



February 22, 2007

Submitted by Email Only On This Date

Ref. No: 56007344

Mr. Mark D. Purcell
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Superfund Division
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Re: Erratum
Site-Wide Supplemental Feasibility Study, Part 1
Church Rock Remediation Standards Update
Church Rock Site, Church Rock, New Mexico

Dear Mr. Purcell:

After submitting the above report to you earlier this week, I have noticed an error that is corrected herein. I ask that you print this letter and slip it inside the back covers of the two hard copies of the report that you received, and place this letter pdf with the full report pdf.

Erratum

Section 6, page 41, continuation of bullet number 8 in the first paragraph on the page:

Replace: "While the NRC did not specifically address background when it arrived at its value for the GWPS, the NRC standard is set at the correct background value for the Southwest Alluvium and very close to that for Zone 3.

With: "While the method that the NRC used to determine background for uranium was different than that used by GE (2006) for the Southwest Alluvium and that used for Zone 3 in Section 4.2.3 of this report, all three methods arrived at essentially the same value."

Sincerely,

A handwritten signature in black ink, appearing to read "Mark D. Jancin". The signature is fluid and cursive, written over a white background.

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Project Manager

email cc: Paul Michalak, NRC
Roy Blickwedel, GE

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The logo for Veolia Water features a stylized globe icon on the left, composed of horizontal lines of varying lengths that create a sense of depth and rotation. To the right of the icon, the text "VEOLIA" is written in a bold, sans-serif font, with "WATER" in a smaller font below it. Below the text, the tagline "Solutions & Technologies" is written in a small font.

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Gallup, New Mexico

Site-Wide Supplemental Feasibility Study, Part I Church Rock Remediation Standards Update Church Rock Site, Church Rock, New Mexico

February 2007



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UNITED NUCLEAR CORPORATION
GALLUP, NEW MEXICO

SITE-WIDE SUPPLEMENTAL FEASIBILITY STUDY, PART I
CHURCH ROCK REMEDIATION STANDARDS UPDATE
CHURCH ROCK SITE, CHURCH ROCK, NEW MEXICO

FEBRUARY 2007

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Solutions & Technologies

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Church Rock Remediation Standards Update
Church Rock Site, Church Rock, New Mexico
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Site-Wide Supplemental Feasibility Study, Part I

Church Rock Remediation Standards Update

Section 1

Introduction and Content Overview

The U.S. Environmental Protection Agency (EPA) selected a remedy for the groundwater operable unit at the UNC Church Rock Site in the September 1988 Record of Decision (ROD), following the assembly and detailed analysis of the combined remedial alternatives documented in the August 1988 Feasibility Study (FS). More than 17 years of active Site remediation, and passive remediation from natural attenuation processes, have left a small number of certain clean-up goals unattained. In EPA's *Second Five-year Review Report* (September 2003), EPA considered the possibility of performing a supplemental feasibility study, and in a letter dated June 23, 2006, EPA directed UNC to conduct a Site-Wide Supplemental Feasibility Study (SWSFS). The stated objective of the SWSFS was to evaluate possible remedial alternatives to meet Site remediation goals as envisioned in the EPA's 1988 ROD; for example, see the *Second Five-Year Review Report* (EPA, September 2003). As later requested by EPA in its letter to UNC dated November 22, 2006, UNC was directed to review the Site standards and to take into consideration new or revised applicable and relevant or appropriate requirements (ARARs).

This document is intended to provide EPA with a comprehensive, organized presentation of the factors that EPA may want to consider in making decisions about whether to revise the clean-up standards that were described in the ROD. The National Contingency Plan (NCP) at 40 CFR 300.430(f)(1)(ii)(B) dictates that requirements that are promulgated or modified after ROD signature must be attained (or waived) **only** when determined to be applicable or relevant and appropriate **and necessary to ensure that the remedy is protective of human health and the environment** (emphasis added). EPA and the regulated community interpret this provision to mean that ARARs are frozen as of the date of the ROD. See 55 Fed. Reg. 8758 (*"a policy of freezing ARARs at the time of the ROD will not sacrifice protection of human health and the environment ..."*).

The NCP also states that *"components of the remedy not described in the ROD must attain (or waive) requirements that are identified as applicable or relevant and appropriate at the time the amendment to the ROD or the explanation of significant difference describing the component is signed."* For this project, it is important to recognize that the remedial action objectives and remediation goals remain unchanged from the earlier FS and the ROD. It is only the standards by which those objectives and goals are to be measured that are being reconsidered in the process of conducting the new SWSFS. Thus the purpose of conducting this SWSFS is not to abandon or disregard any prior decision-making that was undertaken in



compliance with the NCP; but rather, to identify alternatives that may meet the previously identified objectives, compare them relative to an established set of ARARs, and evaluate their likelihood of attaining ARARs. An eventual decision document(s), if any is required (whether an amendment to the ROD or an explanation of significant differences), will consider ARAR waivers as per the NCP.

More than 18 years have lapsed since the ROD was issued, and there are a number of changes to regulatory standards, Site conditions and our understanding of those conditions. If any revisions from the standards expressed in the ROD are necessary in accordance with CERCLA and the NCP, then they should be determined prior to performing the detailed analysis of remedial alternatives in the SWSFS because the analysis requires comparison to specific, established cleanup targets.

This report pertains to contaminant-specific requirements, as opposed to action-specific or location-specific requirements. It begins with a presentation of information from the two sources wherein the existing regulatory decisions are delineated. The first source is the 1988 EPA ROD, which includes remedial action objectives, remediation goals, and baseline ARARs. The second source is the U.S. Nuclear Regulatory Commission (NRC) Source Materials License (SUA-1475) that establishes the groundwater performance monitoring program and on-site groundwater protection standards. The remedial activities addressing source control and on-site surface reclamation are under the direction of the NRC, pursuant to the facility's Source Materials License; the EPA's selected remedy for the groundwater operable unit is integrated into the license. Key elements of the Memorandum of Understanding (MOU) between the EPA and NRC are also reviewed herein, to clarify each agency's regulatory authority and role regarding groundwater quality issues. This report reviews the current compliance status of all three Site hydrostratigraphic units: the Southwest Alluvium, Zone 3 (bedrock unit), and Zone 1 (bedrock unit), with respect to the two governing decision documents.

Following the presentation of the existing standards, we organize and present all pertinent documentation regarding new or revised, promulgated or enacted, applicable or relevant and appropriate standards since the effective date of the ROD and/or license. We also review pertinent new information regarding background concentrations, risk-based criteria and land use. Such information and revisions include:

- NRC license amendments;
- new or revised federal primary Maximum Contaminant Levels (MCLs), which comprise some of the ARARs;
- proposals to revise background concentrations, and the status of their concurrence by the state;
- aspects of health-based criteria developed through a preliminary reassessment of the original Site risk assessment in the 1988 FS; and

- changes in land use or exposure assumptions.

In addition, the ROD contains remediation contingencies. The contingencies are also reviewed in conjunction with the many years of Site groundwater-quality and groundwater-level monitoring data. These data, and performance reviews of past active remedial efforts, provide bases for determining achievable remedial Site goals. Key contingencies derive from:

1. the effects of declining saturated thickness (and the related critical losses of former pumping yields);
2. the pervasive influence of background water quality, for which some constituents exceed Site standards that are only appropriately applied to seepage-impacted waters; and
3. the potential for aquifer restoration times to be unreasonably long.

The NRC's 1996 report on background water quality is reviewed, as are the 2006 license amendments that changed the standards for combined radium in the Southwest Alluvium and Zone 1, and the chloroform standard in all three hydrostratigraphic units. Key geochemical reactions, vital to understanding the geochemical evolution of both the background and seepage-impacted waters, are reviewed. A summary is presented indicating, for each hydrostratigraphic unit, the constituents for which the current remedial goals have been met, with emphasis placed on remedial goal attainment within and outside of the UNC property boundary.



Site-Wide Supplemental Feasibility Study, Part I

Church Rock Remediation Standards Update

Section 2

The EPA's Record of Decision (ROD)

2.1 Selected Remedy

2.1.1 Remedial Action Objectives

According to NCP regulations, the lead agency (in this case EPA) must establish remedial action objectives in the FS by “*specifying contaminants and media of concern, potential exposure pathways, and remediation goals*” (40 CFR §300.430(e)(2)(i)). The EPA remedy was focused on the potential exposure to groundwater because source control and on-site surface reclamation activities were conducted within Section 2 under the direction of the NRC, pursuant to the facility’s NRC license. These activities addressed surficial contamination from windblown tailings solids and control of groundwater evaporation residues, and were expected to eliminate significant potential risks to health and the environment via the direct contact, air emissions, and surface exposure routes.

Because the potential exposure to groundwater can only occur outside the Site boundary, the remedial action objectives (RAOs) for the groundwater operable unit remedy were focused on the areas at the boundary of, or downgradient of, UNC property comprising Sections 2 and 36 (see Section 2.1.1.1 below). This is consistent with the expectation that the property will be turned over to the United States Department of Energy (DOE), as dictated by the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978, which directs DOE to stabilize, dispose of, and control uranium mill tailings at inactive mill sites (DOE, October 1999).

2.1.1.1 Remedial Action Objectives Stated in Feasibility Study

The remedial action objectives identified in Chapter 5 of the FS (as Operable Unit Feasibility Study (OUFS) goals for remediation) are the following:

- Contain downgradient contaminant migration within each target area.
- Restore groundwater downgradient of Section 2, to the maximum amount practicable, to meet the clean-up criteria (i.e., ARARs); and
- Restore groundwater in Section 2 to a level that allows attainment of clean-up criteria at the boundary of Section 2. Note that both Sections 2 and 36 are under NRC jurisdiction.

The executive summary of the FS states the following:

“EPA’s scope of work is limited to groundwater contamination at the UNC Site beyond the boundary of Section 2. However, the reclamation activities directed by the NRC within the Section 2 boundary may influence the effectiveness and implementability of the remedial alternatives contained in this OUFS. Therefore, the development of the OUFS alternatives assumes certain onsite activities and is based on a coordinated and integrated implementation of onsite and offsite actions. The primary assumptions include the following:

“The source of groundwater contamination within the Section 2 boundary will be contained by the PRP [Primary Responsible Party] under NRC requirements.

“Any source control actions will be conducted before, or in sequence with, implementation of EPA required measures.

“Any source control measures used by the PRP to contain contamination at the Site will not adversely affect the measures initiated by EPA.”

2.1.1.2 Remedial Action Objectives Identified in ROD

The overall RAOs are restated the ROD in the following manner:

- The “Declaration for the ROD” states that the remedy is designed to *“contain, remove, and evaporate groundwater contaminated by tailings seepage outside the tailings disposal area, thus preventing further migration of seepage into the environment.”*
- Appendix A of the ROD states that, *“The goal of the selected remedy is to restore groundwater outside the tailings disposal area to concentrations dictated by Federal and State standards or background to the maximum extent practicable and to the extent necessary to adequately protect public health and the environment.”*
- Section 6.3 of the ROD (Statutory Determinations), indicates that the selected remedy is protective of human health and environment, and that *“by containing and removing tailings seepage, will substantially reduce groundwater contamination in aquifers outside the byproduct materials disposal site.”* Furthermore, this section of the ROD indicates that *“contaminant concentration in impacted aquifers will be reduced to ARARs to the maximum amount practicable.”*

In comparing these RAOs with those in the FS, the following ambiguity is encountered. It appears that “groundwater outside the tailings disposal area,”



as used in ROD Appendix A, and “groundwater contamination in aquifers outside the byproduct materials disposal site” in ROD Section 6.3, correspond to “groundwater outside the Section 2 boundary.” With respect to the SWSFS, the ROD statements could also be considered to correspond to the combined outer boundaries of the UNC-owned property (i.e., Sections 2 and 36) because both will ultimately be turned over to DOE under UMTRCA and no groundwater exposure would be possible.

Remediation goals for the selected remedy are specified in the ROD RAOs by the phrase “*concentrations dictated by Federal and State standards or background*” in the above excerpt from ROD Appendix A. The NCP specifies that the ROD shall “*indicate, as appropriate, the remediation goals ... that the remedy is expected to achieve and that performance shall be measured at appropriate locations in the ground water, surface water, soils, air, and other affected environmental media.*” These remediation goals were derived from the evaluation of ARARs, as discussed in Section 2.1.2 of the present report.

A former depiction of the Remedial Action Target Areas is shown in Figure 8 of the ROD. Over time, these Target Areas have been better defined using more groundwater quality data from new wells, and they have changed shape and location as the impacted water has migrated. In the present report, we refer to the Target Areas as the seepage-impacted parts of three hydrostratigraphic units: the Southwest Alluvium, Zone 1 (the Gallup Sandstone Upper Member), and Zone 3 (the Gallup Sandstone Lower Member). Figure 6 of the 2006 Annual Report (N.A. Water Systems, 2007) shows the distribution of impacted groundwater in each of these three hydrostratigraphic units during October 2006.

2.1.2 ARARs

The remediation goals, identified as contaminant-specific groundwater ARARs that relate to the protection of potential and existing drinking water supplies, were specified in Table 2 of the ROD. The ARARs were established from the following enforceable standards and criteria:

- National Primary Drinking Water Standards (Maximum Contaminant Levels, MCLs): MCLs were selected as the clean-up levels for arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, radium-226, radium-228, and gross alpha.
- New Mexico Water Quality Control Commission (NMWQCC) regulation standards: NMWQCC standards were selected as the clean-up levels for aluminum, cobalt, copper, molybdenum, nickel, zinc, chloride, and uranium-238. NMWQCC standards and MCLs were the same for barium, cadmium, chromium, lead, mercury, and silver.

Additionally, the goals were based upon the following:

- Health-based standards, for those contaminants where MCLs and NMWQCC standards were not available: Health-based standards were calculated using reference doses, assuming a 70-kilogram individual who consumes 2 liters of water per day, for antimony, beryllium, thallium, and vanadium. Since the issuance of the ROD, MCLs have been published for antimony, beryllium, and thallium.
- Background standards where background levels were higher than federal and state standards: background standards were set for iron, manganese, sulfate, nitrate, and total dissolved solids (TDS). Alternate background standards for sulfate, nitrate, and TDS were proposed in a report issued by the NRC in 1996 (discussed below in Section 3). The latter changes were approved by the New Mexico Environment Department (NMED).

Appendix C of the ROD describes the evaluation of ARARs in greater detail. The ARARs are tabulated in Section 2.2 of this document in conjunction with a discussion regarding constituents of concern (COCs) and potential ARAR modifications.

2.1.3 Components of Selected Remedy

The remedy selected in the ROD for the UNC groundwater operable unit consisted of six components and incorporated source control remedial action (surface reclamation, capping, and mill decommissioning) under the NRC's licensing requirements, as specified in the Memorandum of Understanding (MOU) between EPA and NRC (EPA, 1988): The six components of the remedy are described in Section 6.1 of the ROD, as follows (the underlines are original):

1. *Implementation of a monitoring program to detect any increases in the areal extent, or concentration of groundwater contamination outside the tailings disposal area.* *To ensure that contamination does not exist beyond cleanup target areas developed in the Feasibility Study, a groundwater monitoring program will be implemented during the remedial design. The monitoring program will consist of a groundwater monitoring network comprised of a series of wells to measure water levels and water quality. The monitoring points should be located upgradient, downgradient, and cross-gradient of seepage plumes to further define the extent of contamination in Zones 1 and 3 of the Upper Gallup Sandstone, and the southwest alluvium. Results of monitoring results will be evaluated against contaminant specific ARARs or background to adjust target area (sic) to include any downgradient areas impacted by tailings seepage. The extent of contamination in each aquifer, concentration of contaminants in each well, and observed*

saturated thickness shall be used to identify the most effective pumping well locations.

2. “Operation of existing seepage extraction systems in the Upper Gallup aquifers. Because seepage from tailings has migrated into underlying Zone 1 and Zone 3 sandstones, the selected remedy includes operation of the East pump-back wells in Zone 1 and the Northeast pump-back wells in Zone 3 until adequate dissipation of the tailings seepage mound has been achieved. Operation of these two pump-back systems will be integrated with active seepage remediation that may be required by the NRC inside the tailings disposal area, and with active seepage collection as required by EPA outside the disposal area.
3. “Containment and removal of contaminated groundwater in Zone 3 of the Upper Gallup Sandstone utilizing existing and additional wells. Active remediation of Zone 3 outside the tailings disposal site will be performed in areas contaminated by tailings seepage. The extent of the tailings seepage plume will be determined during remedial design, prior to extraction well installation, and will be delineated on the basis of groundwater flow directions in the aquifer in conjunction with identification of the margin or amount by which standards are exceeded (including background) for hazardous constituents in groundwater. Seepage collection in Zone 3 will be designed to create a hydraulic barrier to further migration of contamination. Final well locations will be guided by observed saturated thicknesses in Zone 3 and the extent of the tailings seepage plume as defined above. Data obtained during performance monitoring of the extraction system should be used determine the optimum rate of pumping and extent and duration of pumping actually required.”
4. “Containment and removal of contaminated groundwater in the southwest alluvium utilizing existing and additional wells. Active remediation in the southwest alluvium will be performed in areas contaminated by tailings seepage. The extent of the tailings seepage plume outside the tailings disposal area will be determined prior to extraction well installation. Delineation of alluvial contamination will be based on groundwater flow directions in the aquifer in conjunction with identification of the margin or amount by which standards are exceeded (including background) for hazardous constituents in groundwater. Seepage collection in the southwest alluvium will be designed to create a hydraulic barrier to further migration of contamination while the source is being remediated. The number of extraction wells required and their final locations will be determined from the observed saturated thicknesses in the alluvium and the extent of the tailings seepage plume as defined above. If existing monitoring wells are likely to intercept



tailings seepage, then contingency plans should be developed to pump from these wells. Data obtained during performance monitoring of the extraction system should be used to determine the optimum rate of pumping and extent and duration of pumping actually required.

5. *“Evaporation of groundwater removed from aquifers using evaporation ponds supplemented with mist or spray systems to enhance the rate of evaporation.” Tailings seepage extracted in pumping wells will be directed to an evaporation disposal system consisting of lined evaporation ponds and mist or spray evaporation systems. Inflow to the evaporation disposal system will be from current and required extraction wells outside and/or within the tailings disposal area. The evaporation pond system, coupled with mist and spray evaporation systems, will be sized and operated in order to provide sufficient evaporative capacity for maintenance of a reasonable operational water balance. Optimization of the evaporation disposal system should occur during the first several months of operation, and shall include pilot testing to determine the optimum pH for water evaporation.*
6. *“Implementation of a performance monitoring and evaluation program to determine water level and contaminant reductions in each aquifer, and the extent and duration of pumping actually required outside the tailings disposal area.” In order to evaluate predicted reductions in contaminant concentrations with time in a particular aquifer, and declines in pumping rates, a performance monitoring program shall be implemented. Monitoring well locations shall be chosen at critical points to allow effectiveness evaluations of hydraulic capture zones in collected tailings seepage. Performance monitoring during active seepage remediation will allow a determination to be made regarding the adequacy of groundwater remedial actions outside the tailings disposal area at the United Nuclear Corporation Site. Monitoring data will also be used to aid in making any modifications in remediation action outside the tailings disposal area, in order to meet CERCLA requirements.”*

2.1.4 Remediation Contingencies

Appendix A of the ROD summarized the hydrologic impact of the selected remedy as predicted by groundwater modeling in the FS, including the uncertainties associated with the model predictions of aquifer restoration rates and the contingencies to be considered depending on the effectiveness of remedial actions as determined from regular performance evaluations. Appendix A stated that the goal of the selected remedy was to “*restore groundwater outside the tailings disposal area to concentrations dictated by Federal and State standards or background to the maximum extent practicable and to the extent necessary to adequately protect public*



health and the environment.” EPA stated that the remedy performance evaluation program may indicate that the response objectives have been met and that the remedy is complete. However, EPA also anticipated that the performance evaluation results may indicate occurrence of the following “remediation contingency” conditions:

- *“Operational results may demonstrate that it is technically impractical to achieve all cleanup levels in a reasonable time period, and a waiver to meeting certain contaminant specific ARARs may require re-evaluation as a result.”*
- *“Operational results may also demonstrate significant declines in pumping rates with time due to insufficient natural recharge of aquifers. The probability of significant reductions in the saturated thickness of aquifers at the Site must be considered during performance evaluations since much of the water underlying the tailings disposal area is the result of mine water and tailings discharge, both of which no longer occur. In the event that saturated thicknesses cease to support pumping, remedial activity would be discontinued or adjusted to appropriate levels.”*

The fact that both of these contingency conditions have occurred, to varying degrees, in each of the hydrostratigraphic units is a principal reason that EPA has directed UNC to conduct this SWSFS. An example of the first contingency is that UNC has submitted to EPA the results of multiple geochemical evaluations that support a demonstration that it is technically impracticable to achieve the sulfate and TDS standards in each of the hydrostratigraphic units (discussed further in Section 3 below).

A second example of the first contingency condition is stated in the *Second Five-Year Review Report* (EPA, September 2003): *“...the portion of the Zone 3 plume that extends off the property into Section 1 was eliminated as a point of exposure (POE) because there is now less than 5 ft of saturation, which is projected to drain out to pre-mining levels in about 10 years. The decision to eliminate this area as a POE is documented in a letter from the NRC (NRC, 1999).”*

Regarding the second contingency, pumping wells in Zones 1 and 3 have been demonstrated to have reductions of saturated thickness (critical loss of pumping rates) significant enough to warrant the cessation of pumping. Furthermore, Tables 1, 9, and 14 in the 2006 Annual Report show that specific performance monitoring wells have gone dry independent of corrective action pumping. The specific contingency conditions will be considered in the assembly and detailed analysis of alternatives in the SWSFS.

2.2 Clean-up Standards

As described in Section 2.1.2, the remediation goals were identified from the contaminant-specific groundwater ARARs that relate to protection of potential and

existing drinking water supplies, established from MCLs, New Mexico Water Quality Standards, background, and health-based standards (see Table 1 below). Table 1 encompasses a broader list of parameters than were actually determined to be COCs. Table 1 also shows the values of proposed modifications to background standards, and the footnotes show relevant changes to ARARs that have been proposed (each of these modifications is discussed further in later sections of this document).



Table 1: Contaminant-Specific Groundwater ARARs

Contaminant	ROD ARAR ^A	Source of ROD ARAR	Cleanup Level or ARAR Currently Exceeded in Impacted Wells Outside Sections 2 and 36??	Cleanup Level or ARAR Currently Exceeded in Background Wells Outside Sections 2 and 36??
Aluminum	5.0	NMWQCC ^J	No	No
Antimony ^B	0.014	Health-based	NOT ANALYZED	NOT ANALYZED
Arsenic ^C	0.05	MCL	No	No
Barium	1.0	MCL, NMWQCC	NOT ANALYZED	NOT ANALYZED
Beryllium ^D	0.017	Health-based	No	No
Cadmium ^E	0.01	MCL, NMWQCC	No	No
Chromium	0.05	MCL, NMWQCC	NOT ANALYZED	NOT ANALYZED
Cobalt	0.05	NMWQCC	Yes ^K	No
Copper	1.0	NMWQCC	NOT ANALYZED	NOT ANALYZED
Iron	5.5	Background Level	NOT ANALYZED	NOT ANALYZED
Lead	0.05	MCL, NMWQCC	No	No
Manganese (Mn)	2.6	Background Level	No	Yes ^L
Mercury	0.002	MCL, NMWQCC	NOT ANALYZED	NOT ANALYZED
Molybdenum	1.0	NMWQCC	No	No
Nickel	0.2	NMWQCC	Yes ^M	No
Selenium	0.01	MCL	No	No
Silver	0.05	MCL, NMWQCC	NOT ANALYZED	NOT ANALYZED
Thallium ^F	0.014	Health-based	NOT ANALYZED	NOT ANALYZED
Vanadium	0.7	Health-based		
Zinc	10	NMWQCC	NOT ANALYZED	NOT ANALYZED
Chloride (Cl)	250	NMWQCC	No	No
Sulfate (SO ₄) ^G	2,160 (2,125)	Background Level (proposed)	Yes ^{N1}	Yes ^{N2}
Nitrate ^G	30 (190)	Background Level (proposed)	Yes ^{O1}	Yes ^{O2}
Total Dissolved Solids (TDS) ^G	3,170 (4,800)	Background Level (proposed)	Yes ^{P1}	Yes ^{P2}
Radium 226 and 228	5 pCi/l	MCL	No	No
Uranium ^H	5.0 mg/L	NMWQCC	No	No
Thorium-230 ^I	15 pCi/l	MCL	No	No
Gross Alpha	15 pCi/l	MCL	No	No

Notes:

- (A) In mg/l, except as noted – two rightmost columns benchmarked to October 2006
- (B) Antimony MCL of 0.006 mg/L published since ROD issuance.
- (C) Arsenic MCL of 0.010 mg/L published since ROD issuance.
- (D) Beryllium MCL of 0.004 mg/L published since ROD issuance.
- (E) Cadmium MCL reduced to 0.005 mg/L since ROD issuance.
- (F) Thallium MCL of 0.002 mg/L published since ROD issuance.
- (G) Background standards proposed in 1996 NRC report are shown in parentheses.
- (H) Uranium MCL reduced to 0.03 mg/L, effective 12/03; proposed NMWQCC for uranium is 0.007 mg/L; background values discussed in Section 3 of this report.
- (I) Based on 15 pCi/l gross alpha.
- (J) NMWQCC - New Mexico Water Quality Control Commission



- (K) Zone 1, well EPA 5 = 0.06 mg/L
- (L) Zone 1, well EPA 4 = 3.53 mg/L
- (M) Zone 1, well EPA 5 = 0.06 mg/L
- (N) N1 – Zone 1, multiple wells, highest at well 515 A = 4,280 mg/L
Southwest Alluvium, multiple wells, highest at well 509 D = 5,180 mg/L
- N2 – Zone 1, multiple wells, highest at well EPA 4 = 4,090 mg/L
Southwest Alluvium, multiple wells, highest at well SBL 1 = 5,320 mg/L
- (O) O1 – Zone 1, multiple wells, highest at well EPA 7 = 134 mg/L
Southwest Alluvium, multiple wells, highest at well GW 3 = 100 mg/L
- O2 – Southwest Alluvium, multiple wells, highest at well 627 = 108 mg/L
- (P) P1 – Zone 1, multiple wells, highest at well 515 A = 7,710 mg/L
Southwest Alluvium, multiple wells, highest at well 632 = 7,120 mg/L
- P2 – Zone 1, multiple wells, highest at well EPA 4 = 4,330 mg/L
Southwest Alluvium, multiple wells, highest at well SBL 1 = 8,820 mg/L

The ROD identified several contaminants to be of specific concern (i.e., potential “Contaminants of Concern” or COCs), based on data collected during the Remedial Investigation (RI; see EPA, 1988). Table 6 in the ROD summarized the contaminants for which the maximum detected concentrations exceeded contaminant-specific ARARs in each of the hydrostratigraphic units. The following Table 2 is equivalent to the ROD Table 6:

**Table 2: Compounds Exceeding Standards
(Source: ROD, 1988)**

Contaminant	Zone 3	Zone 1	Southwest Alluvium
Aluminum	X	X	
Arsenic	X	X	
Cadmium	X	X	X
Cobalt	X	X	X
Manganese	X	X	X
Molybdenum	X	X	X
Nickel	X	X	X
Selenium	X	X	X
Nitrate	X	X	X
Total Dissolved Solids (TDS)	X	X	X
Radium 226 and 228	X		
Gross Alpha	X	X	X

A second list of potential COCs was provided in the Declaration of the ROD, which indicated that the “hazardous substances of primary concern” were considered, at the time, to be arsenic, cadmium, cobalt, nickel, radium 226-228, selenium, and gross alpha.

It should be noted that several constituents (including uranium, thorium-230, and vanadium) were not listed in the ROD as exceeding their standards, despite RI data to the contrary. Each of these compounds appears to have been excluded because

they were detected at only a few locations in Zone 3, very close to the tailings ponds. For example, thorium-230 was detected at very high concentrations in Well 610 (up to 41,300 pCi/L during the RI), but exceeded its MCL of 15 pCi/L at no other locations, and it was concluded in the RI that it was not migrating far from the tailings ponds due to pH control of its solubility. Thorium-230, uranium, and vanadium were included in the original list of performance-monitoring analytes comprising all constituents that were in exceedance of EPA ARARs or NRC groundwater protection standards at the Site (Canonie Environmental, 1989, *Remedial Design Report*; see their Table 1.3).

Currently, only cobalt, nickel, nitrate, sulfate, and TDS exceed their remediation standards in impacted wells outside of Sections 2 and 36 (see Table 1). Of these, nitrate, sulfate and TDS have been shown to have higher concentrations in background water than in off-site tailings-impacted groundwater (discussed further in Section 3).

2.3 Background Contaminant Levels

Background contaminant concentration levels were used as clean-up criteria for a specific contaminant if they represent a higher concentration than the federal or state standards for that contaminant. For the contaminants at the Church Rock Site, EPA established in both the FS and the ROD that background levels of contaminants are based on the quality of the groundwater in the alluvium and Upper Gallup Sandstone in the vicinity of the Site prior to tailings disposal. The ROD indicates that these background levels have been set by EPA “*based on an assessment of the available information from (1) pre-tailings groundwater monitoring at the Site and (2) regional hydrogeochemical sampling in the Gallup Sandstone and alluvium.*”

The ROD also states that “*should additional information become available that would significantly alter the estimation of background levels, such information would be evaluated in terms of its impact on remedial actions in each aquifer.*” As shown on Table 1, additional information regarding background concentrations has become available for four constituents (sulfate, TDS, nitrate, and uranium), and modifications to these background levels have been proposed as described in Section 3 of this document. In addition, further information regarding background levels of combined radium has become available for Zone 1 and the Southwest Alluvium (see Section 3.4 below).



Site-Wide Supplemental Feasibility Study, Part I

Church Rock Remediation Standards Update

Section 3

NRC Source Materials License

3.1 License Standards and Performance Monitoring

The U.S. Nuclear Regulatory Commission (NRC) applies Source Materials License Number SUA-1475 to the Site (Reference Number 40-8907). Through November 30, 2006, 38 formal amendments have been applied to the license. Section 30 of the license specifies the requirements of Site-wide groundwater compliance monitoring. The specific wells mentioned in Section 30.A are differentiated as to requirements for both quarterly groundwater quality and water-level monitoring, versus quarterly water-level monitoring only.

Some of the wells cited in Section 30.A have gone dry. The *2006 Annual Corrective Action Report* (N.A. Water Systems, January 2007) summarizes the status of these wells, their original intended use (pumping or monitoring), whether they are monitored quarterly for water quality or water levels or both, which wells have been designated point-of-compliance (POC) wells by the NRC, the purpose of the wells in the compliance monitoring program, and reasons that certain wells were eliminated from the monitoring program. This information is presented in the 2006 Annual Report in summary tables for each hydrostratigraphic unit: Table 1 (Southwest Alluvium); Table 9 (Zone 3); and Table 14 (Zone 1).

Section 30.B of the license specifies the groundwater protection standards (GWPS) for the POC wells in each hydrostratigraphic unit, as discussed below.

3.1.1 Southwest Alluvium Hydrostratigraphic Unit

The POC wells are GW 1, GW 2, GW 3, 632, EPA 23, EPA 28, and 509 D. Figure 1 (attached) shows that some of the POC wells are outside the Section 2 boundary (GW 1, GW 2, GW 3, and EPA 28 are located in Section 3).

The GWPS apply uniformly to all three hydrostratigraphic units' POC wells (except for combined radium), as follows:

“arsenic = 0.05 mg/L, beryllium = 0.05 mg/L, cadmium = 0.01 mg/L, gross alpha = 15.0 pCi/L, lead = 0.05 mg/L, lead-210 = 1.0 pCi/L, radium-226 and 228 = 5.0 pCi/L in Zone 3, 5.2 pCi/L in the Southwest Alluvium, and 9.4 pCi/L in Zone 1; selenium = 0.01 mg/L, thorium-230 = 5.0 pCi/L; total trihalomethanes = 0.08 mg/L; uranium = 0.3 mg/L and vanadium = 0.1 mg/L.”

EPA has set Site groundwater standards for some, but not all, of the constituents regulated by the NRC; and the NRC does not have GWPS for some constituents for

which EPA has set Site standards. Where both the EPA and NRC have set Site standards, in some cases the concentrations are the same, while in other cases they are not. Specific comparisons are provided in the column headers on each page of the historic groundwater quality data tables provided in Appendices A, B, and C in the 2006 Annual Report. In practice, when a constituent has both NRC and EPA standards, UNC understands the lower of the two concentration values to be the effective compliance standard.

3.1.2 Zone 1 Hydrostratigraphic Unit

The POC wells are 614, 604, EPA 4, EPA 5, and EPA 7. Figure 1 shows that some of the POC wells are located outside the Section 2 boundary (EPA 4, EPA 5, and EPA 7 are located in Section 1). The GWPS have been summarized above under the subsection for the Southwest Alluvium.

3.1.3 Zone 3 Hydrostratigraphic Unit

The POC wells are 517, 613, 708, and 711. Figure 1 shows that Well 613 is located within Section 2; the other three wells are located in Section 36, which is also UNC property. The GWPS have been summarized above under the subsection for the Southwest Alluvium.

3.2 1996 NRC Statistical Analyses of Background Water Quality

On June 10, 1996, the NRC released a report titled:

Evaluation of the Statistical Basis for Establishing Background Levels and Remediation Standards at the UNC Church Rock Uranium Mill Tailings Disposal Facility – Gallup, New Mexico.

The stated purpose of this NRC report was to deliver the NRC staff position on groundwater constituent background levels at the UNC uranium mill and tailings Site at Church Rock. The UNC mill and tailings disposal area are under the jurisdiction of NRC regulations; in addition, the tailings disposal area is on the National Priorities List (EPA, Superfund).

Several of the ARARs in the ROD were based on background conditions designated in the ROD. The ROD also stated that: *“Should additional information become available that would significantly alter the estimation of background levels, such information would be evaluated in terms of its impact on remedial actions in each aquifer.”* Background levels used to establish remediation standards for nitrate, sulfate, and total dissolved solids (TDS) were contested by UNC since the signing of the EPA’s ROD in 1988. Although these constituents are not included in the NRC license, under a Memorandum of Understanding (MOU; EPA, August 26, 1988), the NRC is the lead agency in matters concerning surface reclamation and source control. Because the constituents in question were constituents in the tailings liquor,

NRC elected to analyze the several years of monitoring data that had been collected to help resolve the issue so that appropriate remediation strategies could be developed and implemented.

In July 1995, the NRC agreed to analyze the UNC and other available data for the purpose of discussing possible revisions to the ARARs with EPA (NRC, August 10, 1995). NRC statistical analyses employed non-parametric methods. Review of the data by NRC staff indicated that “...the ARARs for nitrate, sulfate, and TDS are too low because background levels used for establishing the ARARs do not appear to be based upon all available site-specific data representing spatial and temporal variations” (NRC, 1996; p. 4).

Following issuance of NRC’s report, NRC’s revised background levels were endorsed as revised remediation standards by the New Mexico Environment Department (NMED), as documented in the letter of January 6, 1998, from NMED to the EPA. The NRC’s key statistical results are discussed below.

3.2.1 Nitrate

The ARAR for nitrate at the UNC Mill Site is 30 mg/L. NRC concluded that the tailings are not the major contributor of nitrates to the groundwater at the Site (p. 10). They proposed a background concentration of 190 to 205 mg/L for all three hydrostratigraphic units (pp. 19 and 20, NRC Tables 3, 4, and 5). No nitrate concentrations exceed 190 mg/L anywhere on the Site.

3.2.2 Manganese

The ARAR for manganese at the Site is 2.6 mg/L. NRC proposed a background concentration of 2.8 to 2.9 mg/L for all three hydrostratigraphic units (pp. 19 and 20, NRC Tables 3, 4, and 5). NRC noted that background levels for manganese and iron were difficult to establish with certainty because of the lack of data distinguishing dissolved from colloidal aqueous species.

In reference to the Southwest Alluvium, NRC stated, “*The staff generally agrees with the background standard of set (sic) in the ROD, but does not support its use as a remediation standard...the standard as set in the ROD is probably not achievable*” (p. 15).

3.2.3 Sulfate and TDS

Sulfate is the single largest component of TDS in the Site groundwater, in both background and impacted wells (for example, see Figure 9 in the 2006 Annual Report). The ARAR for sulfate at the Site is 2,160 mg/L. NRC proposed a background concentration of 2,125 mg/L (lower than the ARAR) for all three hydrostratigraphic units (pp. 19 and 20, NRC Tables 3, 4, and 5).

The ARAR for TDS at the Site is 3,120 mg/L. NRC proposed a background concentration of 4,800 mg/L for all three hydrostratigraphic units (pp. 19 and 20, NRC Tables 3, 4, and 5).

NRC recommended that different remediation standards be set for sulfate and TDS, based upon multiple factors (p. 17) including: (1) present concentrations; (2) geochemical relationships between sulfate, TDS, and bicarbonate; (3) declining saturation levels in all three hydrostratigraphic units; (4) consideration of geochemical saturation levels for minerals with changing water content; and (5) possible remediation strategies for sulfate and TDS.

NRC made the following key recommendations for sulfate and TDS (p. 17):

*“Establishing appropriate remediation standards which account for all of the above factors may be difficult to do because of the large uncertainties associate (sic) with future saturation levels at the Site. **For these reasons, the staff recommends that EPA consider dropping the standards for these constituents.**”* (Emphasis added.)

Touching on an important issue that has been further developed by UNC (discussed below), NRC stated (p. 16):

*“If the system is effectively ‘drying out,’ then as the TDS increases, the solubility of gypsum ($\text{CaSO}_4 \bullet 2\text{H}_2\text{O}$) will increase ... the standards may become increasingly difficult to achieve with time. Adding fresh water to the system has been considered as a possible remediation strategy. **Although fresh water injection may help dilute the salts in the system, the staff is concerned that there will be no time at which this proposed activity could cease.**”* (Emphasis added.)

NRC emphasized the future need for EPA and NRC to consider the changing groundwater chemistry as the water saturation levels decline in the hydrostratigraphic units: *“Consideration of equilibrium with gypsum, calcite, and gibbsite is acceptable...”* (p. 16).

3.2.4 Supporting Geochemical Analyses by UNC

3.2.4.1 Zone 1 Groundwater Geochemistry (May 2000)

Earth Tech (May 2000) analyzed the Zone 1 groundwater chemistry, including conducting MINTEQ simulations to evaluate the gypsum saturation indices with respect to sulfate concentrations (discussed below). They noted that, at that time, sulfate, TDS, and manganese in both impacted water and background water would continue to exceed the Site standards in the future. Although these constituents are non-hazardous and present in the background water, they are considered COCs for Zone 1.

This report is reviewed in some detail below, because many of the key geochemical concepts are relevant to occurrences of manganese, sulfate, and TDS in both impacted and background waters in all three hydrostratigraphic units.

Manganese

Manganese, like other metals, exhibits decreasing concentrations as the acidic seepage-impacted water is neutralized, but the concentrations do not always decrease to the current standard. Manganese has exceeded the standard over the many years of monitoring background well EPA 8 (see Figure 1). An important natural geochemical mechanism for decreasing manganese concentrations in near-neutral pH water is precipitation of manganese as a carbonate mineral phase. Carbonate is added to the water by dissolution of bedrock matrix calcite or dolomite. The inverse relationship between bicarbonate and manganese concentrations in individual wells empirically demonstrates that manganese carbonate precipitation is occurring (for example, see Figure 12, Earth Tech, May 2000).

Earth Tech evaluated the extent of carbonate precipitation as a mechanism for removal of manganese from solution by inputting groundwater quality data using MINTEQ simulations. MINTEQ is a widely accepted aqueous speciation model distributed by EPA. Water quality parameters are input to the model, which calculates the distribution of the aqueous species as dissolved, adsorbed, and precipitated species at equilibrium conditions (Earth Tech's summary of the evidence for Zone 1 equilibrium conditions will not be reviewed here.)

The MINTEQ results for the highest manganese concentrations at well EPA 5 indicated that when the solution bicarbonate concentration is approximately 710 mg/L, manganese concentrations are below the standard of 2.6 mg/L. Based on such modeling results, Zone 1 waters with bicarbonate concentrations less than 710 mg/L are expected to continue to exceed the Site standard.

At Well 515 A (see Figure 1), bicarbonate concentrations were less than 600 mg/L and observed manganese concentrations were greater than the standard, as the model predicts. Exceedances will continue unless the bicarbonate concentration increases. However, as the water reaches neutral pH conditions, as in 515 A, carbonate dissolution ceases and additional bicarbonate will not enter solution. The result is that the manganese standard will not be obtained. It is important to realize that this applies equally to background water where the pH is neutral. Background wells EPA 8 and EPA 4 have shown long-term manganese exceedances that are unrelated to seepage-impacted water. Like the NRC, UNC concluded that manganese



should not be used as a remediation standard because it is naturally occurring, is dependent upon Eh-pH conditions that are not a function of tailings seepage, and is not universally achievable because of the first two factors.

Sulfate

Sulfate above the standard in background wells indicates dissolution of the naturally occurring mineral gypsum (pervasively present in arid environments such as this Site). As the background mine water flows through the alluvium and into the Zone 1 hydrostratigraphic unit, gypsum dissolved, resulting in a calcium-sulfate type of background water. A second source of sulfate in the tailings-impacted part of Zone 1 was the acidic seepage-impacted water. Sulfate in the impacted water originated primarily from sulfuric acid used in the milling process and occurs in concentrations of tens of thousands of parts per million.

Water quality data were evaluated using MINTEQ. The model results (see Earth Tech's Figure 16) showed the modeled gypsum saturation indices for water at each well location (both background and seepage-impacted). The plotted indices points are all slightly above and very close to where gypsum saturation occurs (the "zero line" on the data plots). The indices unequivocally demonstrated that water in Zone 1 has equilibrated with gypsum regardless of whether it approaches that equilibrium from the concentrated tailings liquors that precipitate gypsum to attain equilibrium, or the naturally-recharged background waters that dissolved native gypsum to attain equilibration long before the tailings were disposed. (This generalization applies, in fact, to all three Site hydrostratigraphic units, as discussed further below.)

That the indices are close to the zero line shows that gypsum precipitation and/or dissolution are important controls on Zone 1 sulfate concentrations. If this were not the case, the saturation indices would be scattered on the chart, rather than nearly parallel to the zero saturation index line. **This plot confirms dissolution of gypsum as the mechanism for the occurrence of sulfate in background groundwater at concentrations above the standard. The fact that the indices for the tailings-impacted wells all fall at the same saturation index attests to the ability of the system to attenuate the sulfate in tailings liquor to equivalent concentrations as the background.**

As a result, it is not possible for sulfate concentrations to change much from what they are or to meet the sulfate standard outside the property boundary in Section 1.



TDS

Because sulfate comprises the largest major ion contribution to TDS, TDS concentrations are primarily determined by the concentrations of sulfate in the water. This is true for all three hydrostratigraphic units and the background waters. Sulfate is expected to remain at concentrations such that TDS will continue to exceed the standard in both impacted and background waters.

3.3.4.2 Southwest Alluvium Groundwater Geochemistry Report (June 2000)

Sulfate

Earth Tech (June 2000) employed MINTEQ simulations to evaluate the controls on sulfate distribution in the Southwest Alluvium. The resultant saturation indices (see Earth Tech Figure 16) demonstrate that water (both trailings-impacted and non-impacted) in the Southwest Alluvium is near equilibrium with gypsum.

Therefore, the corrective action program (then involving pumping and evaporation) is not and will not be an effective means to reduce sulfate concentrations because they are controlled entirely by natural geochemical processes. This important conclusion applies to both seepage-impacted areas and background waters.

TDS

As throughout the entire Site, since sulfate comprises the largest component of TDS, the conclusion directly above (in bold) applies to TDS as well.

3.3.4.3 Southwest Alluvium NA Report and TI Evaluation (November 2002)

Earth Tech (November 2002) assessed the results of an 18-month-long natural attenuation (NA) test (pumping wells were shut off in January 2001), and presented a technical analysis in support of the application of a Technical Impracticability (TI) Waiver to the Southwest Alluvium.

The NA evaluation included statistical analyses of time-series data for multiple constituents. There were no changes in concentration trends for manganese and sulfate. TDS showed an increasing trend due to upward trends in the component ions, bicarbonate and chloride (which are non-hazardous parameters that are useful indicators that the seepage-impacted front has passed). They noted that near the end of the NA test period, bicarbonate and chloride appeared to have stabilized, as would be expected once the rebound from ceasing the pumping had stabilized.



The TI evaluation included a review of ARARs or clean-up standards, the proposed spatial extent of the TI decision, development of a conceptual geochemical model for the evolution of the impacted and background water quality, MINTEQ simulations for both gypsum and calcite saturation indices, determination of potential receptors, evaluation of restoration potential, and cost estimates.

The restoration timeframe for sulfate (and thus TDS) concentrations to meet the Site standards is controlled by geochemical mechanisms that have been described in the reports referenced above. In EPA's *First Five-Year Review Report* (1998), EPA recognized that sulfate and TDS in non-impacted, background waters exceed the Site standards and that the concentrations will not change substantially in response to remediation efforts: "*Restoration of the groundwater to meet the standards is certainly beyond the realm of active remediation.*"

However, if restoration timeframes are evaluated in terms of natural attenuation of seepage-impacted water, it has been empirically demonstrated that restoration has occurred rapidly. The tailings liquid typically had sulfate concentrations of approximately 57,000 mg/L (concentrations as high as 144,000 mg/L were reported in the North Cell). Neutralization within the tailings impoundment reduced concentrations by 73 percent, to 15,200 mg/L (Earth Tech's p. 3-13 cites relevant references).

After the seepage contacted the Southwest Alluvium matrix (which is relatively high in calcite content, which promotes buffering) and groundwater migrated downgradient to Well 801 (see Figure 1), the natural neutralization had reduced concentrations another 19 percent, to about 4,600 mg/L (value reported for Well 801 in October 1989 prior to turning on the remedial action system; p. 3-13). An additional 5 percent decrease in original seepage-sourced sulfate concentrations occurred between Well 801 and the property, as represented by well GW 1. **In total, the natural geochemical processes reduced the sulfate concentrations by as much as 97 percent by the time the seepage-impacted water reached the property boundary.**

3.3.2.4 2006 Annual Report

Since 2003, N.A. Water Systems (previously USFilter Engineering & Construction) has prepared the annual Site corrective action reports. These reports have included review of the occurrence and significance of multiple constituents in all three hydrostratigraphic units, in both the impacted and background waters, including manganese, sulfate, and TDS. Some of the key relevant conclusions from the 2006 report are summarized below:



- The October 2006 exceedances of cobalt and nickel in Well EPA 5 (Zone 1 in Section 1), both by one part per billion, comprise the only exceedances of hazardous constituents outside the UNC property boundary. No other hazardous constituents exceed Site standards anywhere outside the UNC property boundary.
- Hydraulic containment is not a necessary feature of the corrective action program in the Southwest Alluvium because of the geochemical attenuation that occurs naturally.
- Evaluation and prediction of constituent concentrations in the Southwest Alluvium are predicated on understanding the geochemical evolution of both the background water quality and later changes associated with passage of the seepage-impact front. **Hazardous constituents derived from seepage impact are effectively attenuated to acceptable concentrations within the Site boundary.**
- Sulfate, TDS, and manganese are non-hazardous constituents that exceed standards outside the Site boundary in both seepage-impacted and background wells. Sulfate (the primary component of TDS) tends to temporarily fall below the standard in the migrating reaction zone associated with the front and northwestern flank of the migrating seepage-impacted groundwater in the Southwest Alluvium (see Figure 8, N.A. Water Systems, January 2007). Ahead of this migrating front, background concentrations for sulfate and TDS tend to exceed the standards, but this water quality is unrelated to seepage impact and application of the Site standards is inappropriate. Behind this migrating front, impacted groundwater quality off-site will tend to have sulfate and TDS levels approximately equal to, or lower than, those in the background water. Ahead of the current seepage-impact front, downgradient background well SBL 1 has shown very high sulfate and TDS, and minor exceedances of manganese, cobalt, and nickel that are not due to seepage impact.
- Both the Southwest Alluvium and Zone 1 natural systems are at least as effective as the former active remediation systems in attenuating the seepage-impacted water. Acidic seepage is being neutralized, resulting in attenuation of metals and radionuclides. Natural geochemical conditions related to gypsum equilibrium and bicarbonate availability will control sulfate and manganese concentrations in both hydrostratigraphic units, regardless of whether or not the extraction wells are operated.
- Outside the UNC property boundary in Zone 1, the post-pumping groundwater quality continues to improve overall. The October 2006 exceedances of cobalt and nickel in Well EPA 5, both by one part per billion, comprise the only exceedances of hazardous constituents anywhere outside the UNC property boundary. The exceedances of sulfate and TDS in Wells EPA 5 and EPA 7



(see Figure 1) reflect geochemical equilibrium of the groundwater with gypsum; these constituents are non-hazardous.

- The degree of seepage impact in Zone 1 is stable to diminishing. The continuing improvement in off-site water quality, combined with the stability of on-site concentrations, leads to the conclusion that the Zone 1 groundwater corrective action program has achieved success.

3.3.2.5 Zone 3 MINTEQ Simulations

UNC has performed MINTEQ aqueous speciation simulations using October 2006 water quality data. The graphic data results and output files will be presented in the SWSFS; the key results are discussed here.

Impacted and background wells in Zone 3 show gypsum saturation indices distributed similarly to the indices derived from the Southwest Alluvium and Zone 1. The plotted Zone 3 modeled gypsum saturation indices for water at each well location are all slightly above and very close to where gypsum saturation occurs. The indices demonstrate that water in Zone 3 is near equilibrium with gypsum.

That the indices are close to the zero line shows that gypsum precipitation and/or dissolution are important controls on Zone 3 sulfate concentrations. If this were not the case, the saturation indices would be scattered on the chart, rather than nearly parallel to the zero saturation index line.

This confirms dissolution of gypsum as the mechanism for the presence of sulfate in background groundwater at concentrations above the standard. As noted above, TDS concentrations tend to mimic sulfate concentrations.

3.4 Amended NRC Standards for Chloroform (Now Total Trihalomethanes) and Combined Radium

UNC submitted two license amendment requests to the NRC: (1) a revised request for changing the Site-wide chloroform groundwater protection standard (UNC, 2005); and (2) a revised request for changing the method by which compliance with the combined radium groundwater protection standard is evaluated in the Southwest Alluvium and Zone 1 (UNC, 2006; N.A. Water Systems, 2006).

The NRC published its related Environmental Assessment (NRC, 2006a) finding that there would be no significant impact from the requested licensing actions, and subsequently amended (NRC, 2006b) the Site's Source Materials License as follows: (1) changing the former 0.001 mg/L chloroform GWPS to 0.08 mg/L for total trihalomethanes (TTHMs, comprising four compounds including chloroform) in all three hydrostratigraphic units; and (2) revising the former combined radium-226 and

–228 groundwater protection standard of 5 pCi/L to 5.2 pCi/L in the Southwest Alluvium and 9.4 pCi/L in Zone 1 (based on statistical analyses of background water quality; N.A. Water Systems, 2006). The fourth quarter (October) groundwater sampling event of 2006 represents the first quarter in which TTHMs have been analyzed and reported by the laboratory.

3.5 Compliance Status

Table 3 below (on the next page) summarizes the current compliance status at the Site – groundwater quality analytical data underpinning this Table are from October 2006.

Constituents exceeding EPA and NRC Site standards are indicated for each hydrostratigraphic unit. As explained in the footnotes to Table 3, the symbol “X” indicates an exceedance of the EPA ROD standard outside of Sections 2 and 36. The symbol “O” indicates an exceedance of the NRC license standard in point-of-compliance (POC) wells.



Table 3
Compliance Status
Constituents Exceeding EPA and NRC Site Standards for Each Hydrostratigraphic Unit
Based on October 2006 Groundwater Quality Data

Constituent	EPA Standard in ROD	NRC Standard in License	Southwest Alluvium	Zone 1	Zone 3	Comments
aluminum	5.0	NA				
arsenic	0.05	0.05			O	impacted & background
beryllium	0.017	0.05			O	impacted & background
cadmium	0.01	0.01			O	
cobalt	0.05	NA		X		Zone 1 well EPA 5 exceeded by 1 part per billion (ppb)
lead	0.05	0.05				
molybdenum	1.0	NA				
nickel	0.2	0.05		X O ²	O	Zone 1 well EPA 5 exceeded by 1 ppb; Zone 3, impacted & background
selenium	0.01	0.01				
vanadium	0.7	0.1			O	only Zone 3 well 613
chloride	250	NA				
manganese	2.6	NA		X		impacted & background
nitrate	30	NA	X	X		impacted & background
sulfate	2,160	NA	X	X		impacted & background
TDS	3,170	NA	X	X		impacted & background
radium 226+228	5.0 pCi/L	unit specific ¹			O	impacted & background
uranium	5.0	0.3			O	only Zone 3 well 613
TTHMs	NA	0.8		O ²	O	Zone 1 well 614; Zone 3 well 613
thorium-230	15 pCi/L	5 pCi/L			O	only Zone 3 well 613
lead-210	NA	1 pCi/L				
gross alpha	15 pCi/L	15 pCi/L			O	only Zone 3 well 613

Notes:

1 = NRC standards for combined radium are 5.2 pCi/L for Southwest Alluvium; 5.0 pCi/L for Zone 3; and 9.4 pCi/L for Zone 1.

2 = the "O" for nickel and TTHMs in Zone 1 will be addressed by the pending submittal of an Alternate Concentration Limits application to the NRC.

All units in mg/L unless noted otherwise.

"X" indicates an exceedance of the EPA ROD standard outside of Sections 2 and 36.

"O" indicates an exceedance of the NRC License standard in Point-of-Compliance (POC) wells.

NA means there is no NRC groundwater protection standard for that constituent.

TTHMs refers to total trihalomethane compounds.



Site-Wide Supplemental Feasibility Study, Part I

Church Rock Remediation Standards Update

Section 4

New or Revised MCLs and Health-Based Criteria

4.1 New MCLs -- Antimony, Beryllium, Thallium

Antimony and thallium have never been monitored at the Site, and they are not considered to be Site constituents of concern.

The new MCL for beryllium (0.002 mg/L) was promulgated in 1992. The new MCL is below the laboratory method detection limit that has been extant for all the historic groundwater quality monitoring at the Site. Therefore, it is not possible to evaluate the impact of the new MCL for this constituent.

Antimony, beryllium, and thallium were not listed as constituents of the tailings liquids in the ROD (their Table 3). These metals are not associated with the tailings seepage impact at the Site.

4.2 Revised MCLs

4.2.1 Arsenic

The arsenic MCL was reduced from 50 ug/L to 10 ug/L in January 2006.

There are no exceedances of arsenic using the new MCL in the Southwest Alluvium and Zone 1. Arsenic may be removed as a constituent of concern in these hydrostratigraphic units.

Groundwater quality data from Zone 3 during the last several years have few values falling between the old and new MCLs, with the exceptions of wells 711 and 504 B, which are located within the core of the seepage-impacted area (see Figure 2).

Figure 3 shows an arithmetic plot of Zone 3 arsenic concentrations from 1989 to October 2006 (the post-ROD period). The vertical scale is dominated by the concentration spike in background well NBL 1, such that the horizontal lines representing the current standard (orange) and the new MCL (blue), and the brunt of the data points, are squeezed quite close to the bottom. Figure 4 shows a semi-log plot of historic arsenic concentrations for the key wells 504 B, 711, EPA 13, and NBL 1 (these well IDs are flagged with bold type in Figure 2). Figure 4 shows graphically the statement made above: a change to the new MCL will affect impacted wells 504 B and 711.

Figures 3 and 4 also show that the historically highest arsenic concentrations in Zone 3 are shown in background well NBL 1. The next highest, long-term concentrations

are shown in impacted well EPA 13. It is important to realize that arsenic in Zone 3 has shown the highest concentrations in background water – background water must be taken into consideration of the new MCL.

The application of the new MCL will not affect the compliance status of background well NBL 1 or impacted well EPA 13 – they have exceeded both the old and the new MCLs. There is no anticipated exposure to the core of the Zone 3 seepage-impacted water, which is on UNC property (Section 36) that will be deeded to the DOE under UMTRCA Title II.

It is important to take background water quality into consideration. We have statistically analyzed the historic groundwater quality for arsenic in Zone 3 with the following results:

Table 4
Summary Statistics
Historic Arsenic Concentrations in Zone 3

	n	mean	median	95th percentile	low	high
all background	268	0.08	0.01	0.572	0.0005	2.30
all impacted	549	0.05	0.002	0.3172	0.0005	0.82

Note: All units excluding n are concentrations in mg/L

In generating Table 4, non-detects were assigned a value equal to one-half the detection limit (given the underlying data distribution, this has especially affected the calculation of the median and low values). **The summary statistics show that the range is approximately three times higher in the background wells, than in the impacted wells. The 95th-percentile upper concentration limit for background is approximately 60 times higher than the new MCL (0.010 mg/L), and approximately 30 times higher than the new MCL in the impacted wells.**

4.2.2 Cadmium

The cadmium MCL was reduced from 10 ug/L to 5 ug/L in 1991.

The new MCL would have no effect in the Southwest Alluvium or Zone 1, where all historic data are below 5 ug/L.

Only three Zone 3 wells would be affected by application of the new MCL: 517, 613, and EPA 14 (see locations in Figure 2). All of these wells are located in the core of the seepage-impacted zone.

Figure 5 shows an arithmetic plot of historic cadmium data for Zone 3. The wells relevant to consideration of the new MCL are shown in the semi-log plot in Figure 6:

wells 517, 613, and EPA 14. Long-term monitoring at well 613 shows that the concentrations are above both the old and new MCLs, so the potential affect of applying the new MCL is moot. Concentrations in well 517 fluctuate between the old and new MCL values. Well EPA 14 intermittently exceeded the old MCL, and may do so at a somewhat higher frequency under application of the new MCL.

Long-term monitoring shows that the exceedance well locations are stable and there appears to be no migration to other downgradient wells.

4.2.3 Uranium

The uranium MCL was set to 0.03 mg/L in 2003. The ARAR in the ROD of 5.0 mg/L was based on the New Mexico water quality standard. The New Mexico standard has also been changed to 0.03 mg/L. The NRC Site standard for uranium is 0.3 mg/L.

In the Southwest Alluvium, GE (March 2006) demonstrated empirically and geochemically that the range of uranium concentrations is the same in both the background waters and the seepage-impacted waters. The concentration of uranium in Site background waters ranges from a little less than 0.01 to slightly more than 0.3 mg/L in waters that exhibit fairly uniform bicarbonate concentrations.

Background water concentrations approach the existing GWPS set by the NRC. If not adjusted to take into consideration the character of non-impacted water and the geochemistry of uranium in the Southwest Alluvium, the adoption of the new MCL would result in complete dewatering of the Southwest Alluvium, for both background and seepage-impacted waters. GE recommended that the NRC standard be uniformly adopted for Southwest Alluvium compliance purposes. This recommendation is also considered to be protective of human health and the environment because it attains background concentrations in a zone of saturation that could not otherwise be used for consumption without extraordinary treatment to reduce the concentration of natural minerals to potable levels.

In Zone 3, two wells have exceeded the NRC uranium standard during the last several years: impacted wells 613 and EPA 14 (see the locations in Figure 2 here; and concentration time-series in Figure 45 in the 2006 Annual Report).

During the last several years, three wells have fluctuated between the NRC standard and the new MCL: impacted well 711; background to transitional-impact well 420; and background well NBL 1 (see Figure 2).

It is important to take background water quality into consideration. We have statistically analyzed the historic groundwater quality for uranium in Zone 3 with the following results:

Table 5
 Summary Statistics
 Historic Uranium Concentrations in Zone 3

	n	mean	median	95th percentile	low	high
all background	268	0.071	0.043	0.252	0.0002	0.380
all impacted	548	0.202	0.055	1.322	0.0002	2.48

Notes: All units excluding n are concentrations in mg/L
 Outlier 197.1 mg/L value at well 0719 removed in calculation of summary statistics

In generating Table 5, non-detects were assigned a value equal to one-half the detection limit. The summary statistics show that the range is approximately 7 times higher in the impacted wells, than in the background wells. Both the background and impacted wells have median concentrations lower than the NRC standard (0.3 mg/L) and greater than the new MCL (0.03 mg/L). The 95th-percentile upper concentration limit for the impacted wells is approximately 44 times higher than the new MCL. **The 95th-percentile upper concentration limit for background is approximately 10 times higher than the new MCL and slightly less than the NRC standard.**

In Zone 1, one well (614) has historic uranium concentration data that fall between the NRC standard and the new MCL. This well is located in Section 2 (Figure 1). Long-term monitoring indicates there is rapid attenuation and no migration to potential receptors.

4.3 New or Revised Health-Based Standards and Criteria

4.3.1 ROD Health-Based Standards

Many health-based standards have been revised or developed in the period since the ROD was published in 1988, due to changes in risk assessment methods, exposure assessment methods, and contaminant toxicity factors. The ROD contained health-based remediation standards for four constituents: antimony, beryllium, thallium, and vanadium (see ROD Table 2 and Table 1 above). Since the ROD was issued, MCLs have been promulgated for all of these compounds except vanadium (see discussion in Section 4.1). Therefore, vanadium is the only ROD COC that does not have a promulgated MCL. Antimony and thallium are not Site COCs.

The contaminant-specific groundwater ARAR concentration for vanadium listed in Table 2 of the ROD is 0.7 mg/L. Vanadium is not identified in the ROD as a compound exceeding its standard (see ROD Table 6 and Section 2.2 of this document), nor as a hazardous substance of primary concern in the Declaration for the ROD. This is appropriate because the RI data indicated that it only exceeded the

standard at one location (former well 610 in Zone 3, very near the north tailings pond).

The current groundwater performance monitoring standard is 0.1 mg/L, based on the NRC license standard, and the current analytical reporting limit is also 0.1 mg/L. Using this performance standard, vanadium has not been a significant constituent of concern because it has been detected infrequently during the period July 1989 to October 2006, except at wells 613 and 518, which are within the core of the Zone 3 plume.

In the *Second Five-Year Review Report* (EPA, September 2003), EPA identified two health-based criteria as “to be considered” (TBC) for vanadium which were lower than the ROD health-based standard: (1) the EPA Region 3 risk-based concentration (RBC) for tap water ingestion (0.26 mg/L) and (2) the EPA Region 9 preliminary remediation goal (PRG) for tap water ingestion (0.26 mg/L). These criteria are established by combining independently developed toxicity factors (e.g., an oral reference dose or RfDo) with “standard” exposure scenarios at fixed levels of risk. EPA concluded that because vanadium concentrations in groundwater are typically below these criteria (except at well 613, in the core of the Zone 3 plume), these changes did not affect the protectiveness of the remedy.

Since 2003, vanadium toxicity factors have been modified again, resulting in lower health-based criteria. For example, EPA Region 6 has calculated a risk-based Human Health Screening Value (HHSV) of 0.037 mg/L for tap-water ingestion using the updated, provisional toxicity value (1.00E-03 mg/kg/d, National Center for Environmental Assessment [NCEA]). The current Region 3 RBCs and Region 9 PRGs have similar values. Therefore, the new criteria are below the ROD ARAR cleanup level (0.7 mg/L), the current vanadium performance monitoring standard (0.1 mg/l), and the analytical reporting limit for long-term monitoring program (0.1 mg/L).

Despite the fact that a new standard calculated based on the current toxicity factor would be approximately one-third of the current reporting limit, it is unlikely that changing the vanadium health-based standard to 0.037 mg/L would affect the protectiveness of the remedy in any of the three aquifers, as described below.

4.3.1.1 Southwest Alluvium

A reduction of the vanadium health-based standard to 0.037 mg/L would have no effect on conclusions regarding remedy protectiveness in the Southwest Alluvium. Vanadium has been detected only once (at 0.1 mg/L at GW 3) out of a total of 1,336 groundwater samples collected from Southwest Alluvium wells during the period of July 1989 to October 2006. Because there is no pattern of concentrations exceeding current performance monitoring standards, there is no evidence that vanadium is a constituent of concern in

the Southwest Alluvium hydrostratigraphic unit, nor is there evidence of migration to potential receptors.

4.3.1.2 Zone 3

A reduction of the vanadium health-based standard to 0.037 mg/l would have no effect on conclusions regarding remedy protectiveness in the Zone 3 hydrostratigraphic unit. Vanadium has been detected 52 times out of a total of 845 groundwater samples collected from Zone 3 wells during the period of July 1989 to October 2006. All but three of the detected results were collected from wells 613 (in Section 2) and 518 (in Section 36), which are located near the tailings ponds within the seepage-impact core zone where the pH is less than 4.0 (see locations in Figure 2). The others detections were at wells 502 B (0.1 mg/L), 517 (0.4 mg/L), and EPA 14 (1 mg/L). These long-term monitoring data indicate that the plume has not expanded from this area and there is no evidence of vanadium migration from Sections 2 and 36 to potential receptors.

Furthermore, the data show that adoption of a new health-based standard at wells 613 and 518 would be moot, because all detected vanadium concentrations have exceeded the current performance monitoring standard (0.1 mg/L) and, for well 613, all detected values exceed the earlier ROD health-based standard (0.7 mg/L). Therefore, it is not necessary to consider the new health standard to be protective.

4.3.1.3 Zone 1

A reduction of the vanadium health-based standard to 0.037 mg/l would have no effect on conclusions regarding remedy protectiveness in the Zone 1 bedrock hydrostratigraphic unit. Vanadium has been detected in only two Zone 1 groundwater samples out of a total of 840 samples collected during the period of July 1989 to October 2006. Both of these samples were collected from well 615 (in Section 2) during 1991 and the results (0.1 mg/L and 0.14 mg/L) were at or near the analytical reporting limit. Because there is no pattern of concentrations exceeding current performance monitoring standards, there is no evidence that vanadium is a constituent of concern in the Zone 1 hydrostratigraphic unit nor is there evidence of migration to potential receptors.

4.3.2 Public Health Assessment

EPA prepared a Public Health Assessment (PHA) of the UNC Church Rock Site, which was published as Chapter 4 of the FS. The ROD indicates that although there was no exposure at that time to local residents from ingestion of groundwater in domestic and livestock wells within four miles of the Site, EPA concluded that adverse health or environmental hazards could result if no action was taken to



prevent exposure to groundwater contaminants found at the Site. This conclusion would not change if the human health risk assessment were updated using similar exposure assumptions and new or revised toxicity values, or health-based standards.

The PHA conclusions are based on the assumed ingestion of groundwater at contaminant concentrations equal to those measured during the 1985 RI sampling events (Tables 4 and 5 of the ROD), which included a few sampling locations within Section 2 in addition to those in Sections 1, 3, and 36. In the PHA, EPA indicated this assumption was conservative since dilution, dispersion, and natural attenuation were expected to occur if seepage were allowed to continue to migrate downgradient from the Site and would likely further reduce the concentration of contaminants from the concentrations assumed.

Furthermore, an updated risk assessment would be unnecessary for the following reasons.

- There is no reasonably anticipated exposure to the core of the Zone 3 seepage-impacted water in Sections 2 and 36. Sections 2 and 36 will be deeded over to DOE under UMTRCA Title II.
- There is no reasonably anticipated exposure to the portion of the Zone 3 plume that extends off the property into Section 1 because there is currently less than 5 ft of saturation, which is projected to drain out to pre-mining levels in about 10 years. The decision to eliminate this area as a point of exposure is documented in a letter from the NRC (September 1999).
- As in the PHA, background groundwater concentrations of certain contaminants (for example, combined radium) represent significant proportions of, or for some data exceed, those in impacted groundwater. Therefore the risks associated with tailings seepage impacts for these contaminants have been overstated.

The PHA calculated quantitative potential future health risks for carcinogenic effects due to both radionuclides and non-radionuclides and for non-carcinogenic effects. UNC presents these reported risks and effects below, but does not necessarily concur with them.

4.3.2.1 Carcinogenic Risk From Non-Radionuclides

Table 6 shows the potential future excess lifetime non-radiological carcinogenic risk calculated in the PHA for arsenic, based on both the mean and maximum arsenic concentrations in Zones 1 and 3:

**Table 6: Potential Future Carcinogenic Risk Due to Arsenic in Groundwater
(Source: ROD, 1988)**

Hydrostratigraphic Unit	Mean Concentration (mg/l)	Excess Lifetime Cancer Risk at Mean Concentration	Maximum Concentration (mg/l)	Excess Lifetime Cancer Risk at Maximum Concentration
Zone 3	0.59	2.5E-02	2.4	1.0E-01
Zone 1	0.029	1.2E-03	0.1	4.3E-03

The calculated risks exceed the typical risk range used by the EPA in its evaluations of contaminants in the environment (1.0E-04 to 1.0E-06). However, the PHA also acknowledged that a concentration equivalent to the MCL (at that time 0.050 mg/L) corresponded to an excess lifetime cancer risk of 2.1E-03. These risks were calculated using a cancer potency factor (carcinogenic toxicity value now typically known as a slope factor) of 1.5 kg-day/mg, which is identical to the current carcinogenic slope factor.

Currently, arsenic concentrations in Zone 1 are typically much lower than those used in the PHA; in fact, there are no exceedances of the new arsenic MCL, which was reduced from 50 ug/L to 10 ug/L in January 2006. Current Zone 3 mean and maximum arsenic concentrations are up to 10 times lower than those used for the PHA (see Section 4.2.1). However, because the risk documented in the PHA exceeded the acceptable risk range by more than a factor of 10, updated risk calculations, if performed, would likely indicate an elevated risk associated with the ingestion of Zone 3 groundwater. However, such calculations are unnecessary because of the revised MCL.

Therefore, the significance of updated risk calculations would be unnecessary, for three reasons: (1) background groundwater arsenic concentrations exceed those in impacted groundwater, (2) there is no reasonably anticipated exposure to the core of the Zone 3 seepage-impacted water in Sections 2 and 36, and (3) EPA guidance indicates that establishing risk-based cleanup standards where ARARs exist is typically not necessary: “... *when an ARAR for a specific chemical (or in some cases a group of chemicals) defines an acceptable level of exposure, compliance with the ARAR will generally be considered protective even if it is outside the risk range (unless there are extenuating circumstances such as exposure to multiple contaminants or pathways of exposure)*” (Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (OSWER Directive 9355.0-30, 1991)).

4.3.2.2 Carcinogenic Risk from Radionuclides

The PHA calculated the potential future excess carcinogenic risk due to ingesting groundwater containing the four radionuclides detected in the RI: radium-226, radium-228, thorium-230, and uranium-238. Table 7 shows that the potential total excess lifetime carcinogenic risk was greater than 1.0E-04 for mean and maximum radionuclide concentrations under the future exposure scenario. Zone 3 had the highest cancer death risk, with the primary contributors at the maximum concentrations being thorium-230 (1.5E-01) and uranium (3.7E-02).

Table 7: Summary of Potential Future Radiation Risks From Groundwater Ingestion (Source: PHA, FS 1988)

Hydrostratigraphic Unit	Cancer Death Risk - Mean Concentration	Cancer Death Risk - Maximum Concentration
Southwest Alluvium	1.2E-04	3.8E-04
Zone 3	1.9E-04	8.4E-04
Zone 1	1.6E-02	1.8E-01

The PHA risk assessment calculated a radiation dose in millirem (mrem) using a radionuclide-specific dose-conversion factor (DCF) and subsequently estimated cancer risk using a conversion factor of 2.8E-07 excess risk of death from cancer from whole body exposure to one millirem of radiation. Currently, risk assessment methods for radionuclides utilize the cancer slope factors developed by EPA in the Health Effects Assessment Summary Tables (HEAST, EPA 1995a, EPA 1995b). EPA guidance (OSWER Directive No. 9200.4-18, *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination*, 1997) further indicates that cancer risk from both radiological and non-radiological contaminants should be summed to provide a cumulative risk estimate for proposed and final Site decision documents.

If the risk assessment were to be updated using current data and methods, the risk due to ingesting radionuclides in groundwater would likely still be greater than 1.0E-04 (particularly in Zone 3), but the risks would likely be distributed differently among the radionuclides due to changes in toxicity factors and radionuclide activities since the PHA. For example, the current Zone 3 thorium-230 activity is much lower than that reported in the PHA (a maximum activity of 41,300 pCi/L was measured at former well 610 in 1985). The results of the October 2006 sampling show that thorium-230 was only detected at one location (well 613, which is located within Section 2 and the core of the Zone 3 plume) at an activity of 328 pCi/L. While a risk assessment based on current data would likely show less risk associated with thorium-230, the risks due to

combined radium (i.e., the sum of radium-226 and radium-228) would likely be equal to or higher than previous estimates due to changes in toxicity factors.

Based on long-term monitoring data and improved understanding of the Site, it would likely be possible to attribute much of the risk due to combined radium and uranium is likely due to background conditions. The background activity of combined radium-226 and radium-228 is known to statistically exceed the original ROD ARAR (and former NRC GWPS) of 5 pCi/L in the Southwest Alluvium and Zone 1, as demonstrated by the NRC's August 2006 amendment of the Source Materials License (see Section 3.4). Furthermore, in Zone 3, the radium-226 and radium-228 activities measured in groundwater samples from background well NBL-1 are approximately one-quarter to one-third of the maximum values measured in Zone 3 and slightly below the mean values.

4.3.2.3 Non-Carcinogenic Hazard

The PHA assessed exposure to noncarcinogens by comparing the estimated daily intake of four indicator constituents (cadmium, manganese, nickel, and selenium) to the reference dose (RfD) or Acceptable Intake for Chronic Exposure (AIC) developed at the time of the assessment. The results of the PHA indicated that the potential non-carcinogenic hazard index was greater than one under the future exposure scenario, for both the mean and maximum indicator parameter concentrations for each hydrostratigraphic unit (see Table 8 below).

**Table 8: PHA Hazard Index Values
(Source: PHA, FS 1988)**

Hydrostratigraphic Unit	Mean Hazard Index Adult	Maximum Hazard Index Adult	Mean Hazard Index Child	Maximum Hazard Index Child
Southwest Alluvium	5.2	16.2	18.2	56.8
Zone 3	5.5	34.5	13.3	120.7
Zone 1	3.2	13.1	4.6	11.5

If the risk assessment were to be updated using current data and methods, these conclusions would not change, primarily because toxicity values (i.e., RfDs) have been developed for additional Site constituents since the PHA was prepared.

Based on long-term monitoring data and improved understanding of the Site, the hazard associated with certain Site contaminants likely would be attributable to background conditions. For example, manganese and molybdenum are detected at concentrations above the current remediation standards at multiple background locations; for example, Zone 3 well NBL 1. Therefore, these constituents do not require further action.

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Section 5

Land Use Patterns

5.1 Assessment of Changes to Land Use

NRC license Condition 31 requires UNC to submit annual land-use updates. Review of annual land-use updates from 1999 through 2006 was conducted for purposes of the present report. These reviews comprise specific statements of all land-use changes within a 2-mile radius of the former UNC Mill Site. All land use changes have been minor.

Within UNC property (Sections 2 and 36), the following activities are representative of occasional land-use changes: (1) abandonment or installation of new monitoring wells, test wells, or extraction wells; (2) cessation of pumping at some former extraction wells; (3) reinforcement or reinstallation of perimeter fences to prevent trespassing or cattle grazing; (4) improvement of local drainage control; and (5) various remedy enhancement field activities conducted in the Zone 3 impacted groundwater on Section 36.

The most common land use outside the UNC property is cattle grazing; several groups of homes are located within the 2-mile radius. The Circle Wash well (Section 14) continues to be used for livestock and domestic purposes; this well is completed within alluvium along the Puerco River, upgradient of the confluence of this river with Pipeline Canyon (and, therefore, unable to be impacted by the tailings seepage). Well 14T-586 is located approximately 870 ft to the north of the northern boundary of Section 36. This well is completed in the Lower Gallup Sandstone and is indicated as used for livestock and domestic purposes.

Outside the UNC property (Sections 1, 2, 3, 4, 6, 9, 10, 11, 12, 13, 14, 15, 33, 34, and 35) the following activities are representative of occasional land-use changes: (1) slight increases or decreases in the number of homesites located to the north, northwest, and southwest of the Mill Site; and (2) well abandonment.

5.2 Assessment of Potential Changes to Exposure Scenarios

There have been no changes to potential exposure scenarios. In 1999, there were 12 homes in two groupings located within the alluvium along Pipeline Canyon, between approximately 1.3 and 1.7 miles to the southeast of the Mill Site. In 2006, there were 11 homes in these locations. Potable water is supplied to these residences via the Pinedale pipeline.

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Section 6

Decision Analysis

This report presented the derivation of baseline standards that currently apply to the management of the Church Rock NPL Site. It also presented all of the potential changes to the baseline standards that may be considered to ensure the continued protectiveness of the current or planned remedy. The origin of the potential changes include:

- new or revised MCLs
- revisions to existing standards based upon decisions made by NRC
- proposed revisions based upon a better understanding of Site conditions that has developed using the 17+ years of monitoring data
- changes to toxicological information, and
- changes to land use in the vicinity of the site

Using the information and references cited in this report, EPA must determine whether any of these potential changes need to be evaluated in the SWSFS to ensure that the remedy remains protective. Unless otherwise directed by EPA, the SWSFS will proceed using the standards expressed in the ROD. To assist EPA with the decision, it is recommended that EPA consider the following options:

1. The ROD was somewhat ambiguous in tabulating standards and identifying compounds-of-concern. It would be helpful to restrict future performance monitoring to only those constituents that are associated with the tailings seepage. The GWPSs contained in the NRC Source Materials License offer a sound approach.
2. The ROD contained contingencies that may be used as the basis to modify or waive certain ARARs and/or terminate the remediation. Sulfate, TDS and manganese are obvious candidates for a waiver. Not only did the ROD identify practical limitations to the attainment of the standards, but long-term monitoring has proven the desired endpoints to be unattainable, and principles of aqueous chemistry guarantee them to be unattainable regardless of what remedy may be implemented. There is no doubt that these constituents will remain above current standards until no water remains in all three zones. Furthermore, they are not hazardous constituents, and so, they do not directly bear on the protectiveness of the remedy. EPA has expressed an unwillingness to waive these constituents before amending the ROD or offering an Explanation of Significant Difference (ESD), if necessary. Therefore, UNC intends to retain them through the SWSFS process; however, it has been clear for many years that these constituents



ultimately will have to be waived. This was considered from the beginning in the ROD, concluded by the NRC using several years of monitoring data, and further proven by UNC in several studies and on-going annual monitoring. It would simplify future decision-making by waiving these requirements immediately via an ESD or other appropriate mechanism (consider Table 3). All of the data needed to support such a waiver decision is in existence and has been submitted as referenced in this report.

3. EPA may select the NRC-revised background value for nitrate and maintain the protectiveness of the current or future remedy.
4. Antimony and thallium have new MCLs. While these constituents could be added to the site groundwater monitoring program, this is not necessary to ensure the protectiveness of the current or future remedy. These constituents have not previously been considered to be associated with tailings-seepage, and no new evidence has been uncovered to suggest that they are needed for the current or future remedy to be protective.
5. Beryllium would have to be analyzed to a lower detection limit to determine if it exceeds the new MCL. The effect of the new beryllium MCL cannot be ascertained because all existing monitoring data are above the detection limit, and the detection limit is greater than the new MCL. Beryllium is not associated with the tailings-seepage. EPA should consider dropping beryllium from the parameters to be monitored. Any determination to either drop beryllium or change its existing standard must be based on a demonstration that the revised standard (or waiver) is necessary to maintain the protectiveness of the remedy.
6. Arsenic and cadmium may be removed as compounds-of-concern. Within the Southwest Alluvium and Zone 1, they have each been in compliance with the new, more stringent MCL for many, many years, both during and after terminating the pumping. In Zone 3, exceedances have been few, and are restricted to the core of the seepage-impacted area (and background at well NBL 1). Alternatively, EPA might consider monitoring them in Zone 3 only. If EPA decides that they can be removed, or partially removed from the performance monitoring program, then UNC would submit a license amendment to the NRC for concurrence.
7. EPA did not consider any of the trihalomethanes to be compounds-of-concern in the ROD; however, the NRC did, and so trihalomethanes are contained within the Source Materials License and the license employs the MCL as the Site standard. There are no exceedances of the trihalomethane standard anywhere where the MOU between the EPA and NRC gives the EPA jurisdiction.
8. Notwithstanding the unlikelihood of EPA's future exposure scenario, uranium has a new MCL which could be adopted if it is determined by EPA to be necessary to ensure the protectiveness of the remedy. If EPA makes such a decision, then it will have to be modified to take into account the distinctive background

concentrations in the Southwest Alluvium and Zone 3. While the NRC did not specifically address background when it arrived at its value for the GWPS, the NRC standard is set at the correct background value for the Southwest Alluvium and very close to that for Zone 3. The decision should have no bearing on Zone 1 because there are no exceedances of the new uranium MCL anywhere where the MOU between the EPA and NRC gives the EPA jurisdiction.

9. The NRC has amended the standard for radium in Zone 1 and the Southwest Alluvium based on background concentrations. EPA might consider adopting the NRC values. If it does not follow suit, then radium will regularly remain out of compliance regardless of what remedy is invoked, ultimately necessitating a waiver.
10. EPA should consider a re-evaluation of its reasonably anticipated future use scenario. There is no groundwater (seepage-impacted or not) in any of the affected units anywhere in the vicinity of the Site that could supply potable water without significant, impracticable treatment.



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Section 7

References

Canonie Environmental, 1989, Remedial Design Report. April 1989.

Earth Tech, 2000, Zone 1 Groundwater Geochemistry, Church Rock Site, Gallup, New Mexico. May 2000.

Earth Tech, 2000, Southwest Alluvium Groundwater Geochemistry Report, Church Rock Site, Gallup, New Mexico. June 2000.

Earth Tech, 2002, Final Report and Technical Impracticability Evaluation – Southwest Alluvium Natural Attenuation Test, Church Rock Site. Prepared for United Nuclear Corporation. November 2002.

General Electric Corporation, 2006, Regulatory Significance of the Occurrence and Distribution of Dissolved Uranium in Groundwaters of the Southwest Alluvium, Church Rock Site, New Mexico. March 10, 2006.

N.A. Water Systems, 2006, Technical Analysis Report in Support of License Amendment Request for Changing the Method of Determining Exceedances of the Combined Radium Groundwater Protection Standard in Source Materials License SUA-1375 (TAC LU0092), Groundwater Corrective Action Program, Church Rock Site, Church Rock, New Mexico. Revised February 2006.

N.A. Water Systems, 2007, Annual Review Report 2006 – Groundwater Corrective Action, Church Rock Site, Church Rock, New Mexico. January 9, 2007.

Nuclear Regulatory Commission, 2006a, Environmental Assessment Related to Issuance of a License Amendment for United Nuclear Corporation, Church Rock, New Mexico Project; Source Materials License SUA-1475, Docket No. 40-8907. July. (Related Finding of No Significant Impact from the requested licensing action published in the Federal Register on August 2, 2006 (vol. 71, no. 148, p. 43822-43823).)

Nuclear Regulatory Commission, 2006b, Amendment 37 to United Nuclear Corporation's Church Rock, New Mexico, Source Materials License No. SUA-1475 (TAC LU0117). August 9, 2006.

U.S. Department of Energy (DOE), October 1999, From Cleanup to Stewardship, a Companion Report to Accelerating Cleanup: Paths to Closure and Background Information to Support the Scoping Process Required for the 1998 PEIS Settlement Study; DOE/EM-0466.

U.S. Environmental Protection Agency (EPA), 1988, Remedial Investigation, United Nuclear Corporation Churchrock Site, New Mexico; August 1988.

U.S. Environmental Protection Agency (EPA), 1988, United Nuclear Corporation Church Rock Site, Operable Unit Feasibility Study, Gallup, New Mexico. August 1988.

U.S. Environmental Protection Agency (EPA), 1988, Memorandum of Understanding Between U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency; August 26, 1988.

U.S. Environmental Protection Agency (EPA), 1988, Record of Decision, United Nuclear Corporation, Ground Water Operable Unit, McKinley County, New Mexico; U.S. Environmental Protection Agency, Region VI, Dallas, Texas, September 1988.

U.S. Environmental Protection Agency (EPA), 1995a, Health Effects Assessment Summary Tables FY – 1995 Annual, EPA/540/R-95/036. May 1995.

U.S. Environmental Protection Agency (EPA), 1995b, Health Effects Assessment Summary Tables FY – 1995 Supplement, EPA/540/R-95/142. November 1995.

U.S. Environmental Protection Agency (EPA), 1997, Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination, OSWER Directive No. 9200.4-18.

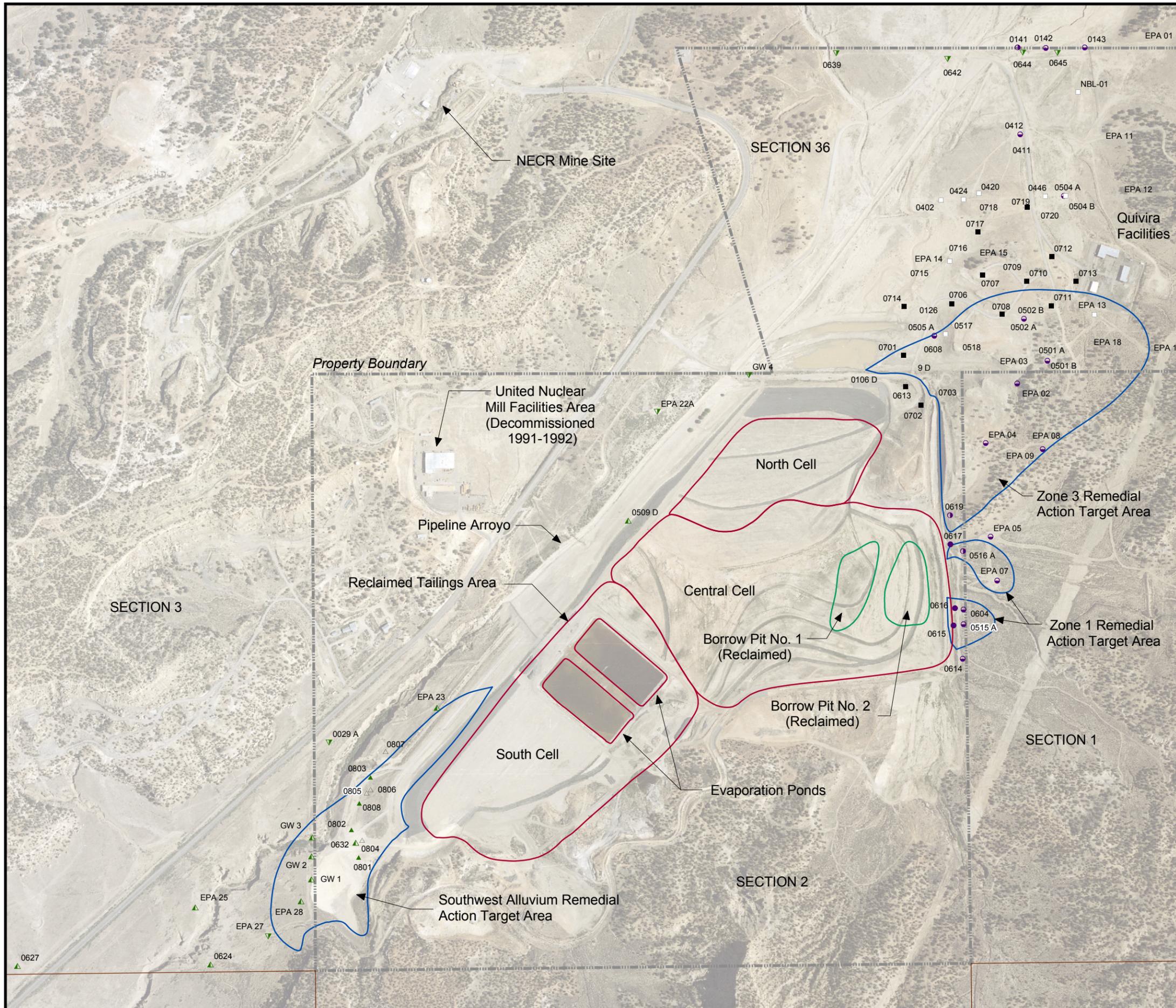
U.S. Environmental Protection Agency (EPA), 1998, Five-Year Review Report. September 1998.

U.S. Environmental Protection Agency (EPA), 2003, Five-Year Review Report – Second Five-Year Review Report. September 2003.

U.S. Nuclear Regulatory Commission (NRC), 1996, Evaluation of the Statistical Basis for Establishing Background Levels and Remediation Standards at the United Nuclear Corporation Church Rock Uranium Mill Tailings Disposal Facility, Gallup, New Mexico; June 10, 1996.

U.S. Nuclear Regulatory Commission (NRC), 1999, Consideration of Temporary Saturation of a Portion of Zone 3 at the Church Rock Site. September 16, 1999.

Figures



Legend

Southwest Alluvium

- ▲ Idled Extraction Well
- ▲ Monitoring Well
- △ Water Level Monitoring Well
- ▼ Dry Monitoring Well

Zone 3

- Idled Extraction Well Used for Monitoring
- Decommissioned or Idle Extraction Well
- Monitoring Well
- Dry or Decommissioned Monitoring Well

Zone 1

- Decommissioned Extraction Well
- Decommissioned Monitoring Well
- Monitoring Well

Note:
1. Aerial photo taken on August 1, 1996.

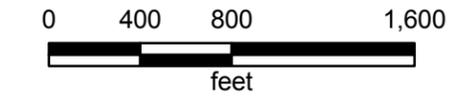


FIGURE 1
Site Layout and Performance
Monitoring Well Locations
2006 Operating Year

United Nuclear Corporation Church Rock Site,
Church Rock, New Mexico



FIGURE 3
 Zone 3 Arsenic Concentrations Over Time
 United Nuclear Corporation, Church Rock, New Mexico

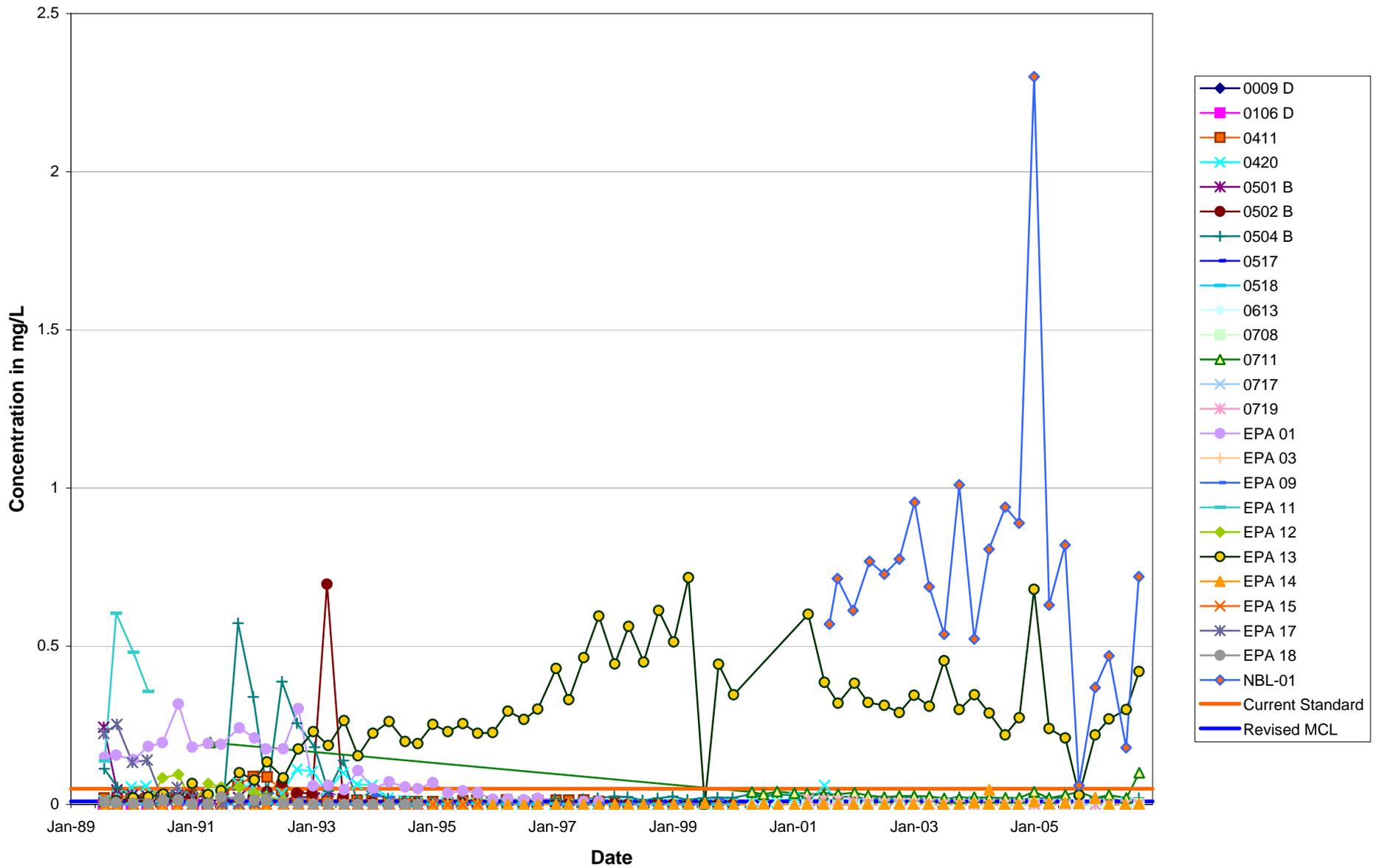


FIGURE 4
Zone 3 Arsenic Concentrations Over Time for Selected Wells
United Nuclear Corporation, Church Rock, New Mexico

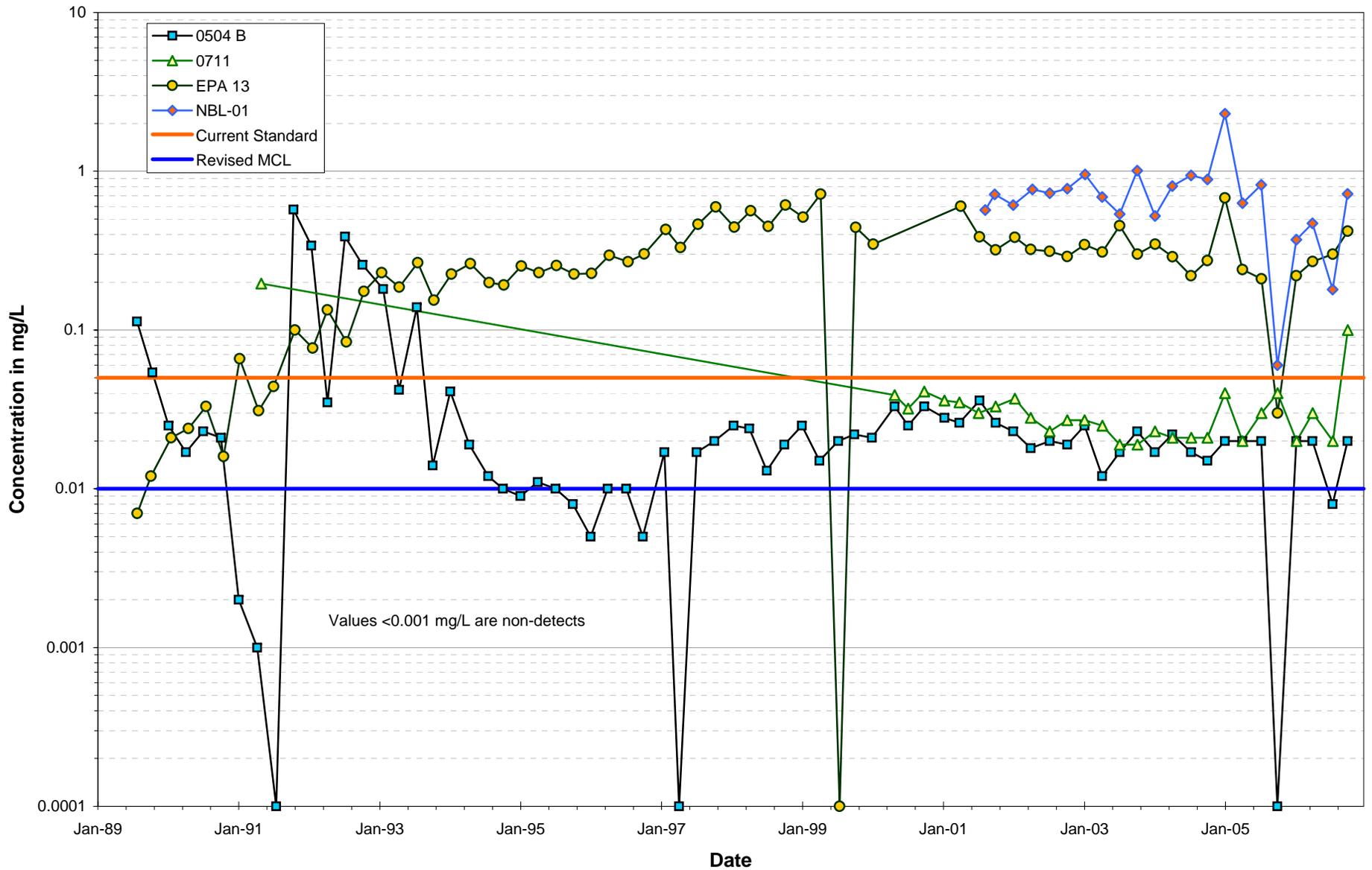


FIGURE 5
 Zone 3 Cadmium Concentrations Over Time
 United Nuclear Corporation, Church Rock, New Mexico

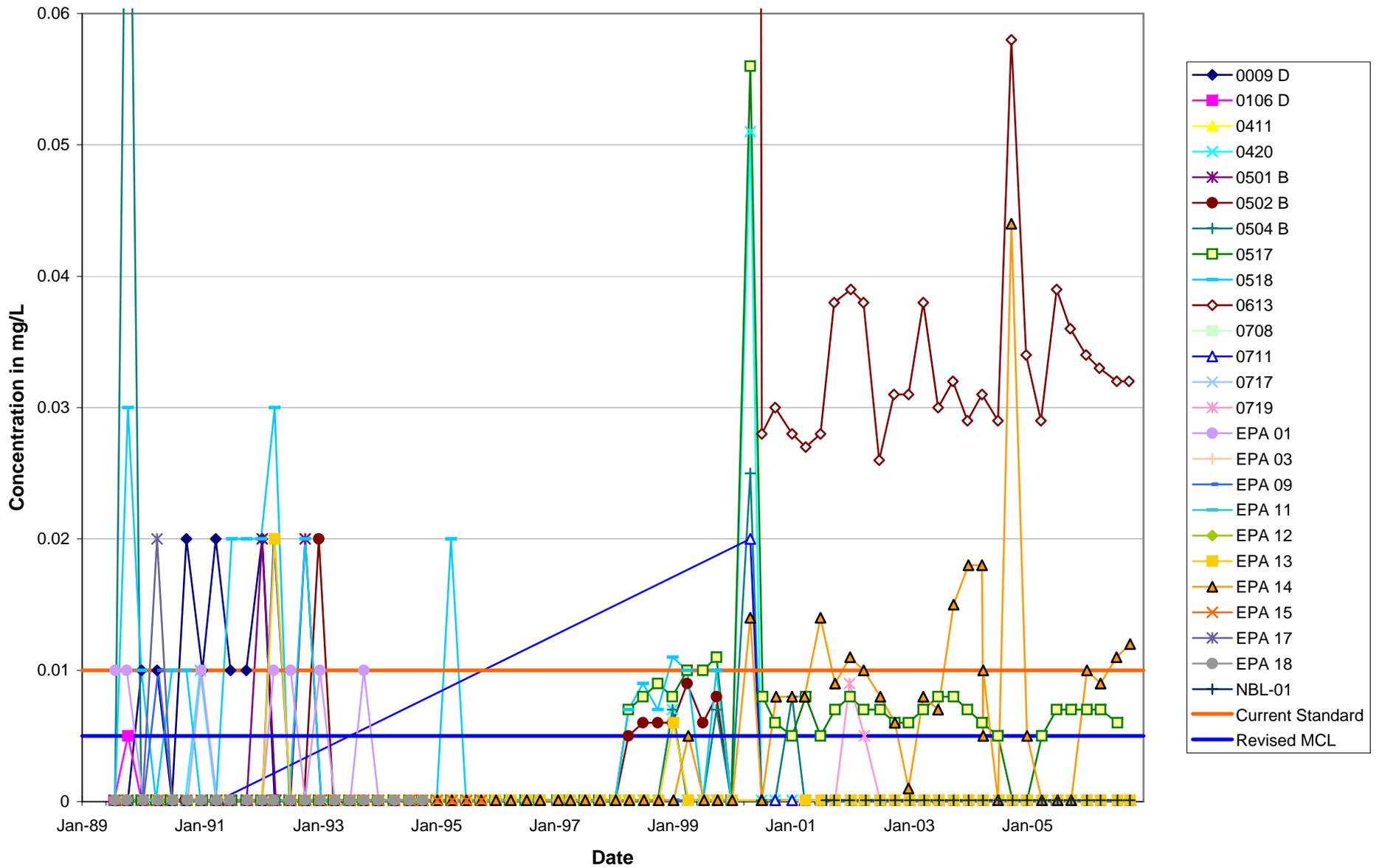


FIGURE 6
 Zone 3 Cadmium Concentrations Over Time for Selected Wells
 United Nuclear Corporation, Church Rock, New Mexico

