AN ALTERNATE CONCENTRATION LIMIT PROPOSAL

FOR THE GROUND WATER RESOURCES

AT THE

BEAR CREEK URANIUM MILL

Table of Contents

Executive Summary

This application for alternate concentration limits (ACL) is being submitted in response to the Nuclear Regulatory Commission's (NRC) letter to Anadarko Petroleum Corporation (APC) dated November 30, 2010 requesting that a new risk-based ACL application be submitted incorporating the ground water data collected over the 13 years since the original ACL application.

APC embarked on parallel paths to study and evaluate the discrepancy between the predicted concentrations of uranium at MW-14 and the observed results.

First, TetraTech GEO the consulting firm that had done the ground water modeling for the 1997 ACL application was retained to re-evaluate the previous model results utilizing the ground water monitoring data collected during the past 13 years. The re-evaluation of the transport model is attached under separate cover.

Secondly, an in-house review of the corrective action program, ground water monitoring data, well completion data and operating conditions observed at the Bear Creek Uranium Company (BCUC) site was conducted by APC personnel.

It is APCs consensus that the anomaly noted in NRCs review and subsequent letter is a singular event created by the early time-frame seepage under the tailings dam, subsequent ponding of low pH water behind the catchment basin dam located about 600 feet below the tailings dam and use of recovery wells located downstream of the tailings area in Lang Draw. By extending the POE for each drainage plume to the property boundary located just north of wells MW-109 and MW-111 and utilizing currently measured water quality data at those points for estimating peak concentrations of contaminates, it would not require a change to the ACLs, which have never been exceeded, nor would this increase risk to the general public.

1.0 Background Information/Chronological Sequence of Events

Background Information

BCUC, originally a partnership of Rocky Mountain Energy (RME) and Mono Power Company and now operated by RMEs successor, APC, began its tailings basin/mill operation in August of 1977 under United States Nuclear Regulatory Commission (NRC) Source Materials License No. SUA-1310. The milling process consisted of sulfuric acid leach, sodium chlorate oxidant, and liquid ion exchange extraction and concentration. Approximately 4.7 million tons of tailings were discharged into the tailings basin as a slurry. This above grade disposal was done in compliance with 10 CFR Part 40 Criterion 3 requirements and approved by the NRC. The January 1996 revised version of the CFR is referenced here and in the remainder of this summary. The mill and solvent extraction buildings were decommissioned in 1988.

The tailings facility, installed in 1977 in a local drainage known as Lang Draw, consisted of a keyed, zone-fill dam and an integral, compacted soil-lined basin. Basin soils were reworked where necessary to meet a $1x10^{-6}$ cm/sec permeability requirement. Subsequent portions of the basin were lined to a permeability of $1x10^{-7}$ cm/sec as the dam was raised to increase tailings capacity. The dam and clay liner were designed to meet or exceed all performance criteria established by the NRC in accordance with 10 CFR Part 40 Criterion 5A. Despite use of these "state of the art" dam and liner construction techniques, BCUC anticipated that some seepage would occur and constructed a seepage catchment structure below the tailings dam to intercept the anticipated seepage and pump it back to the tailings basin. The potential impacts of this anticipated seepage were discussed in BCUCs permit and license applications and in the Final Environmental Impact Statement (FEIS) dated June 1977 and are on file with NRC.

Surface seepage was first observed at the downstream toe of the tailings dam in early 1978. Several wells were developed to determine groundwater contamination potential. Elevated chloride levels, a common seepage indicator, were observed and as a result more wells were developed to expand the monitoring network. This action complies with the requirements established in 10 CFR Part 40 Criterion 7A. Additionally, wells were completed as recovery wells and seepage recovery began in October of 1979 with the operation of pump back wells MW-7, MW-12, and MW-13. This action was in keeping with the requirements of 10 CFR Part 40 Criterion 5D. The aforementioned actions were taken voluntarily by BCUC well in advance of any NRC mandates. The corrective action taken is described in detail in Attachment 1 of the original submittal to NRC titled *Union Pacific Resources Group, Inc. Bear Creek*

Uranium Company Alternate Concentration Limit (ACL) Application dated February 28, 1997

On May 7, 1985 the NRC issued License Amendment No. 6 requiring the implementation of a groundwater detection monitoring program with MW-12 as the point of compliance (POC) well and MW-9 as the background well. This was in compliance with the requirements of 10 CFR Part 40 Criterion 7A. Indicator parameters were designated as Arsenic, Selenium and pH. It was not until 1985 that the NRC formally shifted its attention to the "first underlying aquifer" or N-sand formation. Wells MW-12 and MW-9 are both alluvial N-sand wells. It should be noted that pre-milling groundwater data was focused on the ore sand.

Threshold values were established at 0.005 mg/L and 0.001 mg/L for As and Se respectively. A threshold value of 6.8 s.u. was picked for pH. These values were designated in License Condition 47E issued in Amendment No. 15 September 10, 1987.

The NRC was notified on October 19, 1987 that pH and selenium threshold values had been exceeded at MW-12 and in 1989 a corrective action plan (CAP) and monitoring program were submitted by BCUC and approved by the NRC. This action was required by 10 CFR Part40 Criterion 7A.

Groundwater protection standards were established by the NRC, in accordance with 10 CFR Part 40 Criterion 5D and 13, and implemented by Amendment No. 10, issued on September 12 1990, to BCUCs Source Materials License SUA-1310.

MW-74 was designated, by the NRC, as the POC well in the direction of the northern flow path in January of 1992. This is in compliance with 10 CFR Part 40 Criterion 7A.

In February of 1992, the NRC approved the BCUC tailings reclamation plan. This follows 10 CFR part 40 Criterion 6 requirements.

An application for alternate concentration limits (ACLs) was submitted on February 28, 1997 in accordance with 10 CFR Part 40, Appendix A, Criterion 5B(5), which states that at the point of compliance, the concentration of a hazardous constituent must not exceed the NRC approved background concentration, the Table 5C value or an alternate concentration limit established by the NRC. At that time, all concentrations of hazardous constituents, with the exception of uranium, met the license established background values as measured at the point of compliance locations. However, modeling data, included in Attachment 2 of the 1997 ACL

application, suggested that the low pH plume would eventually reach the POCs before it was completely neutralized and would result in elevated levels of U-nat, Ra-226 and nickel.

A corrective action program (CAP), found in Attachment 1 of the 1997 ACL application, was implemented in response to elevated levels of hazardous constituents found to exist at the NRC approved background location. The up-gradient edge of the tailings impoundment coincides with the near surface formations which could encounter tailings seepage, locally known as the alluvium and the N-sand. Due to this, the NRC selected well MW-9, which resides in a down-gradient setting, as a representative background location. Background values of representative hazardous constituents were derived from this well during a time that the pH was neutral and total dissolved solids concentrations were low.

The CAP was operational for over ten years. During that time, the program recovered 301,000,000 gallons of seepage waters, containing 6.5 tons of heavy metals as well as 9,993 tons of sulfate and chloride. These waters plus an additional 165,000,000 gallons of tailings solution were lost to the atmosphere, by way of an enhanced evaporation system. In total, the system was responsible for the treatment and evaporation loss of 466,000,000 gallons of tailings solution. These efforts resulted in dewatering of the tailings and adjoining formations, to levels consistent with the pre-milling groundwater gradient. Based upon the ground-water quality measured at that time, the resulting water levels, and the mass of constituents that were recovered, it was concluded that concentrations of hazardous constituents were "as low as reasonably achievable" (ALARA), considering the practicable corrective actions. The ALARA evaluation is found in Attachment 3 of the 1997 ACL application. The CAP was discontinued in 1996 in accordance with NRC License Amendment No. 39 in order to facilitate final reclamation of the tailings area. Monitoring of the remaining wells was conducted annually from that time on.

Although the corrective action program was successful in removing hazardous constituents and re-establishing the pre-milling water levels, predictive modeling suggested that within 40 to 60 years following termination of the CAP, the values of nickel, radium 226+228 (radium), and uranium would eventually increase to levels that would be in excess of the background concentrations at the POC locations. The modifications in water quality would accompany a slowly advancing acid front that would pass the POC and reach the point of exposure (POE) over the next 80 to 400 years. The rate at which the water quality would be modified would be dependent upon the individual constituent and the preferential flow path that is selected. The ground water modeling summary referenced in this paragraph is included in Attachment 2 of the 1997 ACL application.

It was also determined that additional corrective actions would have little or no effect on the eventual movement of the acid front. The CAP was successful in decreasing the areal extent of the seepage plume to within the tailings impoundment area. The CAP also reduced the saturated thickness of the alluvium, the N-sand, and the tailings making the recovery of additional acidic solutions technically challenging and expensive. Consequently ACLs that are protective of human health and the environment were proposed for nickel, radium, and uranium.

To determine the potential for hazardous constituent transport the seepage recovery wells were temporarily shut down from September 1994 to January of 1995. The ground-water level response was monitored and used as the basis for a transport assessment. Additionally, geochemical data were collected by coring the alluvium and the N-sand which are the formations that have encountered tailings seepage. These cores were analyzed for their attenuation capacity. Following the development of these data, the amount of alluvium and N-sand attenuation capacity were simulated to encounter the remaining acidic seepage from the tailings and underlying formation. The simulation indicated that the acid front would carry nickel, radium, and uranium beyond the POCs. Significant attenuation would occur between the POCs and the points of potential exposure (POEs). It was predicted that the attenuation would be sufficient to reduce the concentrations of nickel, radium, and uranium to levels that would be protective human health and the environment.

Predictive modeling indicated that the maximum concentration of nickel, radium, and uranium, at the POC locations, would be 3.8 mg/l, 46 pCi/l, and 2038 pCi/l, respectively through the flow paths. Similarly, maximum concentrations of nickel, radium, and uranium at the POEs, would be 0.055 mg/l, 13 pCi/l, and 45 pCi/l respectively. Background concentrations for these constituents, defined at MW-9, were 0.05 mg/l Ni, 9.7 pCi/l Ra-226, and 98.7 pCi/l U-nat. It should be noted that the ACLs at the POCs have not been exceeded to date.

The modeling predicted times to reach peak concentrations at the POC locations would range from 40 to 60 years following termination the CAP. Attenuation beyond these locations would slow the movement of constituents. Consequently, following termination of the CAP, peak concentrations at the POE locations would be seen from 260 to 400 years for nickel, 80 to 100 years for radium, and 80 to 130 years for uranium, dependent upon which of the two preferential flow paths was selected. The predictive modeling was terminated following the 400 year point. This period of time was sufficient to simulate the arrival of the peak concentrations of nickel, radium, and uranium. Radium and uranium arrive and decline to background concentrations prior to the arrival of the nickel plume.

To determine the risk associated with water use having these concentrations of hazardous constituents potential use locations were defined and the POEs were determined. The POE was the down-gradient edge of the land mass that contains the reclaimed tailings as well as the area that contains the buried mill debris. Consequently, it represented the minimal land area necessary to assure long-term control of the reclaimed by product materials. This land mass generally coincided with the original restricted area boundary, does not utilize the "distant POE" concept, and is the area that was determined to accompany an amendment application for a general license. Two POE locations, MW-14 and MW-74, were defined for the Bear Creek site. The POE locations are within the Northern and Lang Draw flow paths. The Union Pacific Resources(UPR) Group Bear Creek Uranium Company Amendment request(AR 1996) to SUA-1310; Docket No. 40-8452, submitted to NRC May 30, 1996, requested that the POEs be located at the furthest point of the property owned by UPR, now Anadarko. The NRC, did not approve that request due to trying to keep the land transfer required by UMTRCA to a small area. The land transfer to the Department of Energy (DOE) ultimately became much larger, for DOEs ease of land management, and now includes the POEs currently being requested. The 1996 document also contains a map of the proposed locations of the POEs, a model summary of hydrogeologic and chemical transport analysis which was conducted by GeoTrans in March of 1995, and maps showing the environmental sample locations and tailings area well locations.

There are no records of past water use associated with the alluvium and the N-sand, which are the formations encountering tailings seepage at the Bear Creek site. This is due to there being little water in these formations prior to the milling operation as well as the limited extent of these formations. Similarly, there is no present or predicted future use of the limited amount of water that now resides in these formations. Groundwater development in the region has been limited to stock watering by windmills. These wells are developed to depths of 400 to 500 feet which have a more reliable source of water with better well yield and water quality.

An exposure assessment indicated that there was no present or predicted future water use associated with the formations that have encountered tailings seepage. Similarly, the water residing in the alluvium and the N-sand is not hydraulically connected to any surface water resource. This is due to the limited extent of the alluvium and the N-sand as well as the lack of surface water resources in the area of the mill.

It is questionable if the alluvium can be considered an aquifer because of low well yield. However, for the purpose of compliance with EPA guidelines for ACL

applications, the original proposal for ACLs assumed that these near surface formations would experience some future use. Although the use of the water in the near surface alluvium and the hydraulically connected N-sand is not predicted to occur, the risk associated with use of this water would be essentially the same as the risk associated with use of water having background hazardous constituent concentrations. Furthermore, the alluvium and the N-sand have no source of recharge other than the minimal amount of precipitation that falls on these formations, which is rapidly consumed by vegetation. All considerations indicate that the proposed alternate concentration limits were associated with a CAP that had reduced levels of hazardous constituents to levels that were as low as reasonably achievable. Assuming this, the resulting water quality, as measured at the POE location, would afford the same protection to human health and the environment as the background water quality. This approach was consistent with 10 CFR Part 40, Appendix A, Criterion 5B (6), which states that "Conceptually, background concentrations pose no incremental hazards..."

As referenced in AR 1996 and based upon NRC Inspection Report 40-8452/94-01 dated July 15, 1995, confirming that "... all 26 settlement monuments had reached 90 percent of the final settlement rate (T-90). ... Now that the T-90 has been met, the final radon barrier can be placed with NRC approval", BCUC began final reclamation of the tailings area and began plug and abandonment procedures of all wells in advance of reclaiming and placement of cover material in the tailings area. The nine wells that remain at this time are the ones required by license conditions for monitoring down gradient seepage of contaminated solution.

The tailings area reclamation was completed in 1999. By letter dated March 16, 2000, BCUC submitted the *Bear Creek Uranium Tailings Reclamation Report* to document the completion of reclamation of the tailings disposal cell at the Bear Creek site. A follow up inspection of the completed reclamation construction activities at Bear Creek was conducted by NRC on July 19, 2000 and their conclusion was that the reclamation of the Bear Creek disposal cell was performed in accordance with the requirements of 10 CFR Part 40, Appendix A, and the BCUC *Tailings Reclamation Plan* as specified in License Condition 44, (ref. USNRC letter dated July 3, 2001 to Mr. Ernie Scott, Anadarko Petroleum Corporation).

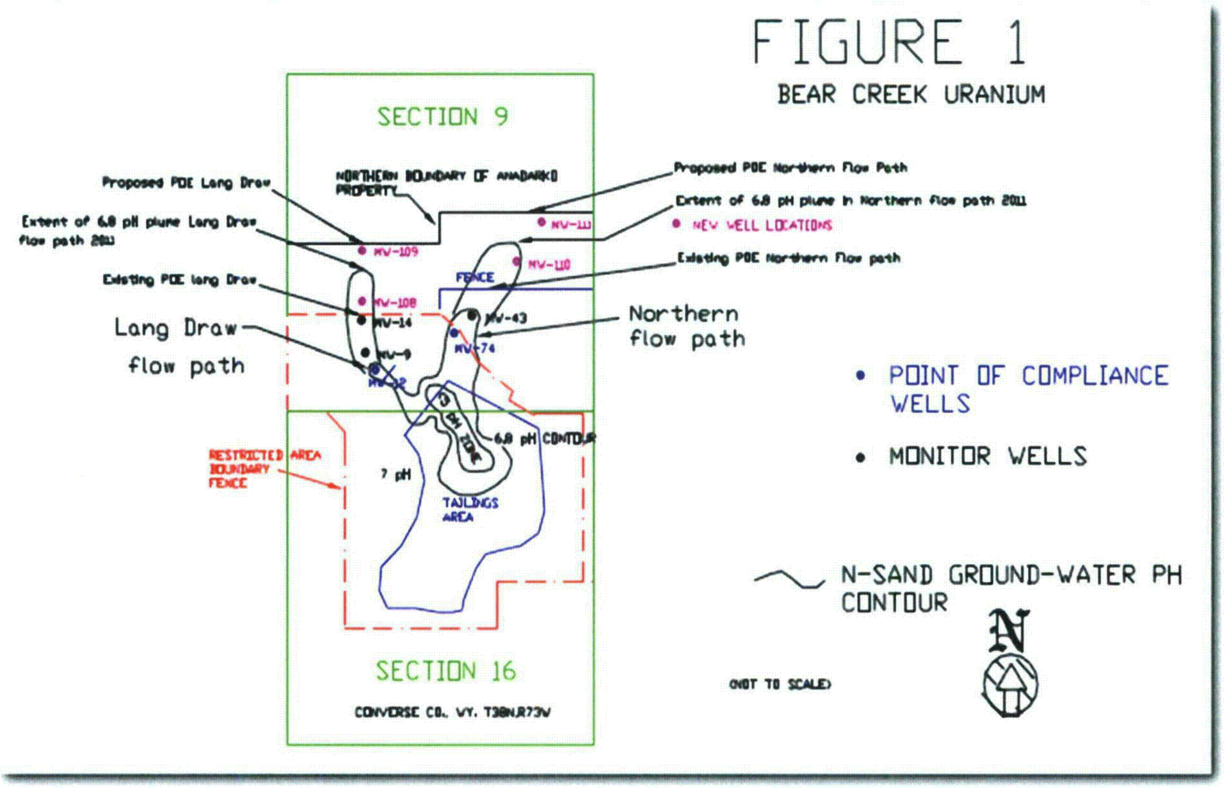
From 2001 until 2011, the water sampling was conducted annually by contract personnel and an annual report of the data collected was submitted to the NRC by Anadarko personnel.

In 2010, in preparation for License termination, NRC reviewed the groundwater data received from the BCUC facility, they found that uranium concentrations had

exceeded the predicted concentration at well MW-14 by more than ten times and requested that a new risk-based ACL be submitted. Although the value predicted by the modeling had been exceeded, at no time did the uranium concentrations exceed the approved ACLs.

TetraTech Geo the consulting firm that had done the ground water modeling for the 1997 ACL application was retained to re-evaluate the previous model results based upon the ground water monitoring data collected during the past 13 years.

In-house evaluation of historical ground water data, operational events, tailings dam construction, well completion and well log data was conducted to assist in this task. Figure 1 shows the general location of the site boundaries and wells.



Chronological Sequence of Events

Although the CAP was not officially implemented until 1989, other tailings management practices were successful in minimizing the seepage that was encountered at the seepage collection dam and at the downstream monitor wells. Similarly, tailings management practices implemented prior to the CAP were successful in limiting the amount of tailings seepage. Additional action and changes implemented during the time frame from 1982 to 2000 that impacted the project are presented here in chronological order. The impact of these changes can be observed in the attached graphs of static water levels and chemical parameters measured in the down gradient monitor wells.

1980 & 1984 Two dam raises were completed and the addition of wings to the east and west portion of the tailings dam allowing increase mill through-put to 2000 tpd.

1985-1989 Utilize monitor/recovery wells in the seepage control basin to pump accumulated seepage to the mill and/or tailings pond. The seepage rate measured at the toe of the dam was 17 gpm in 1985 and decreased to <0.5 gpm in 1988 with no measurable seepage in 1989. It should be noted that the recovery well casings located in the catchment basin were slotted from top to bottom and at times some were under seepage water. This had an impact at down gradient monitor wells.

1986 Mill shut down. Recovery wells and enhanced evaporation system operational.

1988 Placement of interim cover to prevent blowing tailings and construction of the Number 1 clay lined evaporation pond.

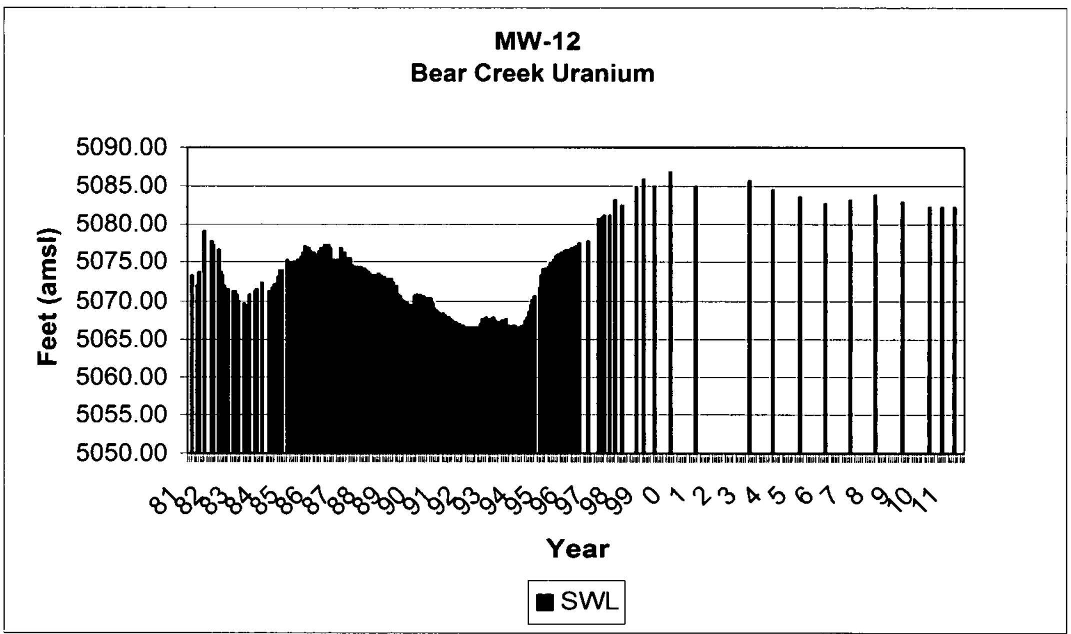
1990 Placement of more interim cover to prevent blowing tailings. Construction of the Number 2 clay lined evaporation pond. Start construction of the Number 3 clay lined evaporation pond.

1991 Complete construction of the Number 3 evaporation pond. Shut down enhanced evaporation system and direct all water from the recovery well system to the clay lined ponds. All surface areas were then covered with enough clay to prevent further recycling of tailings solution back into the tails sands and prevent windblown tailings.

1992-1994 Shut off down gradient seepage recovery wells to prevent pulling contaminated solution away from the tailings pond.

1994 In September of 1994, GeoTrans consultants shut down all recovery wells for 102 days to compare model determined final static water level (SWL) recovery levels against measured levels. GeoTrans predicted 12 foot recovery in SWL at MW-12 with no potential for mounding when the system was shut down for final reclamation of the tailings area. (Hydrogeological and Geochemical Transport Analysis, UPR BCU Mill Tailings Impoundment, GeoTrans, Inc., March 7, 1995).

Measurements of the SWL at MW-12 conducted after reclamation of the tailings area actually show a recovery of almost 22 feet as shown in the graph below.



1996 The recovery well system was shut down for final reclamation of the tailings area. (License Amendment Request dated May 30, 1996, NRC License Amendment No. 39)

1997-1999 Plugged and abandoned all wells not necessary for monitoring of the BCUC mill tailings area site and mining areas. (License Amendment Request dated May 30, 1996; License Amendment No. 45 1996; Report to the Wyoming State Engineer's Office 1999)

1997-1999 Placement of over one million tons of cover material in the tailings area between the ridge line and the tailings dam. This material was placed after the modeling was completed and report submitted with the 1997 ACL application.

2000-2011 Annual water sampling conducted in compliance with Source Materials License SUA-1310 Condition 47, annual survey of land use within two kilometers of the site and reporting as required by License Condition 21, Department of Energy (DOE) site visits and collection of water samples, additional engineering surveys required by DOE for site access, weed control as required.

2.0 Model Review Summary/In-House Data Review

Model Review Summary

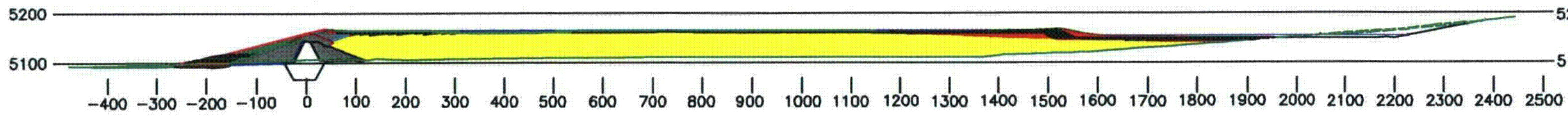
In compliance with NRCs requests that a new risk-based ACL application be submitted incorporating the ground water data collected over the 13 years since the original ACL application, Anadarko contracted with TetraTech GEO (formerly GeoTrans) to complete a new predictive transport model. The transport model is attached under separate cover. The new model has two significant advantages over the 1995 model. First, data are available regarding the transport of uranium and other constituents along Lang Draw and the Northern Pathway for use in calibration of the model. The 1995 model was performed in a predictive mode, without information on transport rates at the site. Second, modeling technology has improved allowing direct incorporation of the chemical reactions into the transport model. Separate models were constructed for Lang Draw and for the Northern Pathway.

As noted by NRC, the 1995 model under predicted the U concentrations that would reach MW-14. The 1995 model in BIO1D used the observed concentrations as the modeling initial conditions down-gradient from the low pH part of the plume. For the upstream boundary condition, the model used the observed uranium concentration at the downstream edge of the pH front, 92 pCi/L. The assumption that was made was that this concentration was a good estimate of future uranium concentrations. As observed in Figure 10B of the attached 2011 model, MW-12 had a uranium concentration of approximately 110 pCi/L in 1994, while MW-9 had a concentration of around 80 pCi/L. Because the modeling was only addressing transport down gradient of the pH front, these values appeared to be reasonable, based on the measurements at that time.

What the modelers did not consider was the effect of dilution during the recovery pumping on the observed concentrations. The recovery pumping was causing steeper gradients west of Lang Draw than present after the pumping was stopped. The steeper gradients produced more water moving into the Lang Draw area than would occur after pumping stopped and water levels recovered. When pumping stopped, the dilution provided by this lateral inflow decreased. This water probably assisted in the neutralization of the acidic plume. The net result was that after water levels recovered, the uranium concentrations increased. Because the 1995 model used an up-gradient boundary condition that was based on concentrations that were "artificially" low because of the recovery well pumping. It is the modeler's contention that this underestimated the peak concentrations that were to develop.

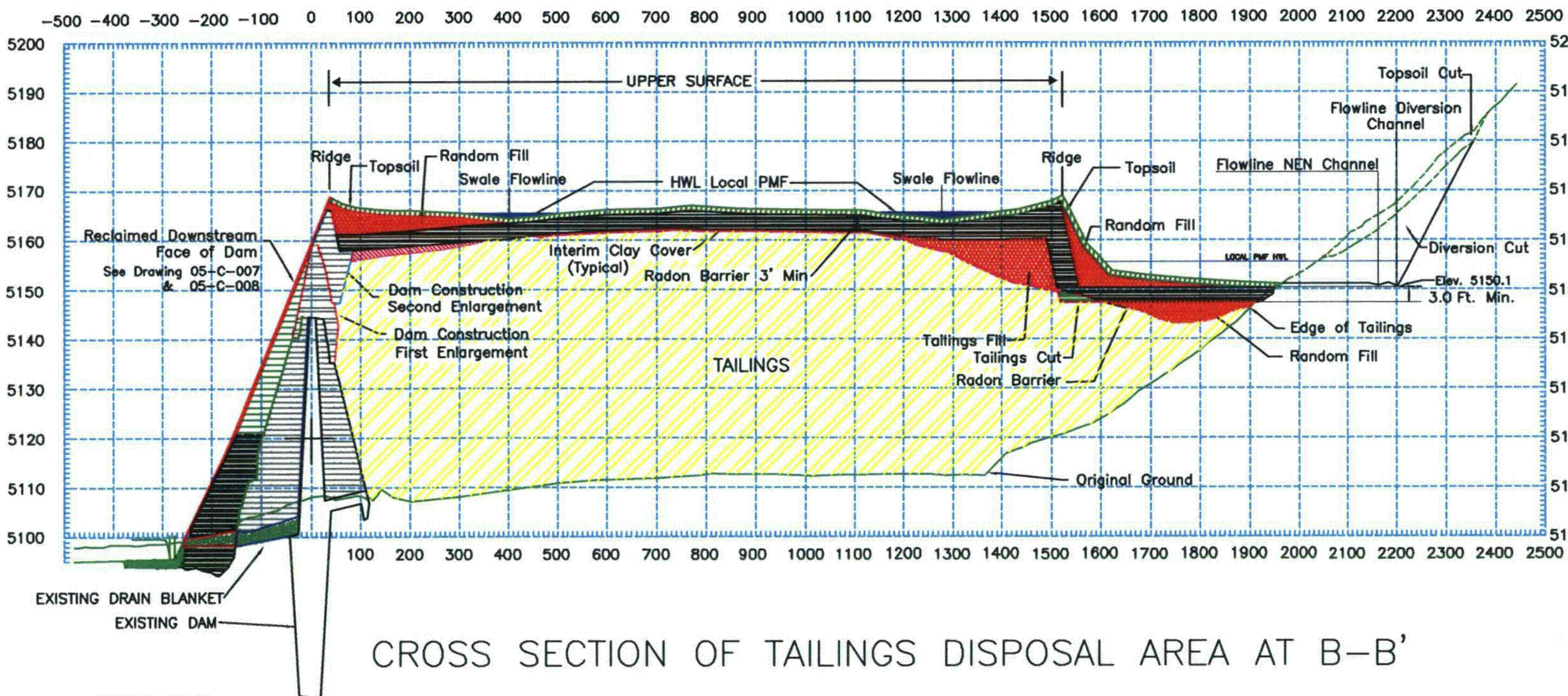
In-House Data Review

The early time-frame seepage from the tailings dam is estimated to have been a major factor that would have influenced the higher than expected uranium values predicted at MW-14 in the first model. A drawing of the tailings dam cross section showing dam raises, drain blanket, and core trench is shown as Figure 2. Figure 3 shows a general cross section of the tailings area.



TRUE SCALE CROSS SECTION OF TAILINGS DISPOSAL AREA

AT B–B'



CROSS SECTION OF TAILINGS DISPOSAL AREA AT B–B'

VERTICAL EXAGGERATION 10:1

All measurements in feet

INDEX MAP

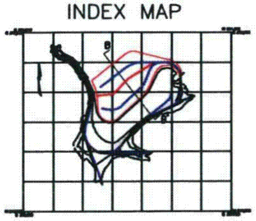


Figure 2

NOTE: Cross section B–B' crosses channel flowline at Sta 66+46.52 tailings North Fork swale at Sta 25+10.52, tailings South Fork swale at Sta. 124+30.79

ANADARKO PETROLEUM CORP.

BEAR CREEK URANIUM

TAILINGS DISPOSAL AREA

CROSS SECTION OF TAILINGS AREA AT B–B'

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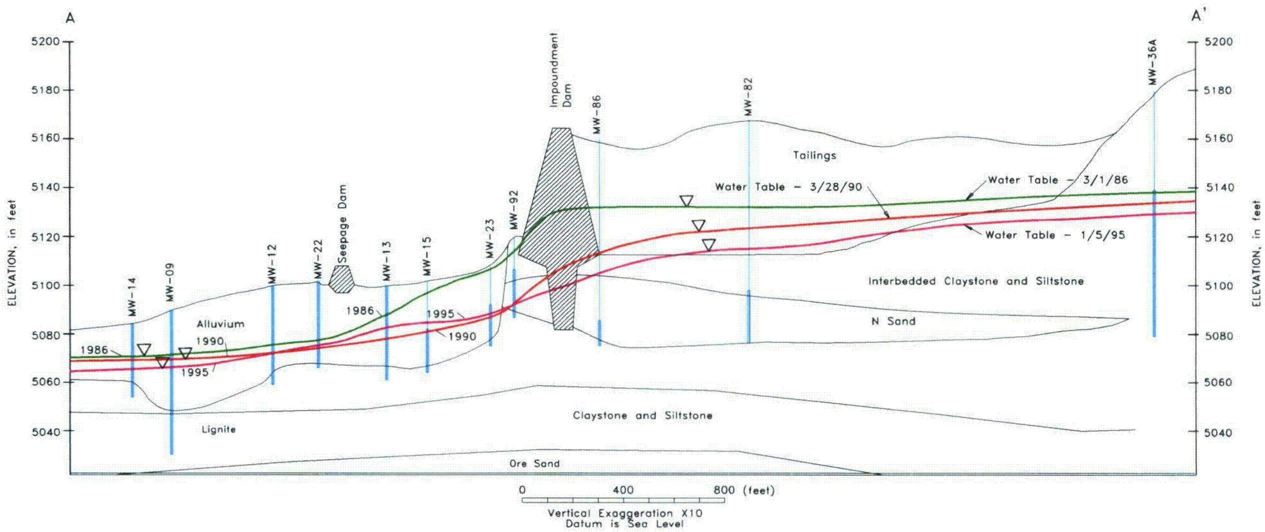

Figure 3 . N Sand/alluvium potentiometric-surface elevations for 1986, 1990, and 1995 along geologic section A-A'.

As referenced in the Background Information, seepage was first noticed at the toe of the dam in 1978. Three wells were drilled to monitor groundwater down gradient from the tailings dam. The wells were designated MW-7(completed Oct. 1980), MW-12 (completed Feb. 1981) and MW-13 (completed Feb 1981). The wells were also used as recovery/pump-back wells, with MW-12 only used for a short period of time. MW-7 and MW-12 were located down gradient from the catchment basin (a map of the N-sand well locations is provided for reference at the end of this section). MW-12 was to later become the point of compliance well. Several wells were drilled and cased in the catchment basin to be used for monitoring and/or recovery wells. The well casings were perforated from top to bottom. As the rate of seepage increased, MW-37 (completed Oct. 1981), which was located in the low spot in the catchment basin near the catchment basin dam, became the major recovery well along with MW-7, MW-13, MW-38, MW-39 and MW-22 located in the Lang Draw flow path. Low pH solution recovered from these wells was pumped to a sump and from there pumped back to the tailings basin. During the time frame of 1978 through 1985 the amount of seepage recovered in the catchment basin and pumped back to the tailings pond was estimated to be 75 million gallons. In 1984 a weir was installed near the toe of the tailings dam and used to more accurately measure seepage flow. Measured flows were 17 and 14 gallons per minute during 1985 and 1986 respectively. During the early use of the pump-back system in the catchment basin improper operation combined with periodic power failures of the system would temporarily allow ponding of seepage water in the catchment basin. The wells with perforated casing from top to bottom became conduits for the low pH solution to enter the groundwater. The only thing that held this solution in check, i.e. from not reporting to down gradient monitor wells, was the continued use of the recovery well system combined with the drawdown impact from tailings basin recovery wells. The catchment basin recovery wells were pumped until 1994. When the tailings dewatering system was shut down in 1996, the overall hydraulic gradient in the tailings basin increased and the solution previously held in check in the catchment basin was then free to migrate down gradient. (see MW-13, MW-12 and MW-14 U-nat graphs note peak concentration difference and the well locations on the N-sand well location map and Figure 3)

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"BEAR CREEK URANIUM TAILINGS DISPOSAL BASIN N-SAND WELL LOCATIONS WITH Ph CONTOURS"

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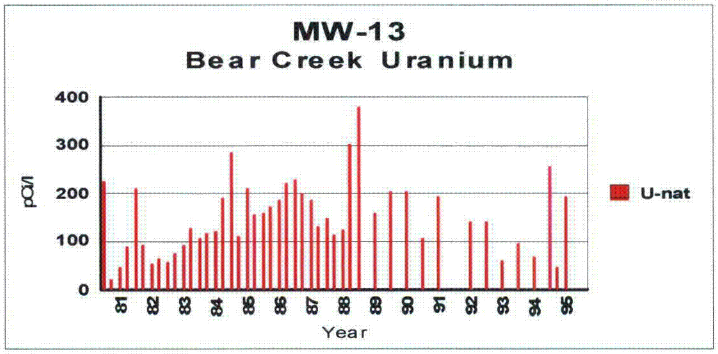
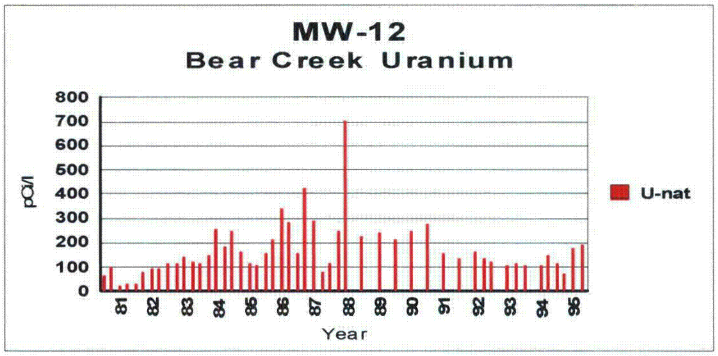

MW-13
Bear Creek Uranium
400
300
200
100
0
pCi/l
U-nat
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
Year


MW-12
Bear Creek Uranium
800
700
600
500
400
300
200
100
0
pCi/l
U-nat
81
82
83
84
85
86
87
88
89
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92
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94
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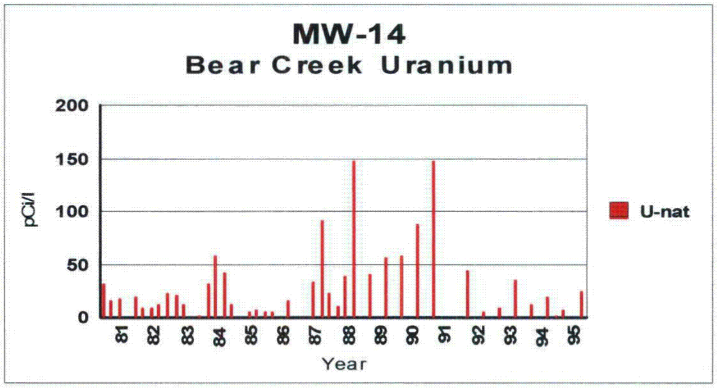
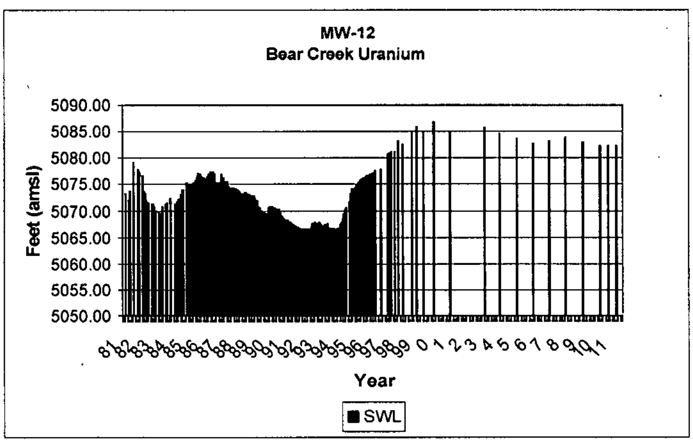
Year

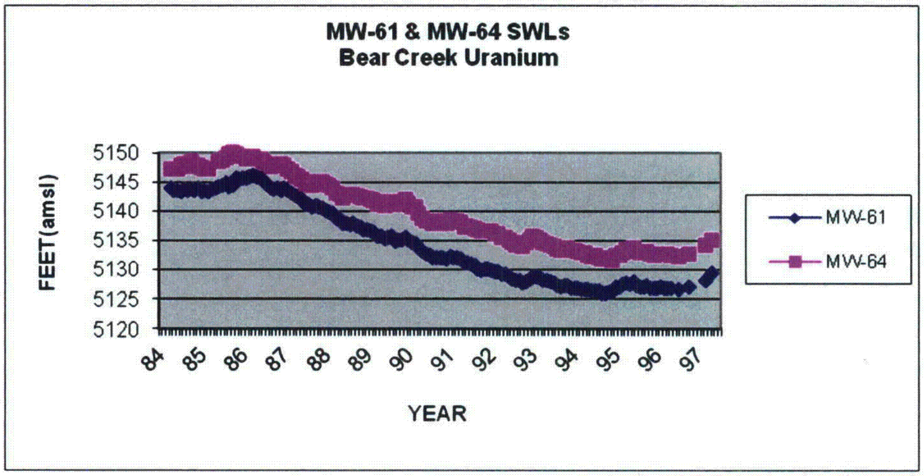

MW-14
Bear Creek Uranium
200
150
100
50
0
pCi/l
U-nat
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
Year

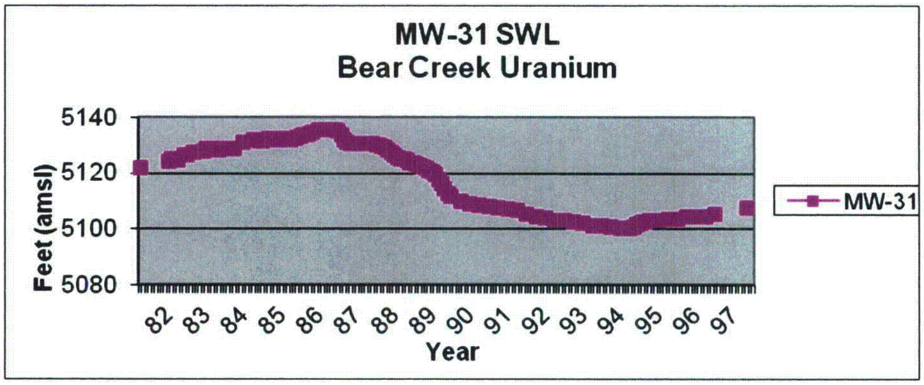
Uranium measured at MW-14 shows similar peaks with high concentrations over three times higher than the 45 pCi/l predicted level at the Lang Draw POE in the 1997 ACL model.

Use of these recovery wells in the catchment basin would also explain the artificially reduced water levels measured in the catchment basin monitor wells during operation of the mill until 1994 when the catchment basin recovery wells were temporarily shut down(i.e. the predicted water level recovery at MW-12 was 12 feet after recovery wells were shut off). In 1996 the tailings basin recovery wells were shut down and the water levels in the catchment basin monitor wells recovered to higher levels than what were seen in these wells during operation of the mill at peak levels.



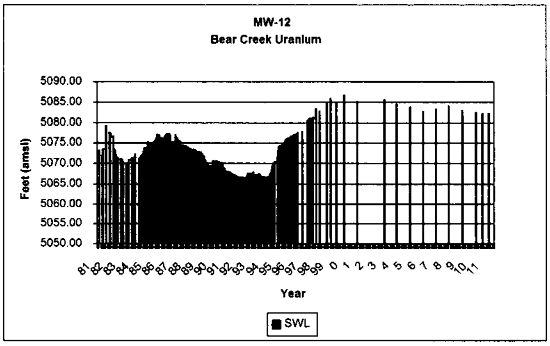
Another event that was not considered in the model was the impact of fresh water dilution on the low pH solution located beneath the tailings in the N-sand. The neutralization impact could have been under estimated. Draw down data from wells MW-61 and MW-64 located 1000 to 1200 feet west of the tailings recovery wells and MW-31 located ~1000 feet east of the tailings recovery wells indicate a cone of depression a half mile in diameter lateral to the tailings basin.

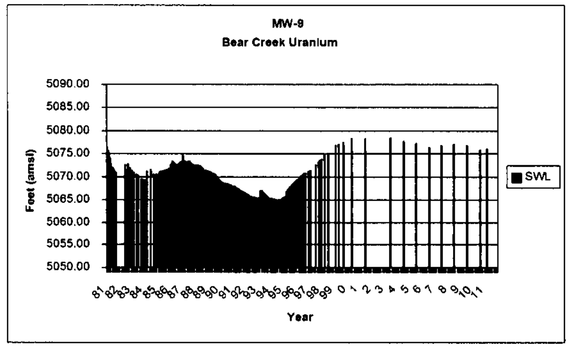


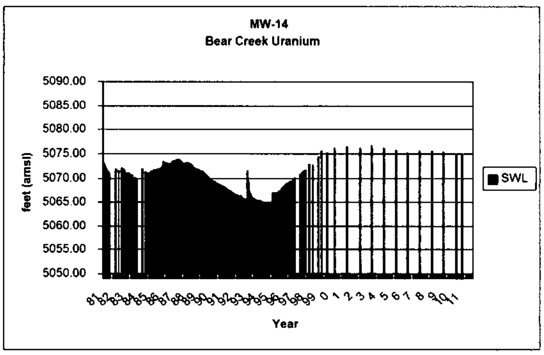


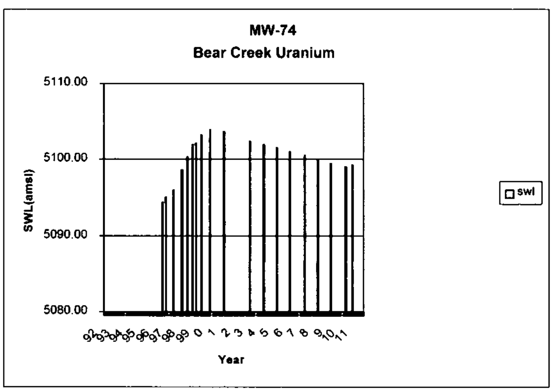
These three wells had good well yields >5 gallons per minute, 7.0-7.2 pH, ~1000 mg/l TDS, ~500 mg/l SO4, ~15 mg/l Cl, 25 pCi/l U-nat. It should be noted that even these wells would not meet Wyoming Class 1 or 2 water standards because of TDS and Sulfate levels. The estimated gradient, using wells MW-61 to MW-86, was 0.017 ft/ft from southwest to northeast. This is about a 20% increase in gradient compared with the MW-36a to MW-86 south to north gradient of 0.014 ft/ft used in both models. Conservative estimates, or not including the impact from the recovery wells, enhanced evaporation, clay cover over exposed tailings, clay lined evaporation ponds (preventing recirculation of recovered solution)and potential for dilution may have overestimated the remaining volume of <5 pH solution in the tailings area.

The static water level graphs show the extent of the actual down gradient drawdown in these wells.









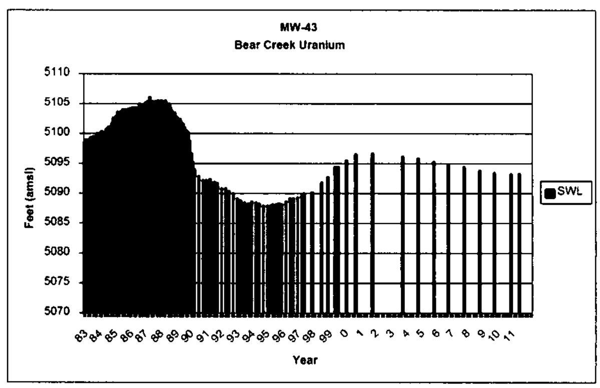


Figure 4 was constructed to see if solution contained in the slimes at the bottom of the tailings sand would follow the declining level of solution in the N-sand or stay bound in the slimes as predicted, i.e. pumping in the slimes area was estimated by bench testing, to get to a point of diminishing returns (about 30% saturation) and would not readily seep out or be pumped out of the tailings sand. Static water levels measured across the tailings basin (see Figure 4) shows visible separation between the bottom of the saturated zone of the tailings sand and top of the saturated zone of the N-sand. A pH of greater than 6.2 was measured at MW-107 in 1994 (Attachment 1, Section 2.a operational year 1994 of UPR Group, Inc. Alternate Concentration Limit Application Feb 28, 1997) indicating that substantial neutralization was

taking place in the N-sand beneath the low pH solution in the tails sand. MW-107 was completed in the N-sand about midway between TS-2 and TS-4 (see Figure 4) and directly in line with flow to the toe of the dam and down Lang Draw. MW-85, also an N-sand well, had a pH of 7. Two other wells, MW-106 and MW-105, were completed in 1994 and were used as N-sand recovery wells as their pH values were 5.6. They were located near the north east section of the dam. Comparing this graph to the attached N-sand Well Location map gives a better perspective to what was happening beneath the saturated zone of the tailings sand. Figure 2 is a cross section looking from north to south through the dam and includes the approximate location of the cut off trench superimposed. The cutoff trench keeps water contained in the west part of the basin as it (the cutoff trench) was completed about 5 feet into the claystone located below the N-sand. This helped create a somewhat confined large source of 7 pH solution that was drawn toward the cone of depression created by the N-sand recovery wells in the tailings basin. Using the N-sand well location map and Figure 3 puts Figure 4 in three dimensional perspective. The main objective of Figure 4 is to show the hydraulic gradient from southwest to northeast and point out the failure of the cut off trench in the northeast section to get below the N-sand into the claystone. It also shows the potential for overestimating the volumes of low pH solution used in the original 1997 ACL Application model (see 1997 ACL App., Attachment 2, Figure. 3-1)

Figure 4

E/W CROSS SECTION THROUGH DAM/TAILINGS

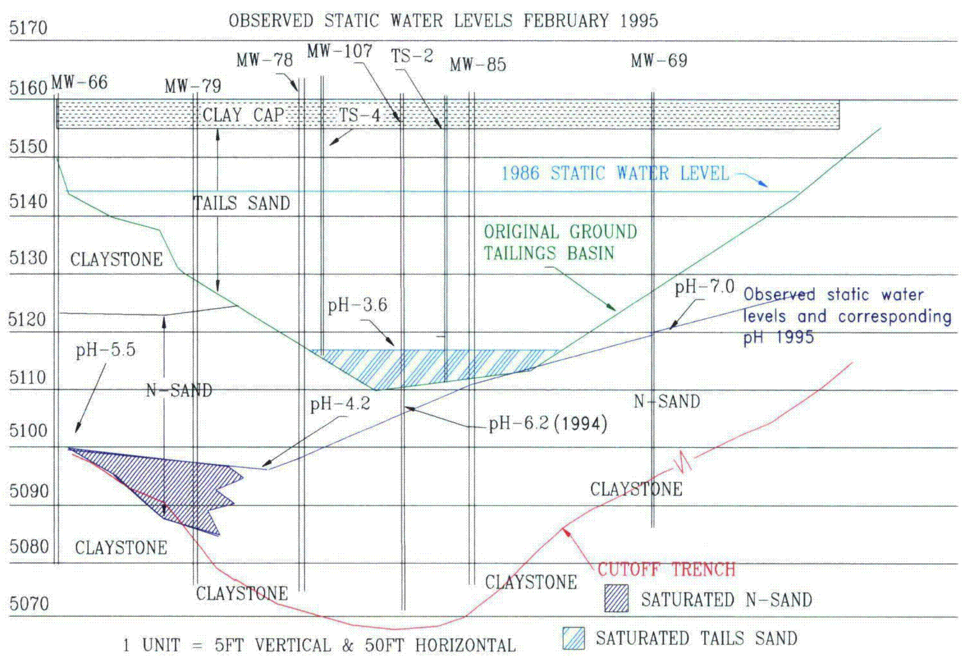


Figure 4 shows where low pH solution was able to seep through and can be seen in well MW-77 (see the N-sand Well Location map in map pocket). When the static water level in the N-sand goes below ~5085 feet, which was defined as the bottom of the N-sand in the northeast corner of the tailings dam, the seepage to the Northern flow path may subside.

The highest potential for seepage from the tailings to the N-sand was estimated to be in the up-gradient, southern, extent of the tailings impoundment where the sand begins to outcrop. The area was graded and lined with clay prior to the dam raise in 1980. By 1996, the low pH solution was located well within the confines of the tailings dam.

In 1991 all of the recovered low pH solution was pumped to clay lined ponds and all of the tails sands were covered with clay material so there was no potential for recirculation of low pH solution back to the tailings sand during the last 5 years of

dewatering of the tailings and N-sand. An estimated 100 million gallons of low pH solution was recovered and evaporated during that time frame.

The table below contains the background concentrations, and predicted breakthrough maximum concentrations (PBMC) for uranium, radium, and nickel as shown in Figures 18A., 18E.,18F., 21A.,21E.,and 21F of the 2011 model for the Lang Draw flow path and the Northern flow path Also included in the table are the results predicted in the 1997 ACL model.

Hazardous constituent	Lang Draw PBMC	Lang Draw year of PBMC	Northern flow path PBMC	Northern flow path year of PBMC	Background concentrations
Uranium 2011 model	*460 pCi/l	2015	75 pCi/l	2032	98.7 pCi/l
Radium 2011 model	2.1 pCi/l	2015	5.8 pCi/l	2040	9.7 pCi/l
Nickel 2011 model	0.032 mg/l	2015	0.034 mg/l	2039	0.05 mg/l
Uranium 1997 ACL model	45 pCi/l	2075	45 pCi/l	2125	98.7 pCi/l
Radium 1997 ACL model	13 pCi/l	2075	10 pCi/l	2095	9.7 pCi/l
Nickel 1997 ACL model	0.053 mg/l	2255	0.055 mg/l	2395	0.05 mg/l

* 2011 model for uranium in Lang Draw does not match any measured data for MW-109, MW-108 or MW-9 (see Figure 18A. Predicted Breakthrough of Uranium Lang Draw, *Re-Evaluation of Metals Transport At Bear Creek Uranium October 2011*)

The 2011 model predicted levels of radium and nickel are less than background in both flow paths and compare well with predicted levels of radium and nickel in the 1997 ACL model. The 2011 model predicted uranium in the Northern flow path to be about 67% higher, still less than background concentrations, than the predicted levels in the 1997 model; however, uranium in the 2011 model for the Lang Draw flow path POE is predicted to be almost 11 times higher, in year ~2015, than what was predicted in the 1997 ACL model. The uranium value measured at MW-109 in 2011 was 60 pCi/l compared to the 2011 model predicted value of ~325 pCi/l. MW-108 and MW-9 show comparable results, 3 to 12 times higher respectively, in predicted versus measured results for uranium.

For a uranium risk assessment calculation at the Lang Draw POE the average value under the curve (see Figure 18A of the 2011 model) of 166 pCi/l for uranium, converted to U238, at MW-109 was used. The calculated risk was 3.8E-4 for a chronic exposure over a 75 year time frame versus 2.3E-4 for the background

concentration. The combined (U238+D and Ra-226+D) radiological cancer risk for the POE on Lang Draw is 4.2E-4 while the combined risk for the same background parameters is 4.3E-4. All parameters, other than uranium at the Lang Draw POE, for both flow paths were predicted to be less than background in the 2011 model at the extended POEs.

Water sampling in both monitor wells MW-108 and MW-109 takes three days to obtain a sample after two casing volumes have been pumped. Measured static water levels prior to pumping took at least 24 hours to recover before another casing volume could be pumped. The 5 inch well bore holds 1 gallon per foot and static water levels indicated 13 to 15 gallons of water in the wells. The estimated well yields on wells MW-108 and MW-109 are <0.01 gallons per minute.

3.0 Hazard Evaluation

The physical setting of the former mill site and the reclaimed tailings is located in a remote semi-arid section of central Wyoming. Annual precipitation measured over twenty years on site averaged 10 inches. The land use is limited to open range used for grazing cattle and sheep. The ranches that encompass the Bear Creek project are each generally thousands of acres or more in size and have been in existence for almost a hundred years. They are now in their third and fourth generation of family operation with no change in the land use scenario. The nearest ranch headquarters is located 4 miles from the project. When homesteads were claimed, the ranch house was normally built close to an artesian spring with good water quality as most "streams," i.e., forks of Bear Creek and the Dry Fork of the Cheyenne River, in the region are intermittent. The towns and cities throughout Wyoming are typically found along the major water ways which are located nearly 50 miles away from the Bear Creek site in any direction.

The ranchers are adamantly opposed to man camps and people living on site within their property boundaries. There is no reason to believe that the land use will change.

The first shallow potential aquifer within 40 feet of the original ground surface below the tailings impoundment has been referred to as the N-sand. The low pH tailings solution that has seeped into this formation travels in a north to northeast direction. There is no history of this upper zone of the Wasatch formation being used for a domestic or livestock water supply in this region of the Powder River Basin in Wyoming. All of the regional livestock wells are completed to depths of 300 to 500 feet in an aquifer that is separated from the N-sand by an aquitard hundreds of feet thick. Water quality is generally influenced by the presence or absence of

mineralized zones and stringers of lignite/coal which are scattered throughout the Wasatch formation in the Powder River Basin. Wells completed into water bearing formations containing lignite or coal are generally marginal for livestock use in this area due to high dissolved solids, Sulfate and Selenium.

The estimated well yield for monitor wells MW-108 and MW-109 are <0.01 gallons per minute which would not be sufficient for daily residential or livestock use. There are several existing stock water wells completed to 430 to 515 foot depths, in which the water bearing formations are separated from the N-sand by hundreds of feet of claystone, located within a mile or less of the proposed POE locations on Lang Draw and the Northern flow path. These wells provide water at 2-3 gallons per minute and the water is utilized for livestock. All three are windmill driven and have been sampled in the past for groundwater parameters. The wells GW-8, GW-10 and GW-15 are located <1/2 mile south-west of the POE on Lang Draw, <1 mile north of both Lang Draw and the Northern flow path, and ~ 1 mile north-west of the Lang Draw flow path POE respectively. Water samples were collected on these wells and reported to the Wyoming Department of Environmental Quality in required annual reports during operation of the mine.

With the mine, mill and tailings sites having been totally reclaimed and re-vegetated the only potential exposure pathway is from drinking water and ingestion of irrigated garden products contaminated by utilizing the water from this shallow formation. There is no potential for airborne inhalation or external exposure increase above background. There has not been in the past and there is no expected use of this water now or in the future.

Several options were considered to meet the as low as reasonably achievable demonstration (ALARA) in 1997 prior to final reclamation of the tailings area (Letter to J.J. Holonich USNRC dated May 13, 1997). Continue to pump and evaporate, passive reactive barriers (one in each plume), pump and treat with reverse osmosis and reinjection, and fresh water injection were considered. All were cost prohibitive at that time and would be even more so now that the site is reclaimed.

A conservative risk analysis was performed and submitted with the 1997 ACL application. The calculated risk to human health at that time for all of the hazardous constituents were in the E-4 range for predicted and background levels of radioactive contamination of groundwater at the POEs. Uranium in the Lang Draw flow path is the only parameter that is estimated in the 2011 model to exceed the level predicted in the 1997 model. It is still within the E-4 risk range. As previously stated, the predicted uranium value in the 2011 model is at least 5 times higher than the measured levels of uranium in the MW-109 monitor well in the same time frame.

The only potential exposure pathway to be considered is from intake of contaminated groundwater as the there is no potential for airborne or external exposure since the site is completely reclaimed.

In 1997, boreholes were drilled by S.M.Stoller north of the POEs located near MW-14 (Lang Draw) and MW-111 (Northern flow path) and south of the Anadarko property boundary. Significant water was not encountered in any of the boreholes along Lang Draw at the time of drilling. Only boreholes near MW-108 in Lang Draw were found to contain wet sands. It was Stoller's opinion that "it is very unlikely that the alluvium will produce enough water to satisfy the NRC definition of an aquifer". Two wells, drilled north of the proposed POEs (MW-109 and MW-111), designated Manning B.C.18 (GW-18, Permit NO. U.W. 64632 completed Aug. 1983) and Hardy No. 4 (U.W. Well permit No.1365 drilled 1947), which were completed to depths of 432 feet and 443 feet respectively, show no water present in the N-sand in the well logs. Both wells are located north of the POEs in Section 9, T 38N, R 73 W. (source on internet "State of Wyoming, State Engineer's Office, Water Rights Data Base, Search by Well Location, ground water information only").

The lithologies encountered north of the Bear Creek Tailings Facility are typical of sediments deposited in a fluvial environment. These deposits are characterized by interbedded sand, silt, and clay units which vary in thickness due to different modes of deposition. The geometry of the stream, at the time of deposition, controlled these facies changes (increasing silt and clay) where sands are typical of stream channel deposits and silts and clays are typical of over-bank deposition. The fining and thinning of the N-sand controls groundwater movement through the study area. Facies changes in boreholes located between Lang Draw and the Northern flow path restricts groundwater flow and separates the study area into two different groundwater flow environments. It is suspected that the facies changes are reflected in the current division of plume migration evident near the tailings facility and may retard flow to the southeast in the Northern flow path. (Stoller 1997).

The water in the Northern flow path is not predicted, in the 2011 model, to exceed background concentrations for the hazardous constituents of interest. Criterion 5B(5) of Appendix A states that conceptually, background concentrations "...pose no incremental hazards..."

There is no known past or current use of this shallow aquifer and no surface expression or communication with lower aquifers or surface water in the area. The remedial action costs are high in relation to the long term benefit. The mine, mill site, tailings area, and five miles of access road were reclaimed and revegetated over ten years ago. All additional monitor wells and piezometer wells were plugged and

abandoned ahead of the reclamation sequence. There is also no likelihood of buildings or structures being placed in the area. The groundwater in this shallow formation should qualify for supplemental standards according to criterion cited in EPA 40 CFR 192.21(b).

The following information was taken from the Department of Energy *Site Observational Work Plan For the UMTRA Project Site At Spook, Wyoming* which is located on the Dry Fork of the Cheyenne River about 2 miles south of the Bear Creek Uranium site. The State of Wyoming held title to the surface area over the disposal cell at the Spook site.

Regional background water quality data from sandstones in the Wasatch Formation were collected by Rocky Mountain Energy (RME) from 22 domestic wells and monitor wells during the period between 1974 and 1977. The data were collected as part of a mining permit application for the RME Bear Creek Project. The regional data demonstrate that ground water from the altered sandstones has uranium and selenium concentrations generally greater than those in the unaltered sandstones and that the altered sandstones contain ground water with ambient uranium and selenium concentrations in excess of the MCLs for UMTRA Project sites.

The Spook work plan concluded that there is no apparent risk to human health and the environment because there are no known exposure pathways for contaminated ground water from the uppermost aquifer to lower aquifers or the surface. No one is using the ground water from this aquifer for any purpose and there is no discharge of ground water from the uppermost aquifer to the surface or to surface water. A baseline risk assessment of site-related contamination was not performed for the Spook site because of the lack of exposure pathways for the uppermost aquifer and because of the naturally contaminated nature of background water from that aquifer.

The rationale being that "ground water in the uppermost aquifer (also the zone of contamination) being classified as limited use, which allows the application of supplemental standards. No one is using or is projected to use the ground water from this aquifer for any purpose; there is no discharge of ground water from the uppermost aquifer to deeper aquifers used for domestic and agricultural purposes or to the surface or to surface water."

4.0 Proposed Action

The recalibrated ground water model predicts that the currently approved ACLs will not be exceeded and the risk assessment confirms there is no unacceptable risk to the public. Therefore, there is no need to change the ACLs.

References:

Final Environmental Statement related to operation of Bear Creek Project (FEIS), NUREG-0129 Docket No. 40-8452 June 1977

Staff Technical Position, *Alternate Concentration Limits for Title II Uranium Mills*, Standard Format and Content Guide, and Standard Review Plan for Alternate Concentration limit Applications, January 1996.

Union Pacific Resources Group, Bear Creek Uranium Company, *Amendment Request to SUA-1310; Docket No. 40-8452, May 30,1996*
Union Pacific Resources Group, Inc., Bear Creek Uranium Company, *Alternate Concentration Limit Application, February 28, 1997*

Union Pacific Resources Letter dated May 13, 1997 to Joseph J. Holonich, Chief USNRC, Attn: Charlotte Abrams, containing *additional information relating to Section 3.5 of Bear Creek Uranium Company's Alternate Concentration Limit Application.*

Union Pacific Resources, Bear Creek Uranium Mill Tailings Impoundment, *Hydrogeologic and Geochemical Transport Analysis*, GeoTrans Project #8386-000, March 7, 1995

Fate and Transport Modeling Analysis of Tailings Water Constituents, Bear Creek Uranium Mill Site, Converse County Wyoming, HSI GEOTRANS, June 30, 1998

2011 Edition of the Drinking Water Standards and Health Advisories, EPA 820-R-11-002, Office of Water, U.S. Environmental Protection Agency, Washington, DC

Code of Federal Regulations (CFR), Energy, 10 Parts 0 to 50, Revised as of January 1, 1996.

Wyoming Department of Environmental Quality, *Water Quality Rules and Regulations, Chapter 8*, Adoption Date: March 16, 2005.

EPA Risk Assessment Guidance for Superfund, Vol. 1 Human Health Evaluation Manual (Part A and B), Environmental Protection Agency (EPA),1989 (RAGS)

EPA Integrated Risk information System (IRIS), U.S. Environmental Protection Agency, New Assessments and Reviews, 2011

EPA Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13, Sept. 1999

EPA Radionuclide Table: Radionuclide Carcinogenicity Slope Factors, Federal Guidance Report No. 13, Morbidity Risk Coefficients in units of picocuries, U.S. Environmental Protection Agency, April 16, 2001

*EPA Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, Table 2.2,*U.S. Environmental Protection Agency, Federal Guidance Report No. 11, 1988

Delineation of N-sand and Lang Draw Alluvium - Bear Creek Uranium S.M. Stoller Corporation, April 7, 1997

Site Observational Work Plan For The UMTRA Project Site At Spook, Wyoming Prepared by the U.S. Department of Energy Albuquerque, New Mexico May 1995 DOE/AL/62350-156 Rev. Oc.1

Re-Evaluation of Metals Transport at Bear Creek Uranium, Converse County Wyoming prepared by Tetra Tech Geo, Louisville, Colorado, October 13, 2011

RESRAD 2.6 Release date July 7, 2010, Argonne National Laboratories

A Comprehensive Risk Assessment

for the

Predicted Concentrations

of

Nickel, Radium and Uranium

at the

Bear Creek Uranium Company Site

TABLE OF CONTENTS

LIST OF TABLES

EXECUTIVE SUMMARY

This assessment of risk is being prepared in support of a request from the Nuclear Regulatory Commission for a risk-based alternate concentration limit (ACL). The measured level of uranium at the point of exposure (POE) down Lang Draw has exceeded the 1997 ACL submittal prediction by a factor of 10. Although the value predicted by the modeling had been exceeded, at no time did the uranium concentrations exceed the approved ACL's.

To determine the risk associated with water use with the predicted maximum concentrations of nickel, radium, and uranium, a residential use scenario was assumed to exist. There is no current use of the affected water resource and none is expected at this site.

Environmental Protection Agency (EPA) Federal Guidance Report (FGR) No. 13 Morbidity Risk Coefficients, in Units of Picocuries were used to determine radionuclide carcinogenicity risks for Uranium and Radium concentrations in drinking water based upon chronic intake over a 75 year life time. Nickel is not currently listed as a contaminate in drinking water by either the State of Wyoming, which defaults to the National Primary Drinking Water Standard, or the EPA Primary Drinking Water Standards which remanded Ni from drinking water standards in 1996. Prior to 1996, the Maximum Concentration Limit (MCL) for Ni in drinking water was listed as 0.1 mg/l with an oral reference dose (RFD) of 0.02 (mg/kg/day). The current, January 2011, EPA lifetime health advisory (LHA) MCL for Ni is listed as 0.1 mg/l. A lifetime HA is defined as: "The concentration of a chemical in drinking water that is not expected to cause any adverse non-carcinogenic effect for a lifetime exposure. The lifetime HA is based on exposure of a 70kg adult consuming two liters of water per day." Nickel was not listed in Table 5c of the Nuclear Regulatory Commission regulations contained in 10 CFR Part 20 for hazardous constituents in drinking water and was based on the EPA national drinking water standards listing prior to 1996. For purposes of determination of relative risk from Ni in groundwater, the EPA's remanded standard was used along with an oral reference dose for soluble Nickel from studies that were conducted and reported on EPA's Integrate Risk Information System (IRIS) web site. The most recent model completed in October of 2011 has predicted nickel and Uranium concentrations to be below background at the points of exposure down Lang Draw and in the Northern flow path.

The carcinogenic risks for individual radionuclide constituents were assessed. The risk associated with radium and uranium was found to be within a reasonable range of E-4. The risk associated with nickel was found to be acceptable because all expected levels of Ni were less than previously remanded EPA standard of 0.1 mg/L

MCL and an oral RFD for soluble nickel. To determine the relative incremental increase in risk due to the reclaimed mill tailings, the risk associated with consumption of water having background concentrations of nickel, radium, and uranium was calculated and compared to the predetermined background levels, the EPA recommended MCL for each constituent and the expected concentration for each constituent at the point of exposure. The assessment of total risk associated with the background conditions indicated that nickel concentrations were within acceptable limits, while radium and uranium were on the order of E-4. The summation of the predicted concentrations of nickel, radium, and uranium did not change the risk order of magnitude.

The exposure assessment indicated that there is no exposed population and it is reasonable to assume that there will be no future exposed populations. However to support the calculation of risk, a hypothetical population was assumed to exist. This scenario demonstrated that the total risk associated with the utilization of background water was within the order of magnitude for the risk associated with the predicted water quality and MCL's for uranium and radium.

1.0 HUMAN HEALTH EVALUATION

1.1 Introduction

This document evaluates the potential risks to human health associated with groundwater water use at the POE locations in the Northern and Lang Draw flow paths. The risk assessment is based on the United States Environmental Protection Agency's (EPA) Risk Assessment Guidance for Superfund, Vol.1 Human Health Evaluation Manual (Part A and B) 1989 (RAGS), the EPA Integrated Risk Information System (IRIS), EPA Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13, the Radionuclide Table: Radionuclide Carcinogenicity Slope Factors Federal Guidance Report No.13 Morbidity Risk Coefficients, and the Federal Guidance Report Number 11: Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, Table 2.2., EPA 2011 Edition of the Drinking Water Standards and Health Advisories

1.2 Selection of Hazardous Constituents for Risk Evaluation

Predictive modeling associated with information collected from monitoring of the corrective action program (CAP) was utilized to determine the parameters for risk evaluation. This predictive modeling indicated that nickel, radium, and uranium

would require alternate concentration limits and an evaluation of risk at the point of exposure (POE) locations.

The modeling information indicated that although other hazardous constituents are present in the water found in the Northern and Lang Draw flow paths, the concentrations are below the license-established standards. Evaluation of past concentrations and current concentrations indicate that, in the near term, they will remain below the license-established standards and eventually diminish to below these concentrations.

1.3 Toxicity Information for Non-carcinogenic and Carcinogenic Effects

The only carcinogenetic toxicity information found for Nickel was from air intake. There is no source for airborne Nickel at the Bear Creek site. Due to the fact that Nickel was remanded from EPA Primary Drinking Water Standards in 1995, a comparison was made to the maximum concentration level (MCL) listed prior to that time and the oral RFD listed in IRIS in an attempt to show relative risk for ingested nickel. Exposures were assumed to be chronic over a 75 year life span. The primary health effect associated with Radium and Uranium is from radioisotope exposure and the resulting potential for cancer although it is commonly accepted that the primary health effect of Uranium ingestion is chemical toxicity to the kidney.

The EPA assumes that there is essentially no level of exposure to a chemical that does not pose a finite possibility, no matter how small, of generating a carcinogenic response. In evaluating carcinogenic effects, no threshold value can be assumed. The EPA uses a two part evaluation in which the substance is first assigned a weight of evidence classification defined by the EPA as a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. Following this, a slope factor is calculated. This value is multiplied by the chronic daily intake of the chemical to produce an estimate of probability of an individual developing cancer due to exposure to that chemical.

Exposure to radioisotopes requires that the slope factor is multiplied by the chronic daily intake over the life span of the individual. These calculations were carried out for Nickel, Radium and Uranium. Slope factors and weight-of-evidence classifications for these constituents are included in Table 1.3.1.

Table 1.3.1 Toxicity Values for Hazardous Constituents

Hazardous Constituent	Uranium-238+D	Radium-226+D	Radium-228	Nickel
Oral Slope Factor	8.71E-11 (risk/pCi)	3.86E-10 (risk/pCi)	1.04E-9 (risk/pCi)	8.4E-1 (mg/kg-day)-1
Weight of Evidence	Carcinogen per EPA	Carcinogen per EPA	Carcinogen per EPA	non-stochastic
Chronic Oral RfD (mg/kg-day)	None	None	None	2E-2
Uncertainty Factor	None	None	None	300
Reference	FGR No.13	FGR No. 13	FGR No. 13	EPA lifetime HA 2011
Target Organ System	Skeletal system	Skeletal system	Skeletal system	Whole body, major organs

There are inherent uncertainties in the toxicity data used to assess risk in this and any other evaluation. For instance, using dose-response information from effects observed at high doses to predict the health effects that may occur following exposure to the low levels of hazardous constituent Concentrations introduces uncertainties. Similarly, using animal studies to predict human response and the use of short-term studies to predict the effects of a lifetime exposure add to the uncertainties.

Experimental studies of animal populations coupled with studies of healthy human populations are used to predict the response likely to be observed in a population consisting of individuals with a wide range of sensitivities.

Uncertainty factors which may overestimate potential risk, and are used to calculate risk, are presented along with toxicity values in Table 1.3.1. These values give an indication of the confidence in experimental data used to determine the associated risk. The greater the uncertainty factor, the greater the uncertainty associated with the experimental data.

1.4 Exposure Pathways

This assessment considered risk to future populations at a POE in the Northern flow path and a POE in the Lang Draw flow path. Ground water within the range for Nickel, Radium, and Uranium concentrations predicted to be present at these points were assumed to be utilized by humans. The exposure matrix assumed that water at the POEs would be a drinking water source and would nourish consumable food products.

Intake of hazardous constituents as a result of exposure to contaminated soils was not considered, as there are no contaminated soils at the BCUC site because the site has been reclaimed. Similarly, dermal and inhalation exposure were not considered a probable exposure pathway and not included in the assessment.

1.5 Ground Water Concentrations

The concentrations of nickel, radium, and uranium that are predicted to occur in the Northern and Lang Draw flow paths were used in this risk assessment. The POE locations are established at the down gradient edge of the land mass that will accompany an amendment application for a general license. Consequently, this land mass is the minimal amount of land that is necessary to assure long term control of the reclaimed byproduct materials. Additional information on the predictive modeling is contained in the modeling summary.

The values for nickel, radium, and uranium that were utilized were predicted to reach their maximums at times in the future varying from 18 to 44 years, from the time that the CAP was terminated. Information for the concentrations of hazardous constituents and the years to attain these concentrations are shown in Table 1.5.1.

Table 1.5.1 Hazardous Constituent Concentrations at the POE Locations

Hazardous Constituent	Lang Draw Max. Conc.	Lang Draw Year of Max. Conc.	Northern Flow Path Max. Conc.	Northern Flow Path Year of Max. Conc.	EPA MCL @ POE	Background Standard
Nickel	0.032 mg/l	2015	0.034 mg/l	2039	0.10 mg/l	0.05 mg/l
Ra-226 + Ra-228	2.1 pCi/l	2015	5.8 pCi/l	2040	5 pCi/l	9.7 pCi/l
Uranium	166 pCi/l*	2015	75.0 pCi/l	2032	20 pCi/l	98.7 pCi/l

* The value for uranium was the average of the model projected curve which is used as the chronic exposure for 75 years.

The values for nickel, radium, and uranium shown in Table 1.5.1 represent the levels that risk was assessed for and represent the entire range of hazardous constituents that are predicted to occur. The risk for nickel was assessed for the background concentration of 0.050 mg/l as well as the predicted maximum concentrations of: 0.034 mg/l and 0.032 mg/l; 0.10 mg/l, which was the previous MCL; and the listed RFD to demonstrate the relative incremental risk associated with these concentrations in nickel. Similarly, the background concentrations of radium and uranium, the recommended MCL concentrations, and the predicted concentrations at the POE's were assessed for relative risk. The entire range of values was evaluated in the Northern and Lang Draw flow paths.

1.6 Future Land Use

Although no exposed populations currently exist within four miles of the BCUC site and none are predicted to be in the area in the future, residential land use was considered in the risk assessment. Lesser exposure scenarios would have resulted in no exposed populations. Although this is the likely scenario it is inconsistent with the ACL guidance document. Exposure pathways considered for future populations include ingestion of contaminated ground water and consumption of vegetables using contaminated ground water for irrigation. Table 1.6.1 summarizes the potential for exposure to future residents across the routes of exposure.

Table 1.6.1 Potentially Exposed Populations and Exposure Routes

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected for Evaluation?	Reason for Selection or Exclusion
Residential	Ingestion of contaminated ground water	Yes	Wells developed in the alluvium and the N-sand
Residential	Ingestion of home-grown vegetables	Yes	The site and the surrounding area is in a rural location, increasing the potential for home gardening. The only source of irrigation water is wells developed in the alluvium and the N-sand.
NA	Dermal absorption through bathing	No	According to the EPA, dermal uptake of radionuclides and metals is generally not an important route of uptake (EPA RAGS, 1989).
NA	Inhalation of contaminated dust	No	The soil at the BCUC site is not contaminated. The site has been reclaimed.
NA	Dermal contact with contaminated soil	No	The soil at the BCUC site is not contaminated.
NA	Inhalation of airborne (vapor phase) chemicals	No	There are no volatile hazardous constituents at the BCUC site.
NA	Ingestion of contaminated soils	No	The soil at the BCUC site is not contaminated. The site has been reclaimed

1.7 Quantification of Potential Risk

The quantification of risk for nickel utilized standard EPA equations and the methodology as discussed in RAGS, 1989 and HEAST tables. Included in this subsection are explanations of the calculations which were performed for each pathway. The equations that were utilized are shown below. EPA FGR No. 13 was used for radionuclides.

Intake of nickel by ingestion of ground water was calculated by using the following equation:

$$\text{Intake (mg/kg-day)} = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

Where: CW = Nickel concentration in ground water (mg/l)
IR = Ingestion Rate (liters/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Average Time (days)

Intake of Nickel due to ingestion of home grown produce irrigated with contaminated ground water was calculated by using the following equation:

$$\text{Intake (mg/kg-day)} = \frac{CW \times IR \times FI \times EF \times ED}{BW \times AT}$$

Where: CW = Nickel concentration in ground water (mg/kg)
IR = Ingestion Rate (kg/meal)
FI = Fraction ingested from Contaminated Source (unitless)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Average Time (days)

For calculation of ingestion of radionuclides, average time (AT) and body weight (BW) were deleted and the resulting intake was multiplied by the dose conversion factor (DCF) in mrem/pCi. The units of intake are therefore discussed in terms of effective dose and expressed as fractions of radiation equivalent man (mrem) over a 75 year time frame and are shown in Table 1.7.1

Table 1.7.1 Radionuclides Expressed in Terms of Effective Dose

Hazardous Constituent	Ingestion of groundwater		Ingestion of home grown plants		Ingestion of groundwater	
	Lang Draw flow path	Northern flow path	Lang Draw flow path	Northern flow path	Background	MCL
U-238+D (mrem)	1192	540	2.9	1.4	710	147
Ra-226+D (mrem)	155	422	0.4	1.1	706	364

1.8 Risk Characterization

The carcinogenic and non-carcinogenic risk associated with exposure to Nickel, Radium, and Uranium under the residential future land use scenario serve as the characterization for this assessment. Although there is no current indication that the ground water in the Northern flow path and the Lang Draw flow path will be utilized under a residential scenario, this type of use was assumed to take place. This use scenario incorporates the most conservative exposure values; i.e., length of residence, and duration of exposure.

If exposure to Nickel, Radium, and Uranium under this land use scenario demonstrates no significant increase in risk of development of cancer and non-cancer illnesses, then it will be assumed to be the case for all other land use scenarios.

A lifetime exposure of 75 years was used for the calculations. FGR 13 risk coefficients for ingestion of radionuclides in tap water or food are expressed as the probability of radiogenetic cancer morbidity per unit intake, where the intake is averaged over all ages and both genders. The exposure pathways under the residential land use scenario include the ingestion of contaminated ground water and the ingestion of home grown produce irrigated with contaminated ground water. The lifetime intake of potentially hazardous chemicals by residents is summarized in Table 1.8.1

Table 1.8.1 Lifetime Intake of Hazardous Chemicals

Hazardous constituent	Ingestion of groundwater		Ingestion of home grown plants		Ingestion of groundwater	
	Lang Draw flow path	Northern flow path	Lang Draw flow path	Northern flow path	background	MCL
U-238 (pCi)	4.4E+6	2.0E+6	11.0E+3	5.0E+3	2.64E+6	0.5E+6
Ra-226 (pCi)	1.24E+5	3.2E+5	3.0E+2	8.0E+2	5.31E+5	2.74E+5
Nickel (mg/kg-day)	1.51E-3	1.57E-3	7.6E-5	7.8E-5	1.4E-3	2.9E-3

The potential risk for residents from the predicted nickel concentrations in the groundwater, is provided by the product of the slope factor and the intake. The potential risk to residents to develop cancer from radium and uranium is determined by the product of the estimated ingested activity in pCi and the slope factor (risk/pCi). The potential risk for residents to develop cancer due to exposure to site contaminants is summarized in Table 1.8.2.

Table 1.8.2 Carcinogenic Risks to Residents

Pathway	Hazardous constituent	Resident Risk (unitless)		background	MCL
		Lang Draw flow path	Northern flow path		
Ingestion of groundwater	U-238+D	3.8E-4	1.0E-4	2.3E-4	0.4E-4
Ingestion of groundwater	Ra-226+D	0.4E-4	1.2E-4	2.0E-4	1.0E-4
Ingestion of groundwater	Ni	1.26E-3	1.34E-3	1.18E-3	2.4E-3
Ingestion of home grown produce	U-238+D	9.5E-7	2.6E-7	4.0E-7	1.0E-7
Ingestion of home grown produce	Ra-226+D	1.0E-7	3.0E-7	5.01E-7	2.6E-7
Ingestion of home grown produce	Ni	6.0E-5	6.7E-5	5.9E-6	1.2E-4

Hazard quotients (HQ) for nickel measured at the background well and the POEs are summarized in Table 1.8.3. A Hazard quotient is defined as the ratio of a substance exposure level over a specified time period to a reference dose for that substance derived from a similar exposure period. The ratios are expected to be less than unity (1) for risk to non-stochastic effects.

Table 1.8.3 Non-carcinogenic Hazard Quotients For Residents

Pathway	Hazardous constituent	Background	Residents HQ (unitless)	
			Lang Draw flow path	Northern flow path
Ingestion of groundwater based on RFD	Ni	7.1E-2	7.6E-2	7.8E-2
Ingestion of food based on RFD	Ni	3.6E-3	6.5E-3	3.8E-3
Ingestion of ground water based on MCL	Ni	5.0E-1	5.2E-1	5.5E-1
Ingestion of food based on MCL	Ni	2.5E-2	2.6E-2	2.7E-2

An overall assessment of the risk of developing cancer or a non-cancer illness due to exposure to nickel, radium, and uranium was conducted. The assessment utilized the residential land use scenario and combined risks and HQs across all pathways. Summing the risks and HQs over all pathways produces a very conservative representation of the risks.

In order for the estimated cancer risk to fall within EPA guidelines for acceptable risk, the risk from an individual chemical should be less than 1E-6, and the combined cancer risk across all pathways from all chemicals should be less than 1E-4. This differs from the ACL guidance, which allows a 1E-4 risk for any individual constituent.

According to the same EPA guidelines, the risk for contracting a non cancer illness, described by the HQ from an individual chemical and combined for all chemicals across all pathways, should be less than one.

The total risk for residents to develop cancer across an individual pathway is summarized in Table 1.8.4.

Table 1.8.4 Total Radionuclide Risk of Developing Cancer for Residents

Pathway	Risk (unitless)			
	Lang Draw flow path	Northern flow path	Background	MCL
Total Risk	4.2E-4	2.2E-4	4.3E-4	1.4E-4

The HQ is obtained by dividing the intake of nickel (units of mg/kg-day) by the RfD for nickel (units of mg/kg-day) and measured levels of Ni in mg/l divided by the lifetime HA MCL. A summary of chronic HQs across each exposure pathway is given in Table 1.8.5.

Table 1.8.5 Total Nickel Hazard Quotient for Residents

Pathway	HQ (Unitless)		
	Lang Draw flow path	Northern flow path	Background
Ni HQ RFD-based	8.2E-2	8.2E-2	7.5E-2
Ni HQ MCL-based	5.4E-1	7.8E-1	5.2E-1

The overall risk for individuals residing at the POE locations to develop cancer is within the range of the 1E-4 required by Alternate Concentration Limits for Title II Uranium Mills (ACL) guidance. Including nickel for the potential carcinogenic risk does not appear to be warranted as there is no data to support cancer risk to humans and currently no listed MCL for nickel in the EPA primary or secondary drinking water standards. Nickel concentrations are less than the MCL and the MCL calculated risk is 2.4E-3. Including this in the summation skews the overall risk evaluation.

The calculations indicate that all hazard quotients for nickel are within recommended levels. Therefore, they are not a contributor to the overall risk. The driving factor for risk is the predicted development of cancer due to the presence of radionuclides in the ground water in the Northern and Lang Draw flow paths.

1.9 Uncertainties in the Characterization of Risk

There are many uncertainties inherent in calculating the risk of developing cancer and non-cancer illnesses due to exposure to Nickel, Radium, and Uranium. Included are the site specific uncertainty factors associated with characterizing the physical setting, and determining the fate and transport, as well as toxicity.

The concentrations of Nickel, Radium, and Uranium that are currently in the background water, as well as the concentrations of those constituents predicted to occur at the POE locations, were utilized in the risk assessment.

Utilizing the ground water model introduces levels of uncertainty in the data, particularly extending the time frame of the model to over a hundred years.

Significant site data gaps occur when site specific data is unavailable or unknown. This specifically occurs when estimating the exposure to future populations. For example, when estimating what the exposure to a future resident will be, there are no current residents upon which to base the estimates of exposure parameters; therefore, the EPA recommended values have been used to estimate exposure to residents. When several options are available, the most conservative value was utilized.

A certain amount of uncertainty exists with the slope values and references doses that were used in the calculation of risk. These values were obtained from EPA sources. The references acknowledge the uncertainty associated with the lack of human or animal data and the extrapolation that is necessary. The uncertainty factors generally overestimate the calculated risk.

2.0 Conclusions

The EPA RAGS methodology, HEAST tables, and EPA January 2011 Edition of the Drinking Water Standards and Health Advisories were implemented in the risk assessment for nickel. The Federal Guidance Report No. 13 was used to estimate risk and dose for radionuclides. The objective of this procedure was to assess the degree of risk associated with the possibility of future residential land use at the POE locations.
The assessment assumed that the maximum predicted concentrations would be realized at the POE locations. The exposure routes included ingestion of contaminated ground water and ingestion of home grown vegetables or produce irrigated with contaminated ground water.

Under a residential land use scenario, the overall risk across all pathways for residents to develop cancer was evaluated at the POE locations. The risk is within the 1E-4 order of magnitude for cumulative pathways for radionuclides.

Although the nickel calculated risk were higher than those observed in the radionuclide constituents, they were within the same order of magnitude as the hazard quotients for nickel found in the background well and less than the risk for the remanded EPA MCL for nickel.

The predicted concentrations of uranium and radium in the ground water will cause a minimal increase in the acceptable risk of cancer to future residents from the ingestion of ground water. Risks of developing cancer from ingesting ground water and eating produce irrigated with water containing uranium are 2.2E-4 and 4.2E-4 in the Northern flow path and the Lang Draw flow path respectively. These risks are within acceptable ACL guidance levels.

The exposure estimates for the exposure pathways were determined by using the most conservative values recommended by the EPA. They represent the worst case scenario and overestimate the potential exposure, i.e. the nickel drinking water equivalent level of 0.7 mg/l listed in EPA's 2011 Edition of the Drinking Water Standards and Health Advisories which is defined as:" A lifetime exposure concentration protective of adverse, non-cancer health effect, which assumes that all of the exposure to a contaminant is from drinking water." That level is seven times higher than the one used here to estimate potential risk from nickel.