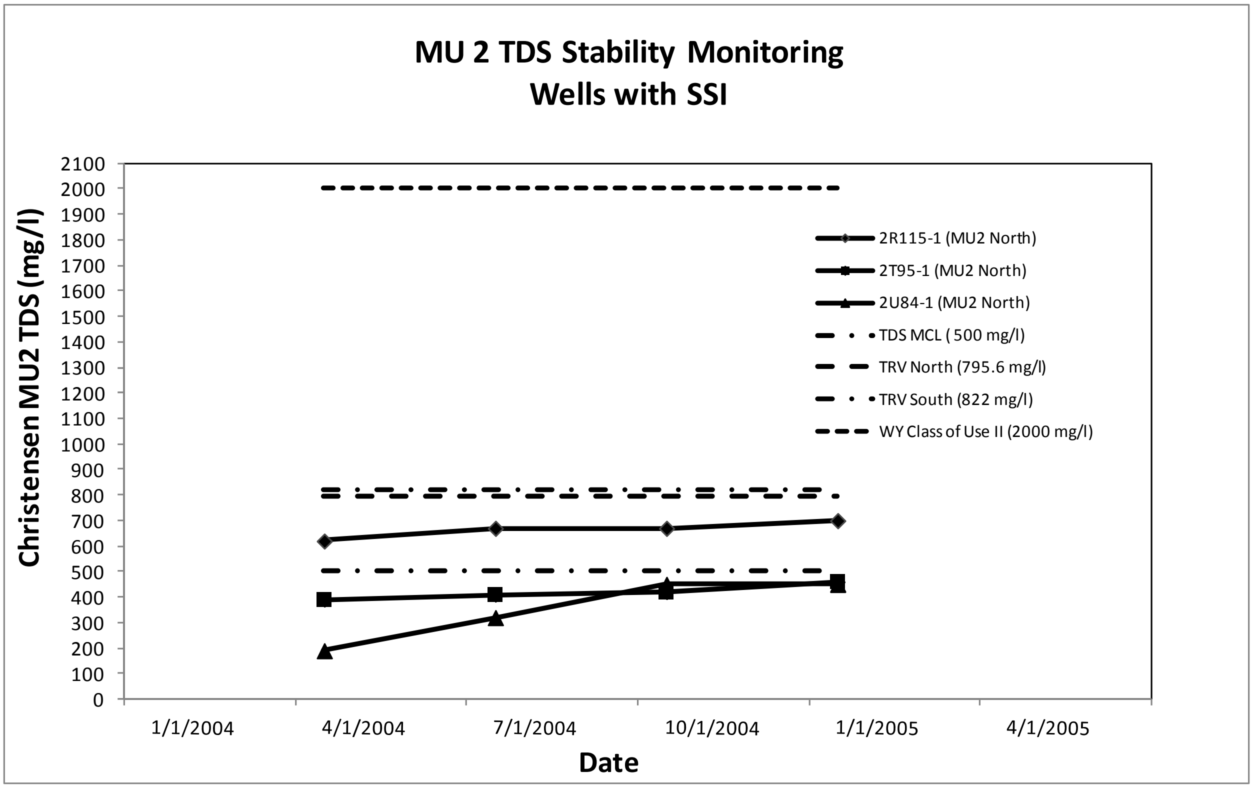

Figure 3a. MU2 North and South TDS Stability Monitoring Trend Analysis

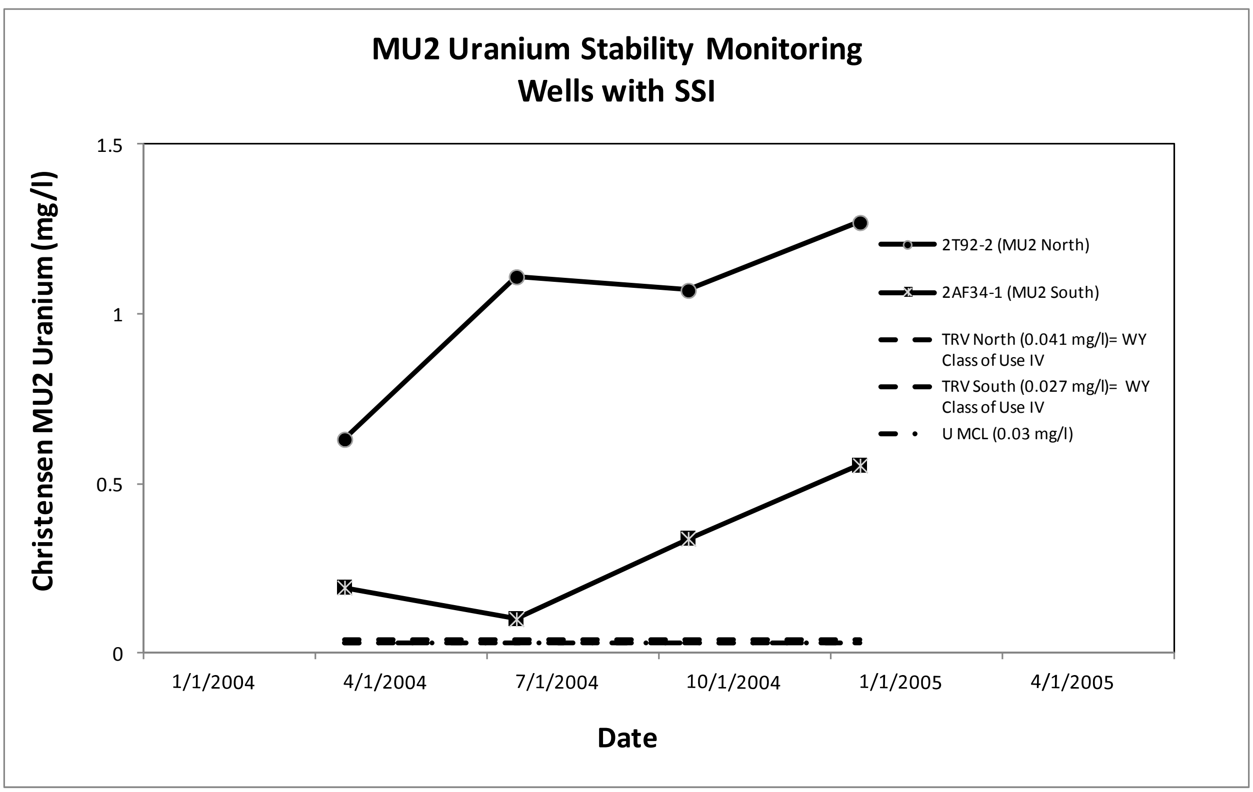

Figure 3b. MU2 North and South Uranium Stability Monitoring Trend Analysis

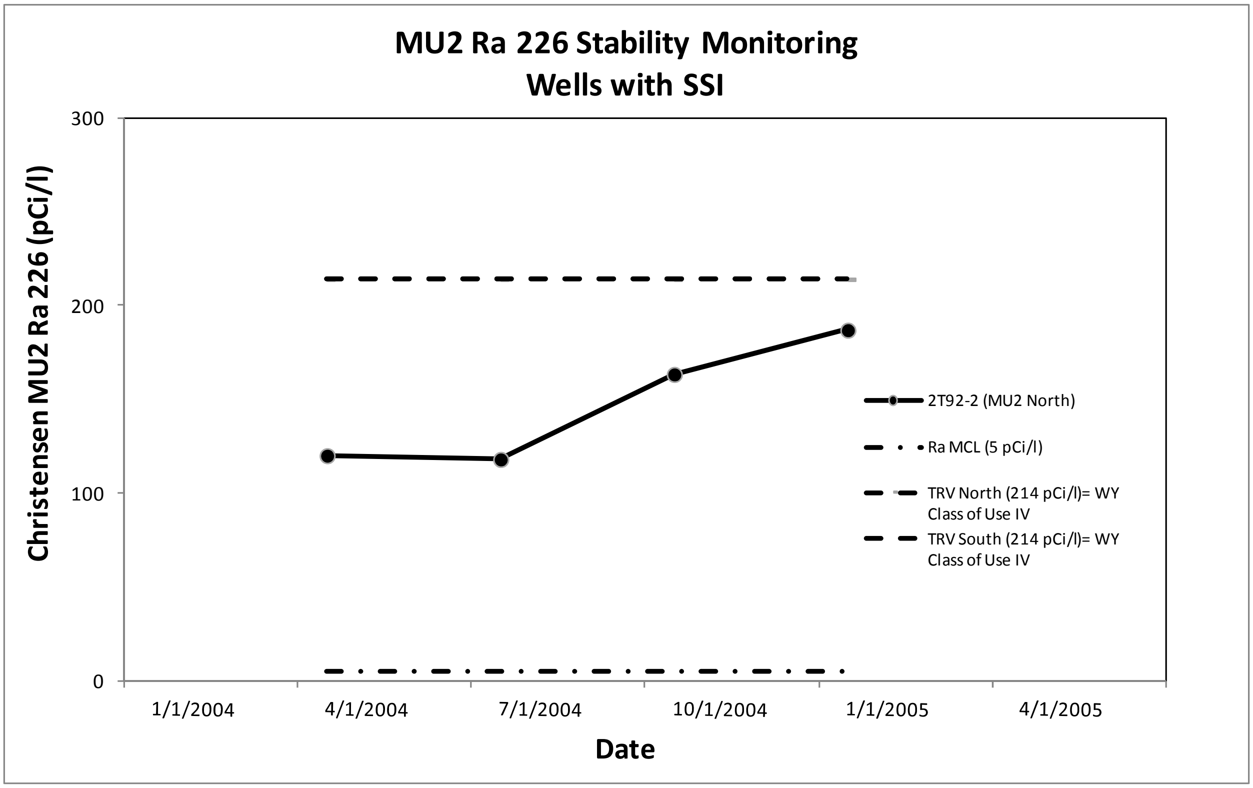

Figure 3c. MU2 North and South Radium-226 Stability Monitoring Trend Analysis

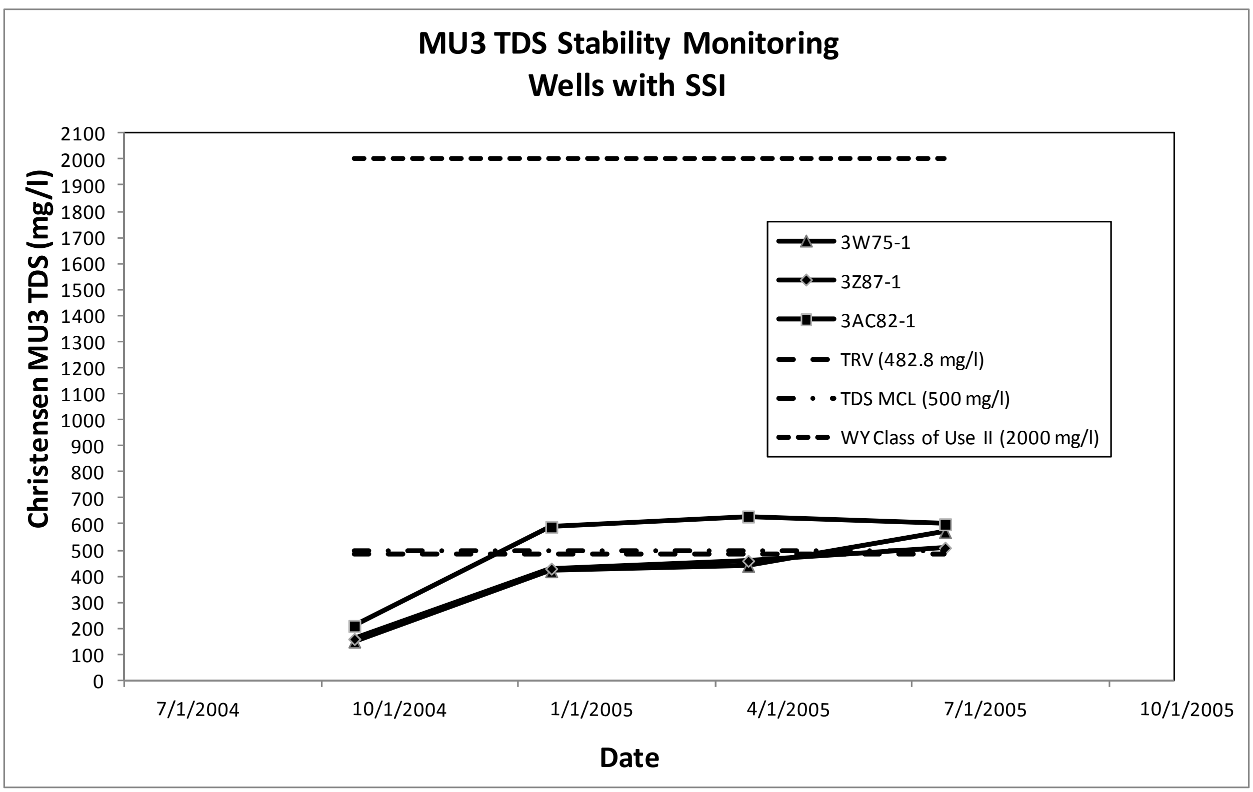

Figure 4a. MU3 TDS Stability Monitoring Trend Analysis

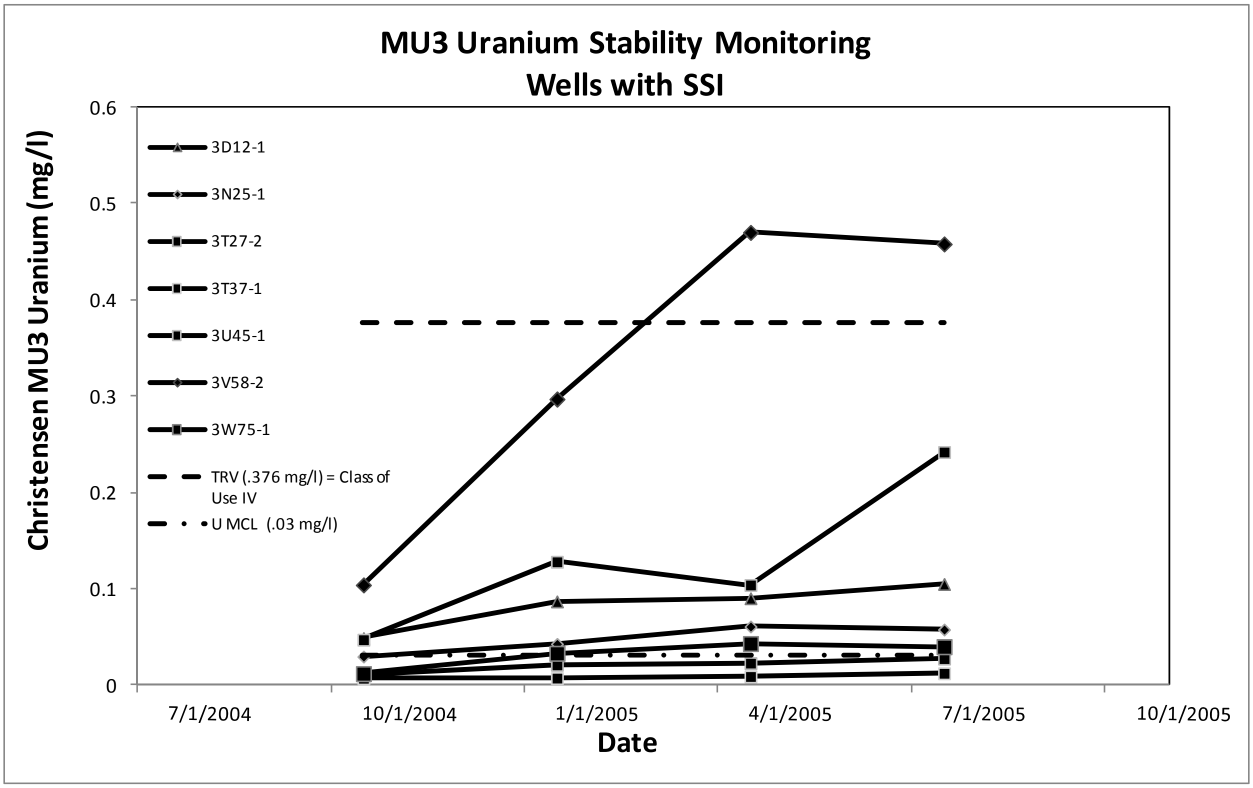

Figure 4b. MU3 Uranium Stability Monitoring Trend Analysis

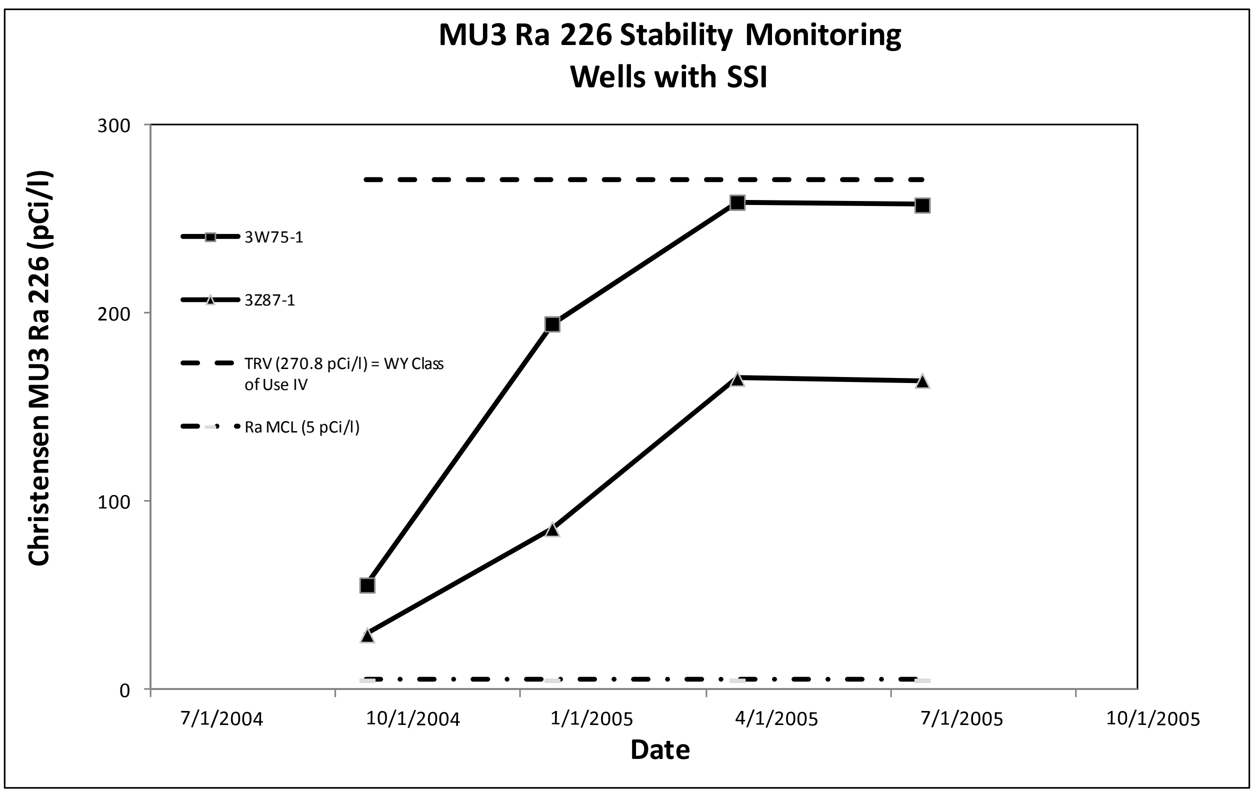

Figure 4c. MU3 Radium-226 Stability Monitoring Trend Analysis