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Gallup, New Mexico

Annual Review Report – 2007
Groundwater Corrective Action
Church Rock Site, Church Rock, New Mexico

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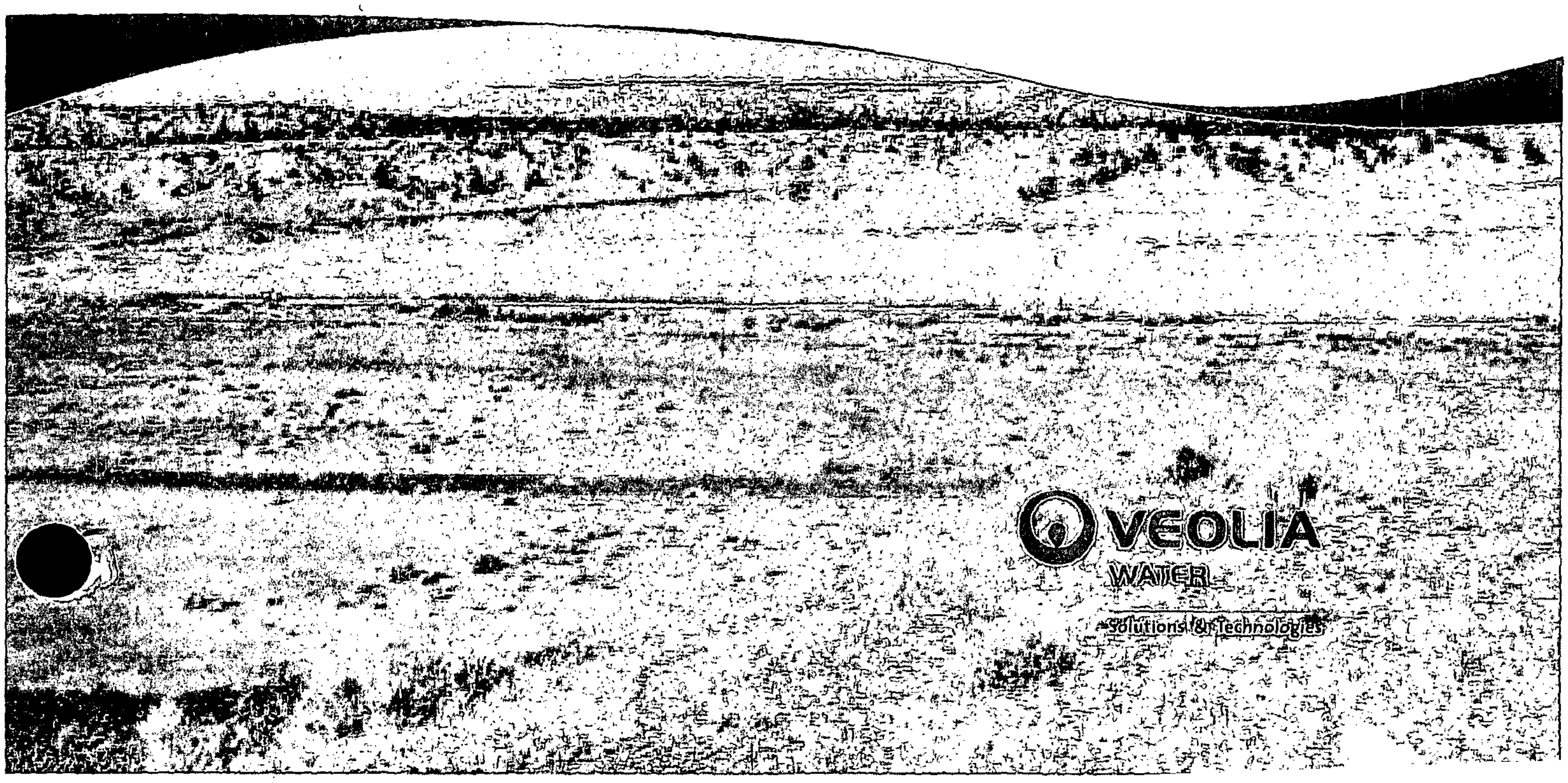

UNITED NUCLEAR CORPORATION
GALLUP, NEW MEXICO

ANNUAL REVIEW REPORT – 2007
GROUNDWATER CORRECTIVE ACTION
CHURCH ROCK SITE, CHURCH ROCK, NEW MEXICO

JANUARY 2008

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List of Acronyms and Abbreviations

ACL	alternate concentration limit
ALARA	as low as reasonably achievable
ARARs	applicable or relevant and appropriate requirements
EPA	U.S. Environmental Protection Agency
FS	feasibility study
ft/yr	feet per year
gpm	gallons per minute
IC	institutional control
MCL	federal primary maximum contaminant level
mg/L	milligrams per liter
MNA	monitored natural attenuation
NA	natural attenuation
NMED	New Mexico Environment Department
NRC	U.S. Nuclear Regulatory Commission
pCi/L	picocuries per liter
POC	point of compliance
POE	point of exposure
ROD	Record of Decision
SFS	supplemental feasibility study
SWSFS	site-wide supplemental feasibility study
SMCL	federal secondary maximum contaminant level
TDS	total dissolved solids
TTHMs	total trihalomethanes
TI	technical impracticability
µg/L	micrograms per liter

Annual Review Report – 2007
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Church Rock Site, Church Rock, New Mexico
Section 1
Introduction

On behalf of United Nuclear Corporation (UNC), N.A. Water Systems has prepared this annual performance review of the groundwater corrective action at UNC's Church Rock Mill and Tailings Site near Gallup, New Mexico, pursuant to NRC Source Materials License 1475, Condition 30C. UNC has submitted an annual corrective action report at the end of each operating year since 1989. This report is the nineteenth in the series and includes groundwater quality analyses and groundwater elevations for the first quarter of 2007 through the fourth quarter of 2007.

This report focuses on both active remediation and the groundwater performance of the natural systems without active remediation. As indicated in the U.S. Environmental Protection Agency's (EPA's) *First Five-Year Review Report* (EPA, 1998) and by the approvals to decommission or temporarily shut off the three corrective action systems, the agencies recognized that those corrective action pumping systems had reached the limit of their effectiveness. EPA (1988b) recommended that Technical Impracticability (TI) Waivers, Alternate Concentration Limits (ACLs), and Monitored Natural Attenuation (MNA) be used to complete the corrective action program. Presentations and reports prepared to document the geochemical processes in the Southwest Alluvium (Earth Tech, 2000d and 2002c; N.A. Water Systems, 2004, 2005a, and 2005b) and the Zone 1 hydrostratigraphic unit (Earth Tech, 2000c; N.A. Water Systems, 2005b) showed that the natural geochemical mechanisms are at least as effective as the active remediation systems in controlling the migration of constituents of concern. This annual report describes how these natural processes are performing. This report updates active remediation efforts in Zone 3, including pumping of hydrofractured extraction wells and the results of the in-situ alkalinity stabilization pilot study. 18 years of active remediation of Zone 3 by the extraction of impacted groundwater and constituent mass resumed with the Phase I hydrofracture study in 2005 and continued through 2007.

The U.S. Nuclear Regulatory Commission (NRC) approved UNC's administrative license amendment request to change the submittal date of UNC's Corrective Action Annual Report from December 31 of each year, to January 30 of the following year (NRC, 2007).

EPA has directed UNC (EPA, 2006a) to provide a Site-Wide Supplemental Feasibility Study (SWSFS). Toward that objective, UNC has submitted a statement of the preliminary proposed content of the SWSFS (N.A. Water Systems, 2006b) and a list of preliminary assembled remedial alternatives (N.A. Water Systems, 2006c). The latter document has been addressed by EPA comments (EPA, 2006b) that were developed with the input of the NRC, New Mexico Environment Department (NMED), and the Navajo Nation Environmental Protection Agency. UNC and the agencies held a conference call on November 30, 2006 and agreed on the next step toward developing the SWSFS: UNC will reassess the provisional site cleanup goals (preliminary remediation goals, remedial action objectives, and Applicable or Relevant and Appropriate Requirements (ARARs)), following the original site Feasibility Study (EPA, 1988a) and the EPA Record of Decision (EPA, 1988b). The results of this work were reported to EPA during February 2007 as Part I of the SWSFS (N.A. Water Systems, 2007b).

1.1 Site Location

The Church Rock Site ("Site") is located approximately 17 miles northeast of Church Rock, McKinley County, New Mexico (see Figure 1). Figure 2 is a Site map that shows the location of the decommissioned and temporarily idled extraction wells, the performance monitoring wells, the evaporation ponds, and the reclaimed tailings areas. Figure 2 also shows the Remedial Action Target Area for each hydrostratigraphic unit, where the impacts of tailings seepage were originally identified and corrective action was implemented (EPA, 1988a). Additional background information on Site facilities and activities is available in the previous annual reviews (Canonie Environmental Services Corp. [Canonie], 1989b, 1990, 1991, 1992, 1993 and 1995; Smith Technology Corporation [Smith Technology], 1995 and 1996; Rust Environment and Infrastructure [Rust], 1997; Earth Tech, 1998, 1999, 2000e, 2002a and 2002d; USFilter, 2004a; and N.A. Water Systems, 2004, 2005b, and 2007a).

1.2 Corrective Action Systems

The corrective action systems for tailings seepage remediation were installed and began operating during the summer and fall of 1989. These systems have been decommissioned or, in the case of the Southwest Alluvium, temporarily shut off, and performance monitoring is ongoing. The Zone 1 system was decommissioned in July 1999 in accordance with the letter from the NRC dated July 30, 1999 (NRC, 1999a).

The Zone 3 system was shut down in June 2000 for maintenance and repairs. Prior to the Zone 3 system being brought back on-line, the agencies agreed that the existing system should be decommissioned (NRC, December 29, 2000 License Amendment). This decision included a provision for UNC to submit a modified corrective action plan, an application for Alternate Concentration Limits (ACLs), or an alternative to the specific requirements of 10 CFR Part 40, Appendix A, if the License standards are not achievable. During 2006 UNC completed an extended pilot investigation to evaluate the suitability of hydrofracturing to enhance the extraction potential within the impacted area of this hydrostratigraphic unit (MACTEC, 2006). The hydrofracture study demonstrated that the new pumping configuration has achieved nearly complete capture of the northward-advancing impacted water, while causing a notable improvement in the water quality within the northern tracking wells. For these reasons, pumping in this part of Zone 3 continued during 2007 (discussed in Section 3 of this report). A new extraction well (RW A) was installed and started pumping on September 24, 2007. Hydrofractured extraction-well pumping (plus converted pumping Well PB 2) has removed more than 6.7 million gallons from 2005 through 2007. The pumped water was conveyed to an evaporation pond overlying part of the South Cell. In October 2006, UNC began an in-situ alkalinity stabilization pilot study in an area of relatively highly impacted groundwater in Zone 3. The objective of the study was to evaluate the potential to enhance remediation through the use of alkalinity injection wells combined with controlled-rate extraction wells (BBL, 2006). This pilot study was completed during 2007 (ARCADIS BBL, 2007) and the results are summarized in Section 3 of this report.

The Southwest Alluvium system was temporarily shut off in January 2001 to allow implementation of the Natural Attenuation (NA) test. The NA test was discussed and approved during the November 14 and 15, 2000, meeting in Santa Fe, New Mexico, and documented in the November 15, 2000, letter from the EPA. As requested by the EPA (2004a; and during meetings in Santa Fe on February 26, 2004, and at Church Rock on May 5, 2005), UNC continues to acquire groundwater quality data from wells in the Southwest Alluvium to monitor the effectiveness of natural attenuation and compare its performance to that of previous remedial efforts.

UNC is in full compliance with the NRC groundwater protection standards in the Southwest Alluvium.

1.3 Performance Monitoring and Supplemental Sampling

1.3.1 Performance Monitoring

The groundwater performance monitoring plan is described by the *Corrective Action Plan* (UNC, 1989a), *Remedial Design Report* (Canonie, 1989a) and *Remedial Action Plan* (UNC, 1989b), and has been approved by the NRC and

EPA. The program has been modified over time, as described in the annual reports (Canonie, 1989b, 1990, 1991, 1992, 1993 and 1995; Smith Technology, 1995 and 1996; Rust, 1997; Earth Tech, 1998, 1999, 2000e, 2002a and 2002d; USFilter, 2004a; N.A. Water Systems, 2004, 2005b, and 2007a), to adjust the monitoring requirements as the corrective action has progressed. The NRC and EPA have approved all modifications.

In accordance with the EPA's request in 1999, UNC developed a revised monitoring program that began with the second quarter 2000 sampling event. The revised program is documented in the letters dated January 13, 2000 (Earth Tech, 2000a), and April 26, 2000 (Earth Tech, 2000b). Details of the revised monitoring program for each hydrostratigraphic unit are provided in the performance-monitoring portion of the following sections and in the appendices.

The field and laboratory data collected from the fourth quarter of 1989 through the fourth quarter of 2007 are tabulated in Appendices A (Southwest Alluvium), B (Zone 3), and C (Zone 1). These tables include the revised background standards for sulfate, nitrate, and total dissolved solids (TDS) recommended by the NRC in its report evaluating background for the Site (NRC, 1996) and supported by the New Mexico Environment Department (NMED) in its letter to the EPA dated January 6, 1998 (NMED, 1998). These revised standards are 2,125 milligrams per liter (mg/L) for sulfate, 190 mg/L for nitrate, and 4,800 mg/L for TDS. Quarterly laboratory analytical data sheets for the 2007 operating year are included at the end of each appendix.

1.3.2 Supplemental Sampling

Following EPA's request on November 15, 2000 (meeting in Santa Fe), a new well was installed in the downgradient part of the Southwest Alluvium during 2004. This well (SBL 1) is not a formal requirement of the performance monitoring program; nonetheless, it is monitored, and the results are reported here.

Groundwater quality monitoring associated with the in-situ alkalinity stabilization pilot study in Zone 3 has been presented in this task's final report (ARCADIS BBL, 2007).

Though not a formal requirement of the performance monitoring program, monthly measurements of select field parameters (pH, conductivity, chloride, and alkalinity (also called bicarbonate)) continued during 2007 in the tracking wells near the northern edge of the seepage-impact front in Zone 3. These data show an improvement in the groundwater quality started in December 2005 and continued through October 2007. For the first time, the northern edge of the seepage impact had receded to the south during 2006 and it maintained approximately the same location during 2007 (discussed in Section 3). A new tracking well (NBL 2) was installed during August 2007.

1.4 Southwest Alluvium

Active remediation of the Southwest Alluvium was suspended when the former extraction wells ceased being pumped in January 2001; those wells have remained idle while natural attenuation continues to be monitored. The NA test involved temporarily shutting off the pump-back wells and monitoring the water quality and water levels on a monthly basis. The results were presented in a "final" report submitted in November 2002 (Earth Tech, 2002c). The effectiveness of NA in the Southwest Alluvium was discussed by N.A. Water Systems in the 2004, 2005, and 2006 annual reports and in a presentation (2005a) at the annual, multi-agency meeting that was held at UNC's offices at Church Rock on May 5, 2005. This annual report presents a continuing assessment of the effectiveness of natural attenuation in the Southwest Alluvium.

1.5 Report Organization

This report presents each hydrostratigraphic unit in a separate section:

Section 2	Southwest Alluvium
Section 3	Zone 3
Section 4	Zone 1
Section 5	Conclusions and Recommendations
Section 6	References

The monitoring data are contained in separate appendices for each hydrostratigraphic unit:

Appendix A	Southwest Alluvium Monitoring Data
Appendix B	Zone 3 Monitoring Data
Appendix C	Zone 1 Monitoring Data

The appendices to this report, unlike the report body, are printed and paginated double-sided.

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Section 2
Southwest Alluvium

2.1 Corrective Action Summary

The Southwest Alluvium corrective action pumping system remained idle in 2007. Attenuation via natural geochemical processes has been shown to be at least as effective as pumping. No hazardous constituents exceed Site standards outside the UNC property boundary.

2.2 Mass of Chemical Constituents Removed

The mass of chemical constituents removed was calculated for the 12-year period from November 1989 through January 2001. These calculations were presented in the previous annual reviews, and the final summary was presented in the *2001 Annual Review* (Earth Tech, 2002a).

2.3 Performance Monitoring Evaluation

The current performance monitoring program in the Southwest Alluvium is summarized in Table 1 and comprises quarterly monitoring of water levels in 16 wells and water quality in 14 wells. The monitoring well locations are shown on Figure 2. A summary of constituents detected in the Southwest Alluvium in October 2007 is provided in Table 2, which shows that none of the Point of Compliance (POC) wells in the Southwest Alluvium had any exceedances of hazardous constituents. Historic groundwater quality and groundwater elevation data through October 2007 are provided in Appendix A (Table A.1).

2.3.1 Water Level Evaluation

Groundwater in the Southwest Alluvium in the vicinity of the tailings impoundments was created by the infiltration of pumped mine water that was discharged to the Pipeline Arroyo. This water percolated into the alluvium and created temporary saturation in the vicinity of the tailings impoundments. This temporary saturation caused by discharged mine water is the recognized Southwest Alluvium background water (EPA, 1988a; 1988b; 1998). The level of saturation has been declining since the mine water discharge ceased in 1986. As a result, the flanks of the alluvial valley and the northern property boundary alluvium have completely de-saturated and, by 2000, a 31 percent saturation loss had been observed further to the south (Earth Tech, 2000d). The October 2007 saturated thickness for each well in the performance monitoring program is provided in Table 3. During 2007, all wells have shown overall decreasing groundwater elevations (with small fluctuations), indicating that the groundwater flux continues to decline with the shrinking of the zone of saturation. The saturation measured in these wells has collectively declined by an average of 20 percent since 1989.

The Southwest Alluvium potentiometric surface map for October 2007 is shown in Figure 3. This figure shows a local, eastward turn to the saturated alluvium, beneath the northwestern part of the South Cell, reflecting the presence of a relatively high area (bulge) in the bedrock surface between Wells 509 D and EPA 23. This bulge encompasses the area including the "Nickpoint" along Pipeline Arroyo. The Nickpoint (Figure 3) has been referred to in earlier reports. It is a local, rim-like bedrock high along the arroyo, below which the streamway becomes incised and continues downgradient as Pipeline Canyon.

Figure 4 shows water levels over time in Southwest Alluvium wells, illustrating the overall long-term trend of decreasing levels as water continues to drain from the Southwest Alluvium. Water levels in the vicinity of the pumping wells increased temporarily after they were turned off in January 2001 for the start of the NA test (see Figure 5). Water levels in the former pumping wells have since stabilized at elevations similar to those measured in nearby monitoring wells. These stable to declining water levels indicate that the hydraulic system has fully recovered from the effects of pumping (recovery was complete during approximately April to June 2002). A summary of operational data for the Southwest Alluvium extraction wells is provided in Table 4.

Southwest Alluvium groundwater flows to the southwest, along the Pipeline Arroyo. Based on calculations of the volume of background groundwater drainage through the valley in comparison to historic pumping rates, the drainage had exceeded the total pumping volume throughout the corrective action period by 30 percent or more (Earth Tech, 2000d). Groundwater pumping did not fully contain seepage-impacted water; however, it is important to realize that hydraulic containment is not a necessary feature of the corrective action program in the Southwest Alluvium because of the strong geochemical attenuation that occurs naturally. The SWSFS (in preparation) will include a comprehensive review of the remedial alternatives appropriate to the Southwest Alluvium.

2.3.2 Water Quality Evaluation and Current Extent of Seepage-Impacted Water

As discussed below, no hazardous constituents exceed Site standards outside the UNC property boundary within seepage-impacted water. Most constituents show time-series variations that have become "routine" in the context of 18 years of groundwater quality monitoring. Former pumping did not improve the groundwater quality, nor would future pumping do so. During October 2007, no hazardous constituents exceeded Site standards within the UNC property boundary.

The area currently containing seepage-impacted groundwater in the Southwest Alluvium is shown on Figure 6. As explained more fully below, common ion geochemistry in the delineated area has been changed by the neutralization of tailings fluids migrating through the alluvium. The area of seepage impact extends southwest along the western margins of the North, Central, and South Cells, and continues approximately 1,400 ft across the southeastern corner of adjacent Section 3 and approximately 340 ft into the north-central portion of adjacent Section 10. The total length of the area is approximately 5,080 ft.

Historically only two constituents, sulfate and TDS, exceed the Site standards in the Southwest Alluvium seepage-impacted groundwater outside the United Nuclear property boundary in Sections 3 and 10. Sulfate and TDS, which are non-hazardous constituents, also exceed groundwater quality standards in the background water (Wells 627, EPA 28 and SBL 1). The majority of TDS is composed of sulfate; therefore, TDS concentrations mimic sulfate concentrations (Earth Tech, 2000d).

Historic sulfate concentrations through October 2007 are shown graphically in Figure 7. This figure shows that the long-term concentrations in most wells have remained approximately steady with the following exceptions: (1) the concentrations in Wells 801 and 509 D decreased in January 2000 and October 1999, respectively, and have since remained at these relatively lower levels; and (2) the concentrations in Well GW 2 have shown overall increasing trends since the shutoff of pumping. The 12 data points in the upper right part of this chart represent the sulfate measurements from new Well SBL 1. In October 2007, this well had the highest sulfate concentration (4,960 mg/L) of any well in the Southwest Alluvium (including all historic measurements), including the nearest, hydraulically upgradient Well 624 which is impacted by seepage and had a sulfate level in October 2007 of 1,990 mg/L.

Figure 8 is a bicarbonate isoconcentration map of the Southwest Alluvium during October 2007. As explained in earlier annual reports and in the first natural attenuation evaluation (Earth Tech, 2002c), bicarbonate concentration is the main attribute by which the presence and extent of seepage-impacts can be evaluated. The seepage-impacted area has near-neutral pH values as a result of the high capacity of the alluvium to neutralize the acidic tailings seepage. The neutralization capacity has also prevented the migration of metals from the former tailings impoundments. The neutralization capacity is strongly tied to relatively large amounts of calcite ($CaCO_3$) in the alluvium that is available for buffering: Canonie (1987, Table 4.4) reported measured alluvium $CaCO_3$ fractions of 2.58 percent in a sample collected during drilling of Well EPA 23; 0.77 to 0.28 percent near the Pipeline Arroyo Nickpoint; and 0.02 to 12.6 percent elsewhere.

The bicarbonate isoconcentration contours shown in Figure 8 illustrate the zone of seepage impact with fine resolution. Prior to the 2004 annual report, the seepage impact zone was based on assumptions of seepage migration rates and delineated by a line encompassing estimated bicarbonate concentrations exceeding 1000 mg/L. It has since been recognized that there is a core of more significant impact (bicarbonate concentrations exceeding 2000 mg/L) surrounded by progressively less impacted groundwater (approximated by the 1000 mg/L contour).

The groundwater quality characteristics of the non-seepage-impacted water samples from Well SBL 1 differ in several important aspects from seepage-impacted water (refer to Figure 9 and Appendix A). Well 624 is the closest seepage-impacted well (500 ft) upgradient from Well SBL 1 (Figure 3). Although the following observations compare these two wells in particular, they apply equally well to most, if not all, of the seepage-impacted wells:

- Well SBL 1 contains a magnesium-sulfate ($Mg\text{-}SO_4$) type water while Well 624 contains a calcium-sulfate ($Ca\text{-}SO_4$) type. The presence of much higher magnesium concentrations in SBL 1 is suggestive of the dissolution of magnesium-salts in the alluvium (for example, epsomite or magnesite) during the earlier flushes of mine discharge water down Pipeline Arroyo.
- The alkalinity (bicarbonate or HCO_3) of Well SBL 1 water is much less than the seepage-impacted water in Well 624 samples. As acidic tailings liquids seeped into the alluvium beneath the tailings impoundments, the acid was neutralized by dissolution of carbonate minerals. The reaction between the acidic water and carbonate-bearing minerals released bicarbonate in relatively high concentrations. Chloride concentrations in Well SBL 1 are also lower than those indicative of seepage-impacted groundwater (see Appendix A and the discussion below in Section 2.3.4).
- Geochemical speciation calculations using EPA's MINTEQ numeric modeling code confirm that several aluminum-hydroxide (Al-OH) salts are oversaturated in Well SBL 1 water while they are not in Well 624 water. Similar to the explanation given above for the high magnesium concentrations, it is inferred that the water further downgradient than the seepage-impacted water may show signs of the dissolution of soluble salts associated with earlier flushes of the alluvium.

- Well SBL 1 water and seepage-impacted water are alike in that both appear to be in approximate equilibrium with an assemblage of Ca-SO_4 (as anhydrite or gypsum), magnesium-carbonate (Mg-CO_3, as magnesite or dolomite), and calcium-carbonate ($CaCO_3$, as calcite). MINTEQ simulations show that when acidic water (i.e., tailings liquid) is exposed to these mineral phases, there is a geochemical shift toward higher bicarbonate concentrations and lower sulfate concentrations (e.g., Well 624) than would occur in the absence of the acid (e.g., Well SBL 1). This type of re-equilibration is exactly the type of shift in water chemistry that is observed in seepage-impacted water compared to water that lies outside the zone of seepage-impacted water. It is a natural consequence of the law of mass action whereby the releases of calcium and bicarbonate that occurred, when acidic fluids were added to the alluvium, were accompanied by the tendency of the system to maintain constant calcium concentrations via the precipitation of additional gypsum. The result is a tendency to increase bicarbonate, decrease sulfate, and maintain constant calcium concentrations as the seepage-impact front migrates. By the Phase Rule, the presence of two calcium-bearing phases forces the system to try to maintain constant aqueous calcium concentrations.

An interesting consequence of the migration of the seepage front should be that the ratio of sulfate to bicarbonate is at a minimum where the tailings seepage front meets and reacts with non-impacted areas in the alluvium. Sulfate concentrations are greater within the core of the seepage-impacted areas because sulfate concentrations in the tailings liquids were up to two orders-of-magnitude greater than the amount that remains in the seepage-impacted water. A significant amount of gypsum had to precipitate in proximity to the concentrated tailings liquids to cause the reduction of sulfate concentrations to levels that are in equilibrium with gypsum. Out in front of the seepage-impacted water, the dissolution of the alluvium gypsum (or anhydrite) produced sulfate in the background water at levels above the standard. The general areas where sulfate concentrations are lower than the Site standard of 2,125 mg/L are shown in Figure 8 with stippled pattern, and they confirm the expectation that sulfate concentrations should be lowest along the periphery of the tailings seepage front.

Figure 8 shows that the area comprising sulfate below the standard is relatively small and mostly confined to the area of impacted groundwater. Consequently, sulfate is expected to exceed the standard over an openly large area of background water, as well as within the core zone of seepage impact. The area depicting sulfate less than 2,125 mg/L in Figure 8 is elongate parallel to the bicarbonate isoconcentration contours. This area represents a migrating reaction zone separating two areas of relatively elevated sulfate: one due to seepage impact in the transport "wake" of the reaction zone, and the other downgradient (or side-gradient) in background water that the reaction zone has not reached.

The area of seepage-impact is very small in comparison to the area of background sulfate levels above the standard; the latter condition is likely to persist downgradient within the alluvium for miles. This large area of background sulfate exceedances has an origin unrelated to the tailings impoundments and seepage impacts.

These same conceptual geochemical models, for both the earlier evolution of the background water chemistry and the later, progressive evolution of seepage-impacted water chemistry, can be constructively applied to consideration of the groundwater chemistry data shown in Figure 9. Figure 9 shows the primary components of TDS in the Southwest Alluvium in October 2007. The chart arrangement of the wells runs approximately from those located upgradient, on the left of the chart, to those downgradient on the right. Three background wells (627, EPA 28 and SBL 1) show relatively elevated sulfate combined with high ratios of sulfate to bicarbonate. Former background Well EPA 25 shows a relatively lower ratio of these two parameters in conjunction with relatively elevated calcium. The long-term geochemistry there (Appendix A) suggests that full seepage impact waters have been nearby, consistent with its hydraulically side-gradient location with respect to the bicarbonate isoconcentration map in Figure 8. Figure 9 shows the highest contribution of sulfate to the TDS is in Well SBL 1 (this also had the historically highest sulfate concentration of any Southwest Alluvium well), which also shows the lowest contribution from bicarbonate (HCO_3) and a very low contribution from chloride ("Chl" on the figure) and calcium (Ca).

The above observations and analysis confirm that Well SBL 1 has been placed further downgradient than the current extent of seepage-impacted water. They also confirm, as do the raw analytical data, that the quality of both the seepage-impacted water and non-seepage-impacted water do not meet New Mexico water quality standards for TDS. There is a shift in the composition of the dissolved solids in each case, with magnesium and sulfate in higher concentrations in the non-seepage-impacted water and calcium and bicarbonate being higher in seepage-impacted water (Figure 9). There is no situation that can be envisioned in which the quality of alluvium background groundwater can be degraded by the migration of seepage-impacted water. In some respects, particularly regarding sulfate concentrations, the seepage-impacted water may be viewed as an improvement. Groundwater quality within the Southwest Alluvium is further discussed in Section 2.3.4.

Two other constituents are present at concentrations that historically have exceeded the Site standards primarily within the property boundary:

- Chloride – Chloride is a non-hazardous constituent. Chloride concentrations exceed the Site standard (250 mg/L) at Well 509 D. This well has exhibited an overall stable trend since 1996 with fluctuations ranging from 278 to 411 mg/L (see Figure 10). The chloride concentration at Well 632 has fluctuated about the standard with no discernible trend since 1990, and continued to do so during 2007 (Appendix A). Historically, chloride concentrations also exceeded the standard in Well 801, but a long-term, gradual decreasing trend (average -2 mg/L per year) has produced recent concentrations below the standard and the concentrations stabilized below the standard in July 2002 (see Appendix A). For the third time since the first exceedance in January 2004, chloride slightly exceeded the standard at Well GW 1 (POC well in Section 3) in October 2007. Chloride concentrations (including Well GW 1) are discussed more in Section 2.3.4.

- Chloroform – In August 2006 the NRC modified the Site license to change the former chloroform standard of 1 ug/L to a total trihalomethanes (TTHMs) standard of 80 ug/L (NRC, 2006b). Starting with the October 2006 sampling event, the laboratory has analyzed for TTHMs – all four component compounds (of which chloroform is one) are measured, and all Site groundwater samples (including the Southwest Alluvium) show that the TTHMs concentration equals the chloroform concentration (i.e., chloroform is the only TTHM compound present).

  In occasional discussion of "chloroform concentrations" in this report, the reader should bear in mind that the Site standard (and laboratory analysis) of relevance is now for TTHMs and not solely for chloroform as was previously the case.

Table 2 shows that during October 2007 Southwest Alluvium TTHMs were detected at levels far below the Site standard of 80 ug/L in the following wells: 632, 801, 802, 803, 808, GW 1 and GW 2. The very low concentration at Well GW 2 (0.64 ug/L) is very close to the laboratory TTHMs reporting limit of 0.50 ug/L, which in turn is one-half the former reporting limit of 1 ug/L when the laboratory analysis was solely for chloroform (see Appendix A).

Prior to the installation of Well SBL 1 and its first groundwater quality analysis in October 2004, the only historic exceedances of manganese (>2.6 mg/L) were within the Site boundary. Well SBL 1 had a manganese exceedance at 3.35 mg/L in October 2004 and was slightly above the Site standard at 2.7 mg/L in October 2007 (Table 2). Manganese exceedances (see Table 2 and Figure 11) occurred in onsite Wells 509 D (stable concentration trend since July 2003), EPA 23 (overall steady but fluctuating about an approximate level of 5 mg/L), and 801 (declining concentration trend since January 1993 with a small uptick in October 2007). Historically, the standard for manganese has occasionally been exceeded in Wells 802, 803, and 808 (Earth Tech, 2002c) (see Appendix A).

Long-term off-site seepage impacts to the groundwater have been limited to exceedances of the sulfate and TDS standards, both of which are non-hazardous constituents. Unlike Zone 1 and 3 impacted waters, the pH of the Southwest Alluvium impacted water is nearly neutral. Consequently, there are no exceedances of the metals or radionuclides standards within the seepage-impacted water, with the exception of the noted exceedances of manganese (a non-hazardous constituent) located well within the property boundary.

The non-impacted background water at downgradient Well SBL 1 showed October 2007 exceedances of nickel (0.08 mg/L) and manganese (2.7 mg/L), and three years earlier this well showed exceedances of manganese, cobalt, and nickel. These metals exceedances are unrelated to seepage impact to the groundwater because seepage-impacted water has not yet migrated to this location. Therefore, they should be viewed as a background condition, i.e., of post-mining/pre-tailings origin and age. The NRC's statistical evaluation of background water quality led to their recommendation that manganese, sulfate, and TDS should not be regulated site constituents and they should not be used as bases for corrective action (NRC, 1996; also see the SWSFS Part I, N.A. Water Systems, 2007b).

2.3.3 Rate of Seepage Migration

Earth Tech (2002c) has previously analyzed concentration trends of chloride and bicarbonate to infer the rate of constituent migration. Seepage impacts were observed to have migrated beyond the Site property boundary by 1982, but the only constituents showing exceedances in the impacted water offsite have been sulfate and TDS. However, bicarbonate and chloride have been determined to be the more effective indicators of seepage impact for reasons described in Section 2.3.2. Using chemical trends and estimates of hydraulic conductivity, hydraulic gradient, and effective porosity, Earth Tech calculated an average migration rate of 77 ft/yr beyond Well 624. Their transport rate was applied to the updated depiction of the inferred, southern edge of the impacted water during October 2003 (Figure 3 in USFilter, 2004a).

Subsequently, new groundwater velocity calculations have been made to estimate the rate of downgradient seepage-impact transport. These estimates are Darcy seepage velocities equal to the product of the hydraulic conductivity and the hydraulic gradient, divided by the effective porosity. The resultant groundwater velocities are upper-bound estimates of constituent transport velocities because no retardation or attenuation factors are applied.

Table 5 shows Southwest Alluvium groundwater velocities determined using hydraulic gradients based on the October 2007 measurements of groundwater elevations at Wells 805, 624, 627 and SBL 1. Upper and lower estimates of seepage velocity are based on a range of effective porosities adopted from

Canonie (1989b) and Earth Tech (2002c). The average calculated velocities are effectively based on a median porosity estimate of 0.31. Application of the mean hydraulic conductivity value of 3.69 x 10^{-3} cm/sec formerly used by Earth Tech (2002c) results in the prediction that seepage impact should already have arrived at Well SBL 1, which is not the case. The hydraulic conductivity value used in this annual report is 2 x 10^{-3} cm/sec, which was determined to be an appropriate mean value based on an extensive review of relevant site reports (USFilter, 2004b). This same mean alluvium hydraulic conductivity value was used in the groundwater modeling accomplished as part of the Zone 3 Supplemental Feasibility Study (MWH, 2004).

The average calculated groundwater velocity from Well 624 to Well SBL 1 is 34 ft/yr. This is approximately half the velocities associated with the other two upgradient well pairs, because the hydraulic gradient from 624 to SBL 1 is approximately half that associated with the other pairs (Table 5). The downgradient limit ("nose") of the 1,000 mg/L bicarbonate isoconcentration contour shown in Figure 8 is 34 ft farther to the southwest than it was in the comparable figure in the 2006 Annual Report.

The onset of persistent attainment of the "full impact threshold" values for bicarbonate (1000 mg/L) and chloride (150 mg/L) in Well 624 occurred in October 1996 (11 years prior to October 2007). Using the updated average groundwater flow rate from Wells 624 to SBL 1 of 34 ft/yr, it is inferred that the October 2007 location of the seepage-impact front is 341 ft downgradient from Well 624. This is consistent with the groundwater chemistry at Well SBL 1, which indicates no seepage impact. At the calculated velocity of 34 ft/yr, it would take approximately 4.7 years, or until 2012, for the seepage impact front to traverse the 159 ft from its present inferred position to Well SBL 1. This estimate assumes a constant seepage velocity, which may only be approximately the case as saturation levels continue to decline. There are also uncertainties in the hydraulic parameters used to make this estimate. Therefore, the timing of the arrival of seepage impacts at SBL 1 is not subject to precise prediction.

It took more than seven years of gradual concentration increases, from the start of monitoring in July 1989, for full seepage-impact levels of bicarbonate and chloride to develop at Well 624. Therefore, the start of future possible gradual increases in the bicarbonate and chloride levels in Well SBL 1 may be imminent. Continued monitoring of the water quality at this location should eventually allow back-calculation of the relevant, minimum average hydraulic conductivity.

2.3.4 Continuing Assessment of Southwest Alluvium Natural Attenuation and Earlier Technical Impracticability Waiver Request

UNC conducted a natural attenuation test from February 2001 to July 2002 to determine whether shutting off the Southwest Alluvium extraction wells would adversely affect water quality. The Southwest Alluvium extraction wells were shut off in January 2001 for the duration of the test. The NA report was submitted to the EPA, NMED, and NRC on November 4, 2002 (Earth Tech, 2002c). The NA test report concluded that turning off the extraction wells does not have an adverse effect on water quality and that the natural system is as effective as, or more effective than, pumping for controlling the migration of the constituents of concern. EPA has not reached the same conclusion based upon the *Second Five-Year Review Report* (EPA, 2003) and further comments on the NA report (EPA, 2004a), and so additional monitoring is being performed.

The Technical Impracticability (TI) evaluation concluded that natural conditions maintain sulfate and TDS concentrations at non-impacted background concentrations, which are nonetheless greater than Site standards. Physical and geochemical processes that reduce the tailings-impacted groundwater concentrations to background (or lower than background) concentrations have operated since mine water discharge began. This is demonstrated by the sulfate concentrations from impacted wells that contain constituent concentrations equivalent to, or variously higher or lower than, the non-impacted background concentrations. (See Figures 7 and 8; compare background Wells 627, EPA 28, and SBL 1 with wells located within the area impacted by tailings seepage.) The same is true of TDS, for which historic concentrations are shown in Figure 12. Overall, ranges of TDS concentrations are no higher in impacted wells than in background wells. Background Well 627 has fluctuated about the Site standard (4,800 mg/L); background Well EPA 28 has persistently exceeded the standard; and background Well SBL 1 had the highest concentration of any well during October 2007 (excluding earlier measurements at SBL 1, the most recent concentration that exceeded this standard was in impacted Well 801 during January 2000). The remediation system did remove sulfate and TDS mass, but this is irrelevant because concentrations are dependent on the chemical equilibrium of gypsum; therefore, they have been and will continue to remain similar to those achieved through geochemical processes within the groundwater system. Thus the concentrations are not dependent on continuing the former pump-and-evaporate corrective action program, but are instead controlled by natural geochemical reactions; in particular, the pervasive equilibrium between the groundwater and naturally occurring gypsum (or anhydrite).

Under the federal drinking water standards, sulfate and TDS are assigned secondary drinking water standards (SMCLs), which are non-enforceable guidelines regulating chemical constituents that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water (EPA, July 1992). EPA recommends secondary standards to water systems, but does not require those systems to comply. Under applicable New Mexico regulations (20 N.M.A.C.1101(TT)), TDS and sulfate are not defined as "toxic pollutants" for purposes of groundwater and surface water protection. Additionally, they are not included on NRC's hazardous constituent list applicable to groundwater, nor were they assigned Site groundwater protection standards by NRC. The standards set for sulfate and TDS are not for the protection of human health. The secondary standards are not federally enforceable, but are intended as guidelines. Therefore, a TI Waiver has previously been deemed appropriate for sulfate and TDS (Earth Tech, 2002c; USFilter, 2004a; N.A. Water Systems, 2005a).

UNC believes that the earlier part of this report demonstrates an understanding of, as well as the distinctions between, the geochemical evolution and characteristics of both background water and seepage-impacted water. The concepts demonstrated above require that a Southwest Alluvium zone to be covered by a TI Waiver be viewed in a non-traditional manner. Sulfate and TDS exceedances in the background water are unrelated to seepage impact. It is inappropriate to apply the TI zone concept to the extensive downgradient area of exceedances of sulfate and TDS. Instead, UNC is presenting the extrapolated location of the seepage-impacted water 197 years from now (shown in Figure 59), and has concluded that the area meets ALARA (as low as reasonably achievable) principles, and that Alternate Concentration Limits (ACLs) should be established by the NRC and applied to the management of this zone. This depiction derives from application of the average October 2004 groundwater velocity from Well 624 to Well SBL 1 (30 ft/yr) over a 200-year period, and it assumes purely advective transport of seepage impacts with no retardation, dilution, or attenuation. The extrapolated impact-area along the alluvium is predicted to advance by approximately 6,000 ft with the impact front of year 2204 located as shown in Figure 59. As part of the development of a SWSFS, UNC is currently reevaluating the technical bases for a potential Site-wide TI Waiver request for sulfate and TDS, as well as the applicability of ACL applications.

2.3.5 Reassessment of the Performance of the Natural System

The natural attenuation evaluation report (Earth Tech, 2002c) included nonparametric trend analysis to determine whether increases in contaminant concentration occurred during the test and whether the changes were significant. Increases in upward trends were identified for bicarbonate, chloride, and TDS, although bicarbonate was evaluated as an indicator parameter only, not as a constituent of concern. These increases were attributed to the elimination of the partial capture provided by the extraction wells. No change in trend was observed for the sulfate concentrations because these are naturally equilibrated with gypsum. The natural attenuation evaluation (Earth Tech, 2002c) also concluded that there was no change in trend for manganese, chloroform, or uranium. It was concluded from these analyses that, although seepage-impacted water continues to migrate as shown by upward trends in bicarbonate, the migration of metals and radionuclides is arrested by attenuation processes (i.e., adsorption and precipitation). Continued groundwater quality monitoring through October 2007 supports this conclusion.

Table 6 shows the predicted performance of natural attenuation in the Southwest Alluvium. Sulfate and TDS concentrations are not expected to meet Site standards within seepage-impacted areas because calcium availability and gypsum equilibrium in the groundwater limits reduction of sulfate concentrations. Sulfate and TDS concentrations within the background waters are unrelated to seepage impact and application of the Site standards is inappropriate. Groundwater quality in background Well SBL 1, and our understanding of the geochemical systems associated with both background water and seepage-impacted water, have been incorporated into the entries in Table 6. Within seepage-impacted water the metals and radionuclides are expected to meet the standards through attenuation by neutralization and adsorption. The individual indicator parameters and constituents of concern are discussed below.

Calcium and Bicarbonate

Calcium and bicarbonate are non-hazardous constituents. Figure 13 illustrates the long-term stability of calcium and bicarbonate concentrations at Wells 627 and EPA 28, which are examples of background wells that have not been impacted by tailings seepage. Calcium concentrations in Wells 627 and EPA 28 have been essentially the same through time. Figure 13 shows that during the onset of seepage impact in Well 624 (indicated by the increasing bicarbonate), the calcium concentration increased by approximately 100 mg/L and then re-equilibrated at a concentration of 650 to 700 mg/L. Under changed groundwater quality flux, calcium concentrations remain fixed in the presence of calcite and gypsum by the Phase Rule; the long-term consistency of calcium concentrations in the Southwest Alluvium attests to the established equilibrium between the groundwater and these minerals. In general, calcium concentrations do not vary appreciably anywhere in the groundwater flow system (see Figures 9 and 14).

Figure 15 shows the bicarbonate concentrations over the same period. Bicarbonate is a non-hazardous constituent that serves as the primary indicator of seepage impact in the Southwest Alluvium. Post-shutoff uptrends in GW 3 stabilized in approximately January 2003; in GW 1 in approximately October 2004; and in GW 2 in approximately April 2005. These observations indicate an increased degree of seepage impact has been reaching the GW-series wells since shutoff, and that neutralization and geochemical attenuation is still occurring naturally. Bicarbonate concentrations in Wells GW 1, GW 2, and GW 3 may have achieved a chart "plateau" level of relatively constant values, indicating the natural neutralization processes have attained readjusted equilibrium.

Sulfate and TDS

Sulfate and TDS are non-hazardous constituents. They do not have federal drinking water MCLs; they do have SMCLs. The provisional Site standards (2,125 mg/L for sulfate and 4,800 mg/L for TDS) derived from a background water quality analysis by the NRC (1996), with which NMED concurred (NMED, 1998).

Sulfate concentrations exceed the standard in both the seepage-impacted water and the background water in the Southwest Alluvium. Regardless of whether the extraction wells were operating, sulfate concentrations in the Southwest Alluvium are controlled by the system's equilibrium with gypsum. Figure 16 shows sulfate concentrations from 1999 through October 2007; Figure 17 presents TDS concentrations over the same period. Figure 16 shows that sulfate concentrations in Well GW 1 increased modestly after shutoff until January 2002; since then this parameter has been stable. TDS in Well GW 1 has been stable since April 2004. Sulfate in Well GW 2 was approximately stable after shutoff through October 2004, when an increasing trend started that continues to present.

Such changes in sulfate and TDS are unrelated to the very high concentrations that were originally present in the tailings. The groundwaters at various locations, both background and impacted, are always in equilibrium with the Southwest Alluvium matrix gypsum (or anhydrite), and the differences in sulfate and TDS concentrations are a reflection of the different water chemistries that are in equilibrium with the gypsum.

When viewed over the entirety of the Southwest Alluvium, sulfate has been very stable for the entire period of monitoring, regardless of whether there has been an active or passive remedy in place.

Based on the results of the geochemical investigation presented by Earth Tech (2000d), sulfate is not expected to meet the clean-up standards in the Southwest Alluvium. As shown on Figure 9 (and consistent with Zone 1 and Zone 3), most of the TDS comprises sulfate. Accordingly, TDS concentrations are not expected to meet the clean-up standards.

Chloride

The Site standard for chloride derives from the New Mexico Water Quality Act; 250 mg/L is also the federal SMCL (this constituent does not have a federal primary MCL). Chloride is chemically nonreactive and serves as a geochemically passive tracer of tailings fluid impact.

Figure 10 presents chloride concentrations from 1999 through October 2007. Well 509 D is the only location where chloride concentrations have persistently exceeded the standard (250 mg/L). Occasional, typically minor exceedances have occurred in the past at Wells 632, 801, and GW 1 (this occurred in October 2007 in Wells 632 and GW 1).

Figure 10 shows that during the 18 months after the pumping shutoff, there were small Site-wide increases in chloride, after which concentrations returned to their pre-shutoff levels. The small increases may have been (at least partially) an artifact of the more frequent, monthly water quality measurements that were made for the 18 months following shutoff (after which the frequency returned to quarterly monitoring). Pumping had no effect on chloride concentrations with the apparent exception of Well GW 1, where post-shutoff increases stabilized in January 2004 at concentrations that occasionally show very small exceedances.

Manganese

Manganese is non-hazardous constituent. It does not have a federal drinking water MCL; it does have a SMCL. The Site standard (2.6 mg/L) was cited as background water quality in the ROD (EPA, 1988b).

Figure 11 presents manganese concentrations from 1999 through October 2007. Manganese is the only metal that exceeds its current standard in seepage-impacted areas. Exceedances have occurred typically at three wells: 801, EPA 23, and 509 D. The concentration trends have been relatively flat at Well 801 since July 2004 and at Wells EPA 23 and 509 D since 2000. Well 509 D is an upgradient well that was not hydraulically influenced by the former downgradient extraction well pumping, and the changes of manganese concentrations are probably unrelated to previous pumping.

Two of the monitoring wells in proximity to the southwestern "nose" of the South Cell (802 and 808) continued to show low manganese concentrations during October 2007 that were below the standard. Nearby, Well 632 maintained a very gradual increasing concentration trend that started in December 2001, but the 2007 values were still below the standard. All three of the GW-series wells continued to show long-term stable trends below the Site standard.

These observations indicate that manganese natural attenuation continues effectively in much of the seepage-impacted waters. It is expected that concentrations will continue to be below the standard in most of the seepage-impacted wells; however, exceedances are expected to continue at Well EPA 23, and sporadic exceedances appear likely to continue in Well 509 D (both of these are POC wells located significant distances upgradient of the Section 2 property boundary). Based on long-term trends, modest exceedances may continue at Well 801.

There was a minor exceedance of the manganese standard at background Well SBL 1 in October 2007 (2.7 mg/L; Table 2 and Figure 11). Well SBL 1 has also had an exceedance of nickel and has shown relatively high concentrations of magnesium (Table 2; Figure 9; Appendix A). These characteristics do not reflect the presence of seepage-impacted water at this location. Rather, as explained earlier in Section 2.3.2, the geochemistry of groundwater at SBL 1 reflects background conditions that are very likely related to the dissolution of soluble alluvium minerals associated with the initial discharge of mine waters.

Uranium

Uranium concentrations do not exceed either of the current Site standards of 5 mg/L as listed in the ROD, or the NRC License standard of 0.3 mg/L. A summary of historic Southwest Alluvium uranium concentrations through October 2007 is provided in Appendix A and in the time-series charts discussed below.

The statistics included in the NA report (Earth Tech, 2000c) determined that there was not a significant increase in trend for uranium; however, the graphs of uranium concentration in several wells indicated a possible increase prior to and during the NA test. For this reason, UNC has continued to reassess the uranium trends as part of the Site annual reporting.

GE (2006) has evaluated the regulatory significance of the occurrence and distribution of dissolved uranium in the Southwest Alluvium. That report was prepared to assist EPA in deliberations about applying the current MCL for uranium (0.03 mg/L) as a formal cleanup criterion in the Southwest Alluvium. EPA has orally indicated that they are considering the adoption of the current MCL for uranium as their standard at Church Rock, although they have not yet proposed a formal modification to their current standard in the ROD (5 mg/L). Figures 18 through 34 (discussed below) show that most of both the impacted and background wells have long-term uranium concentrations exceeding 0.03 mg/L.

The concentration of dissolved uranium in seepage-impacted water is a function of the bicarbonate concentration, and has been empirically found to lie within the same concentration range as the background (post-mining/pre-tailings) water. The covariance of uranium and bicarbonate concentrations is an important observation for which some examples are provided below.

Graphs of uranium concentrations in all fourteen wells comprising the Southwest Alluvium water-quality performance monitoring program, through October 2007, are included as multi-well plots in Figures 18 and 19. These plots cover the period from April 1999 through October 2007, thus providing a visually expanded time (horizontal) scale spanning shutoff. Figure 18 shows only the seven POC wells; Figure 19 shows other select wells, including background water quality. Graphs of uranium concentrations are shown separately for each well in Figures 20 through 34. The plots indicate that uranium concentrations at each well have been below the NRC license standard. Furthermore, none of the time-series exhibit trends from which future exceedances might be predicted. These charts show the following additional key observations:

- **Well 509 D** (Figure 20): The uranium concentration in Well 509 D, which is located upgradient of the South Cell and the other Southwest Alluvium wells, increased one full year prior to the NA test starting in October 1999 (pumps were shut off in January 2001). Relatively large fluctuations have been characteristic since shutoff and during earlier periods. The concentration trend has been overall stable (i.e., approximately horizontal on the chart) since July 2000, at the higher end of the historic range. Well 509 D is located outside the zone of influence of the former pumping wells; Well 509 D is not a good indicator of whether there is a benefit to pumping. However, if Well 509 D were postulated to be in the zone of influence, then the uranium data would indicate that there is no benefit to pumping because the concentrations increased while the pumps were operating and stopped increasing when they were shut off.

- **Well 801** (Figure 21): The uranium concentration in Well 801 increased to its maximum just prior to shutdown and decreased through most of the NA test. The concentrations decreased and stabilized, approaching the long-term average concentration that had been extant during pumping. This indicates that although slugs of uranium-bearing water may pass through the system, they will tend to approach a stable, average concentration whether or not the pumps are running.
- **Well 802** (Figure 22): Well 802 was a pumping well that was shut down on January 8, 2001. Subsequent concentrations increased through September 2001, were stable through October 2003, and have been decreasing since then. The decreasing trend since October 2003 is within the upper part of the historic range. If a long-term linear trend line were to be established for this well, it would seem that the discontinuance of pumping in 2001 would have no discernible effect on the long-term trend.
- **Well 803** (Figure 23): The uranium concentration in Well 803 spiked in the year 2000, more than one year before the NA test. Only one of the 33 samples collected since shutdown showed higher uranium concentrations than the two relatively high concentrations that were measured during 2000, before the shutdown. Post-shutoff concentrations increased through July 2002 to a similar value measured pre-shutoff during May and July 2000. Since July 2002, the trend has been decreasing and concentrations are consistent with the historic range. There is no statistically discernible advantage to pumping based on well 803.
- **Well GW 1** (Figure 24): The uranium concentrations in Well GW 1 began to increase in 1999, well before the NA test, and therefore cannot be attributed to the cessation of pumping. Post-shutoff concentrations continued to increase at an accelerated rate through July 2002 and then decreased through January 2004, at which time they stabilized. Concentrations have since been stable at levels consistent with the early- to mid-1990s, but slightly above the lowest concentrations reached in the late 1990s. This chart also shows the bicarbonate concentrations over the entire history of monitoring. The covariance in uranium and bicarbonate concentrations is characteristic of all wells in the Southwest Alluvium (GW 1 provides an example from a seepage-impacted well, that may be compared with the example from Well EPA 25, below). This important relationship can be explained by the basic geochemical principles presented in GE (2006).
- **Well GW 2** (Figure 25): Post-shutoff concentrations were stable through October 2002; then they increased to January 2005, after which they appear to have stabilized. The post-shutoff range concentrations have been lower

than most historic concentrations and similar to concentrations that were achieved prior to the cessation of pumping.

- **Well GW 3** (Figure 26): Post-shutoff concentrations were stable through October 2002; then they increased to January 2005, after which they appear to have stabilized.
- **Well 624** (Figure 27): Post-shutoff concentrations have been stable at the lower end of the historic range. There is no statistically discernible advantage to pumping based on Well 624.
- **Well 632** (Figure 28): Post-shutoff concentrations have been stable at the lower end of the historic range (excluding a drop to non-detect in April 2004). There is no statistically discernible advantage to pumping based on Well 632.
- **Well 627** (Figure 29): Post-shutoff concentrations have been stable along the historic trend that is associated with a low range. There is no statistically discernible advantage to pumping based on Well 627.
- **Well 808** (Figure 30): This well was installed in conjunction with the planned shutoff of the extraction well system; it has no pre-shutoff history. The post-shutoff uranium concentration showed a large upward spike through September 2001; since then the trend was strongly downward through October 2002, subsequent to which the concentrations have stabilized.
- **Well EPA 23** (Figure 31): Post-shutoff concentrations have been stable at the lower end of the historic range that is associated with a low range. There is no statistically discernible advantage to pumping based on Well EPA 23.
- **Well EPA 25** (Figure 32): Concentrations have been quite stable since July 1999 along the upper part of the historic range. There is no statistically discernible advantage to pumping based on Well EPA 25. This chart also shows the bicarbonate concentrations over the entire history of monitoring. The onset of seepage impact at this well occurred during October 1995. Such covariance in uranium and bicarbonate concentrations is characteristic of all wells in the Southwest Alluvium. This important relationship can be explained by the basic geochemical principles presented in GE (2006).
- **Well EPA 28** (Figure 33): Concentrations have been quite stable since July 1989. There is no statistically discernible advantage to pumping based on Well EPA 28.
- **Well SBL 1** (Figure 34): Concentrations at this newest, downgradient background well have varied from 0.0176 mg/L to 0.0332 mg/L.

This comprehensive review of historic uranium concentrations demonstrates that most of the seepage-impacted wells have shown overall stable to decreasing trends since shutoff. Overall, none of the wells have shown post-shutoff concentrations that exceed historic values, and many of the wells show that both gradual and sudden variations are common.

None of the wells have shown exceedances of the standards. *The time-concentration plots indicate that natural attenuation, by neutralization and adsorption, is at least equally as effective as a pumping remedy.* This conclusion is bolstered by earlier discussion indicating that in comparison to background water quality, the passage of the seepage-impact front presages an improvement in sulfate and TDS concentrations.

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Groundwater Corrective Action
Church Rock Site, Church Rock, New Mexico
Section 3
Zone 3

3.1 Corrective Action Summary

While operating, the corrective action system in Zone 3 performed as designed to enhance dewatering of the seepage-impacted area and remove constituent mass. Historic corrective action in Zone 3 consisted of pumping the three sets of extraction wells shown on Figure 35: (1) Northeast Pump-Back System (green triangles), (2) Stage I Remedial Action System (filled blue squares), and (3) Stage II Remedial Action System (empty black squares). The Northeast Pump-Back wells started operation in 1983; the Stage I and II wells were added later as part of the *Remedial Action Plan* (UNC, 1989b) implemented in 1989.

Eighteen years of remedial pumping have shown that once the saturated thickness falls to approximately 25 ft or less, well efficiency declines and pumping rates fall to less than 1.0 gpm (Earth Tech, 2001). Table 7 presents the reductions in saturated thickness for Zone 3 monitoring wells between the third quarter of 1989 and the fourth quarter of 2007. Values of saturated thickness greater than 25 ft are shaded. The number and pumped volumes of the former extraction wells, during the period of Zone 3 corrective action from 1989 through 2000, have been summarized in Earth Tech (2002d, Figure 3-2).

The saturated thickness in Zone 3 has declined by 68 percent on average since the third quarter of 1989. Only one well, EPA 14, had a saturated thickness greater than 25 ft in October 2007. As discussed in the "Technical Memorandum, Change in Zone 3 Saturated Thickness" (Earth Tech, 2001) submitted to the NRC on April 23, 2001, the loss of saturated thickness over time resulted in a decrease in the efficiency of the extraction wells to the point that only three of the total 24 wells were still pumping at rates greater than 1.0 gpm in June 2000. UNC's May 2000 License amendment request to shut off remaining Zone 3 pumping wells (Earth Tech, 2000b) concluded that operation of these pumping wells accelerated the rate of downgradient constituent migration. UNC requested that these extraction wells be shut off to reduce the migration rate, allowing more time for the background water to neutralize the seepage and attenuate the hazardous constituents. Additionally, these wells were pumping background-quality water and served no purpose in reducing contaminant mass in seepage-impacted waters. The NRC amended the License (with approval from NMED and EPA) to shut off the three remaining wells (716, 717, and 718) in

December 2000. This decision included a provision for UNC to submit a modified corrective action plan, an application for ACLs, or an alternative to the specific requirements of 10 CFR Part 40, Appendix A, if the License standards are not achievable.

At the request of the EPA (2004b), UNC has conducted a Supplemental Feasibility Study (SFS) to evaluate all appropriate remedial options for Zone 3 (these options will be reviewed during the development of the SWSFS). Prior to reporting the SFS (MWH, 2004), UNC submitted (2004) a Technical Memorandum including a chronology of events that led to UNC's initiative to aggressively develop remedy modifications or enhancements that might improve the performance of the remedy in Zone 3. The SFS report presented (1) groundwater modeling of the Zone 3 sandstone unit and the locally overlying alluvium, (2) the pilot-hole hydrofracturing study results, (3) a remedial alternatives analysis, and (4) conclusions and recommendations for enhancing or optimizing remedies for Zone 3. The hydraulic modeling indicated that for most of the alternative remedies to be effective (excluding Alternative 6 – Cutoff/Containment Wells), the recharge from the alluvium to Zone 3 should be reduced or eliminated.

Extraction of impacted groundwater from a new array of wells in the northern part of the Zone 3 was tested in April 2005 as part of the Phase I (i.e., post-pilot) hydrofracture program (MACTEC, 2006). Continuous pumping of these wells began in May 2005. Phase I ended in January 2006; however, as discussed later in this section of the report, the pumping has been continued because of its success in both intercepting northward-advancing impacted water and in improving groundwater quality along the northern front of the seepage impact. Approximately 6,792,114 gallons of groundwater has been pumped from this new Zone 3 extraction well network from January 2005 through the end of November 2007, and piped to the evaporation pond.

The former remediation system wells (the last three of which were shut off in 2000) partially dewatered Zone 3; however, it also accelerated the downdip migration of seepage-impacted water into non-impacted parts of the formation. Figure 35 shows that between 1989 and the fourth quarter of 2007, a very large portion of the Zone 3 Remedial Action Target Area has been desaturated (effectively dewatered). The eastern limit of Zone 3 saturation has shifted to the west-northwest over this time period (from the location of the wavy blue line, showing the saturation limit in 1989, to the dashed brown line showing the approximate October 2007 "zero" saturation limit).

UNC conducted an in-situ alkalinity stabilization pilot study to evaluate the potential to enhance the ongoing Zone 3 remediation through the use of alkalinity injection wells combined with carefully controlled extraction pumping at the site.

The proposed approach for the pilot study was presented in the *In-Situ Alkalinity Stabilization Pilot Study* (BBL, 2006), which was approved by EPA.

The pilot study was initially designed to test the injection of alkalinity-rich groundwater from a non-impacted part of the Southwest Alluvium into the Zone 3 aquifer. The injected water (so-called "fixiviant") would flow through the Zone 3 formation to recovery wells where the fixiviant could be pumped to the surface for treatment and disposal. However, concerns were expressed by NMED that the groundwater from the Southwest Alluvium did not meet applicable groundwater standards for sulfate, total dissolved solids and manganese. Following the original submission of this pilot study (in October 2005) and subsequent discussions, NMED identified groundwater withdrawn from a formation below Zone 3 and the underlying Mancos Shale (the Dakota Formation), via the onsite Mill Well, as a potential alternative source of groundwater to use as the injection water. The pilot study approach was revised to include injection of the Mill Well water (amended with sodium bicarbonate to add alkalinity) into Zone 3, as described in the approved *In-Situ Alkalinity Stabilization Pilot Study* dated June 2006.

As presented in Figure 36, the pilot study well field includes a central extraction well (EW-1) surrounded by four injection wells (IW-1 through IW-4) that were installed by UNC in 2006. The central extraction well provides the primary monitoring location to evaluate the effectiveness of the pilot study in terms of removing and/or immobilizing the target constituents of concern. The four surrounding injection wells provide a means to inject the amended Mill Well water. In addition, the injection wells serve to hydraulically isolate the central extraction well from the surrounding groundwater flow system, and provide a controlled, closed hydraulic system for monitoring the effectiveness of treatment over time during the pilot test. The four outer extraction wells (wells 608, 517, 518, and EW-2) provided overall hydraulic control during the pilot study.

The pilot program objectives were to determine whether the following, potentially beneficial effects occur in the affected area of Zone 3: (1) pH increase (buffering); (2) changes in aqueous/solid partitioning and precipitation reactions that would reduce or eliminate the migration potential for certain constituents of concern; and (3) extraction of uranium, and fixation of radium and other metals that may exceed the ROD's cleanup objectives, and piping of the pumped water to the evaporation pond.

Installation of equipment in the pilot study well field began in August 2006. Installation of pilot study injection and extraction wells, and the conversion of existing wells to be used as extraction or injection wells as appropriate, was completed and the system was activated in October 2006. An approximately 18,000-gallon Baker tank was staged at the injection site to store groundwater collected from the Mill Well, to be used for injection. The necessary piping, fittings, and instrumentation were installed to allow amended Mill Well water to be gravity-injected from the storage tank to the four injection wells. An air compressor, pneumatic pumps and associated piping were also installed to extract and convey groundwater from the extraction wells to the existing surge tank for discharge to the on-site evaporation pond.

The pilot study was conducted from October 24, 2006, to February 15, 2007. The observed injection and extraction rates were unexpectedly low. As a result, the estimated travel time between the injection and extraction wells became prohibitively low and the pilot test was terminated. Data obtained as part of the pilot study indicated that the mineral feldspar in the Zone 3 arkosic sandstone had been altered by the acidic tailings liquids, generating kaolinitic clay that significantly clogged pore spaces and reduced hydraulic conductivity. The pilot study indicated that it would take 10 times longer to accomplish remedy goals than had been hypothesized. Using what had been envisioned as an approximate 5 year remedy enhancement could actually take 50 years or more. Based on these results, the use of alkalinity rich solutions to remediate the Zone 3 impacted groundwater in-situ is not feasible (ARCADIS BBL, 2007).

The effects of both the former and the present-day, reconfigured remediation pumping in partially, locally dewatering Zone 3 are presented in Figure 37. The figure marks the start of recovery pumping from the new well array installed during the hydrofracture study in April 2005. The locations of these new pumping wells (RW-11, RW-12, RW-13, RW-16, RW-17, and PB-2) are shown on Figure 38 and Figure B-1 in Appendix B. Also shown is the location of a new extraction well, RW A, that started pumping on September 24, 2007.

The in-situ alkalinity stabilization study unexpectedly found that the seepage-induced alteration of feldspathic minerals is reducing the bedrock permeability. This will tend to restrict the migration of tailings seepage. The main reason that the groundwater flows toward the north is that the Zone 3 bedrock unit dips toward the north. The hydraulic head that drives the flow comprises two components: the elevation head plus the pressure head. The long history of extraction pumping in Zone 3 has reduced the pressure head component of the total hydraulic head. However, it is not possible to reduce the slope-related elevation head – that is a driving force component that cannot be changed. Continued pumping has been helping in the short-term as Figure 37 shows; however, the saturated thicknesses in this hydrostratigraphic unit are quite low and there will eventually be no further possible reduction in the pressure head. UNC has been doing all that it can to counteract the overall hydraulic head. This is gradually approaching practical limits as the well yields decrease beneath the well decommissioning criteria. At some time in the future, there will likely be a balance between the tendency for the irreducible elevation head to promote the continuing northward migration of seepage-impacted water and the tendency for the seepage-induced permeability reductions to hold the groundwater in place. The exact timing and location of the development of this critical balance cannot be predicted – but such a condition should inevitably occur.

3.2 Mass of Chemical Constituents Removed

The mass of chemical constituents removed was calculated for the 12-year period from July 1989 through June 2000. These calculations were presented in the previous annual reviews, and the final summary is presented in the 2000 Annual Review (Earth Tech, 2000e).

As previously discussed, extraction well pumping that originated with the hydrofracture program has continued to present. Table 8 shows the estimated mass removal by this pumping from December 2006 through November 2007 (the similar Table 8 in the 2006 Annual Report showed data through November 2006); the RW-series extraction wells (and converted pumping well PB 2) are shown on Figure 38 and Figure B-1 in Appendix B. Also included is the relatively minor contribution from two of the extraction wells associated with the pilot study discussed earlier. The recovered masses were estimated by multiplying the volume of groundwater pumped by the estimated concentration of each constituent in the pumped water. The constituent concentrations were estimated from concentrations measured in groundwater samples taken from other Zone 3 wells during October 2006 (water quality analyses were not determined for the actual pumped water). These estimates were made using the method of kriging to spatially interpolate the measured concentrations, in a way analogous to that used to produce contour maps.

3.3 Performance Monitoring Evaluation

The current Zone 3 performance monitoring program is summarized in Table 9 and comprises quarterly monitoring of water levels in 23 wells and water quality in 11 wells. This program went into effect in the second quarter of 2000 and was modified in the second quarter of 2001, at the request of the NRC, to include the following additional components:

- Water quality monitoring at Wells EPA 13, 717, and 719;
- Water level and water quality monitoring at Well 708; and
- Installation of Well NBL 1 (July 2001) as a new downgradient monitoring well.

The location of Well NBL 1 (see Figure 35) was selected to both bound the downgradient extent of the impacted water and function as a tracking well.

To supplement the performance monitoring program, four monitoring wells were installed (June 2002) between Wells 504 B and NBL 1: PB 1, PB 2, PB 3, and PB 4 (Figure 35). Drilling logs and well completion forms are included in Earth Tech (2002d, Appendix B). These wells serve to track the advance of the northernmost seepage-impact boundary. Well PB 1 was installed within impacted water and has been excluded from further monitoring that is intended to track the advancing front. Monthly water levels and general water quality analyses (pH, specific conductance, chloride, and alkalinity) are collected from the remaining five wells. Well PB 2 was converted to an extraction well in November 2005 to complement the RW-series pumping wells in the northern area of the impacted water. Chloride and alkalinity analyses are performed using Hach field-testing kits. Quarterly samples from these three boundary "tracking" wells are submitted to a laboratory to check the field results (the laboratory analyzes TDS in lieu of specific conductivity). Based on these comparisons, the field parameters provide a good indication of the migration of the seepage-impacted water. As discussed later in this section, the new pumping array has resulted in three beneficial effects: (1) capture of most if not all of the northward-advancing impacted water (i.e., partial hydrodynamic control); (2) marked groundwater quality improvement and recession of the seepage-impact front to the south; and (3) dewatering. The groundwater quality improvement is expected to be temporary. Pumping rates have begun to decline and this is expected to continue because this has been the case for all other pumping wells in the past.

Two piezometers were installed in July 2004 to the base of Zone 3 just north of the northeastern boundary of the Central Cell (see Figure 35, piezometers Z3M-1 and Z3M-2). These installations were made following recommendations in UNC's investigation (USFilter, 2004b) of the potential for the covered tailings cells to continue to source seepage impact and recharge to the updip part of the Zone 3 hydrostatigraphic unit. The first two quarters of water-level monitoring showed that both piezometers were dry (excluding small amounts of drilling fluid). Therefore, the piezometers are no longer monitored.

During August 2007, a new monitoring well (NBL 2; 187 ft deep) was installed approximately 400 ft to the west of NBL 1 (see Figure 35).

3.3.1 Water Level Evaluation

Water level data from 1989 through the fourth quarter of 2007 are presented in Appendix B. Water levels from October 2007 are shown on the potentiometric surface map in Figure 38. These potentiometric contour lines indicate groundwater flows toward the north and northeast, approximately parallel with the eastern limit of Zone 3 saturation. This potentiometric field is similar to, though lowered from, those depicted for the fourth quarters of 2001 (Earth Tech, 2002a), 2002 (Earth Tech, 2002d), 2003 (USFilter, 2004a), 2004 (N.A. Water Systems, 2004), 2005 (N.A. Water Systems, 2005b), and 2006 (N.A. Water Systems, 2007a).

Figure 38 shows the locations of pumping wells during October 2007 and monitoring wells. Both measured groundwater elevations (see legend; shown in rounded parentheses) and estimated groundwater elevations (shown in squared brackets) have been used to develop this map. The estimated groundwater elevations were determined by graphic extrapolation – these data were employed in an attempt to show the effects of pumping drawdown at locations RW-16 and RW-17 (to the south of Well 719) and RW-11, RW-12, and PB-2 (to the north of Well 719). With the exception of Well PB 2 through July 2007, no water level data were measured in the pumping wells. The effect of pumping is shown on Figure 38 in the vicinity of RW-16 and RW-17, but it is not clearly visible in the pumping wells to the north. This is because the 10-ft contour interval used in Figure 38 is greater than the estimated drawdown in the vicinity of these wells.

Maps presented by MACTEC (2006) well-illustrate the effects of pumping on the Zone 3 saturated thickness (their Figure 3.6), total groundwater drawdown (their Figure 3.7), and the capture zone created by the northern part of the pumping array (their Figure 3.11). Those maps were developed by incorporating pumping-well groundwater elevations (data unavailable from October 2007), which facilitated use of a smaller contour interval than that shown in Figure 38. MACTEC's interpretation of the Zone 3 piezometric surface indicated potentially incomplete groundwater capture. However, if groundwater had locally escaped capture it is of much improved quality than was previously the case. This is indicated by the marked improvement in groundwater quality at the tracking wells following the initiation of pumping from PB 2 (see Section 3.3.2). Based on MACTEC's Figure 3.11 and their recommendation, UNC installed new extraction well RW A approximately 200 ft to the northeast of extraction well RW 11 (see Figure 38).

Mine water discharge into Pipeline Arroyo ceased in 1986. Since then, Zone 3 groundwater flow directions became more generally north-northeasterly as recharge from, and groundwater mounding within, the alluvium to the southwest and west has decreased. The earlier east-to-northeast flow direction caused the distribution of groundwater impacts that was the original basis for delineation of the Zone 3 Remedial Action Target Area, as shown on Figure 35. Effects on the potentiometric surface from alluvium recharge (mine water discharge) have largely dissipated, and rates of water level change in Zone 3 are mostly very slow (excluding the influence of recent pumping). Variations from the depicted direction of groundwater flow are unlikely, except where flow may be locally redirected by the new pumping configuration. Since cessation of mine water discharge, water levels have been declining. Pumping of extraction wells prior to January 2001 temporarily accelerated the local rates of water level decline until the saturated thickness was reduced to less than ~ 25 ft, after which the decline in levels slowed to natural rates of drainage. By October 2007, the saturated thickness in the vicinity of monitoring wells had reduced to about 15 feet on average (Table 7).

Contours of saturated thickness during the fourth quarter of 2007 (Figure 39) show the combined effects of former pumping, current pumping, and natural drainage on Zone 3. This map was developed by evaluating the differences between two interpolated surfaces: the base of Zone 3 and the potentiometric surface for October 2007. The eastern extent of saturation has contracted to the west, so that the current boundary of saturation is approximately where the 25-ft saturated thickness contour was located in 1989 (for comparison, see Earth Tech, 2002d, Figure 3-1). Also, the wells located to the west, closer to the recharge area, have lost substantial saturation. For example, Well EPA 14 had 76 ft of saturation in 1989 and 30 ft in the fourth quarter of 2007 (a 61 percent reduction in the saturated thickness; see Table 7). Table 10 shows the saturated thickness in each Zone 3 well during October 2007. From 2002 through 2007, most wells have shown overall decreasing groundwater elevations (usually with small fluctuations), indicating that the Zone 3 potentiometric field that drives groundwater flow and constituent migration continues to become lower as the groundwater further drains away. Pumping, primarily from the hydrofractured extraction wells, has removed more than 6.7 million gallons from 2005 through 2007.

3.3.2 Water Quality Evaluation and Current Extent of Seepage-Impacted Water

Figure 35 shows the approximate recharge area, located to the north and northeast of the North Cell, where mine water in the alluvium percolated into the underlying Zone 3 hydrostratigraphic unit. This figure shows the approximate configurations of the saturated portion of the alluvium/Zone 3 contact as well as the unsaturated portion of this same contact zone. The temporary saturation caused by the mine water discharge is considered the background water for Zone 3 (EPA, 1988a; 1988b; 1998).

This background water was later impacted by acidic seepage from tailings in the North Cell. These seepage fluids contained elevated concentrations of metals, radionuclides, and major ions including sulfate and chloride. Source control (neutralizing and later dewatering of the North Cell), neutralization of the seepage by natural attenuation, and mixing with the background water have reduced constituent concentrations.

Seepage-impacted water, some of which exceeds Site standards, is contained within the property boundary in Section 36. The portion of the impacted water that extends off the property into Section 1 (Figures 6 and 35) was eliminated as a point-of-exposure (POE) because of limited saturation. The decision to eliminate this area as a POE is documented in a letter from the NRC (1999b).

It is important to recognize that exceedances of Site standards in some Site wells represent background water quality. For example, exceedances of the combined radium and sulfate standards in Well EPA 14 significantly pre-date the beginning of strong seepage impacts that were first observed at that well during 2000 (the water quality history of this well is discussed below). From 1989 through 1997, Well 411 showed long-term background exceedances in combined radium, cobalt, molybdenum, nickel, and sulfate. Background water quality is discussed further in the natural attenuation system performance evaluation.

Delineation of the extent of the seepage-impacted water in Zone 3 (Figure 35) is based primarily on the values of two parameters: pH and bicarbonate concentrations. The following threshold or bracketing values for pH and bicarbonate, which indicate seepage impact to the water, have been discussed in the Technical Memorandum (GE, 2000):

- A pH <5.0 indicates seepage impact. Such impacted water has not yet migrated far enough to reach equilibrium, or to react sufficiently, with carbonate minerals in the Zone 3 strata (Canonie, 1987, Table 4-5 indicates a measured $CaCO_3$ content of 0.02 percent in the Zone 3 bedrock). A pH >5.0 indicates either no seepage impact, or acid neutralization to varying degrees (usually a function of residence time and migration distance).
- Bicarbonate (HCO_3) concentrations <100 mg/L and >500 mg/L indicate seepage impact. In non-impacted areas, background water has approximately reached equilibrium with the carbonate minerals resulting in bicarbonate concentrations ranging from approximately 100 to 500 mg/L. These threshold values reflect sequential chemical reactions. When acidic seepage-impacted water first entered Zone 3, it lacked bicarbonate. Once the seepage water migrates a short distance from its point of entry, bicarbonate is generated by reaction with calcite in the bedrock. With increasing time of neutralization at a given location, the bicarbonate typically shows a gradual increase to levels above background (generally >500 mg/L). Eventually, the neutralization capacity is exceeded and bicarbonate values reduce to near zero. Further discussion of bicarbonate concentration trends is provided below.

Seepage-impact extent is primarily based on evaluation of pH and bicarbonate concentrations over time in (1) seepage-impacted wells (e.g., Wells 613, 518, and 517), (2) background and former background wells (e.g., Wells EPA 1, 411, and 420), and (3) the new boundary wells PB 2 through PB 4. Table 11 presents the monthly field parameter measurements for the northern tracking wells (from south to north, Wells 504 B, PB 2, PB 4, PB 3, and NBL 1). (The quarterly laboratory analytical results are provided in the back part of Appendix B.) Evaluation of these data indicates that bicarbonate concentrations at Well PB 4 have decreased since February 2003, and the pH has fluctuated while showing an overall decrease through December 2005, when it started to increase. The increase has continued and the bicarbonate concentration was 329 mg/L in October 2007 (the highest value ever recorded in this well).

Historic groundwater quality data (see Appendix B) from fully impacted wells indicate that it takes from one to three years, from the onset of geochemical changes associated with the arrival of seepage-impacted groundwater, for full seepage-impact to develop. In discussing Table 11 in the 2005 annual report, it appeared that the development of full-stage seepage impact was imminent at Well PB 3 (i.e., it appeared likely that bicarbonate would very soon fall to levels persistently below 50 mg/L, accompanied by a subsequent decrease of pH to below 5.0). This is shown on the bicarbonate time-series charts in Figures 40 and 41 (it should be noted that the bicarbonate values plotted in these charts are those derived from laboratory analyses of the quarterly monitoring samples; see the laboratory analytical summary sheets in the back of Appendix B). The northern limit of seepage impact on Figure 35 of the 2005 Annual Report was shown passing through Well PB 3, because of the duration of bicarbonate decrease at this location, culminating with the bicarbonate value of 51 mg/L in October 2005. Subsequently (see Table 11, which includes the monthly field bicarbonate measurements from the northern tracking wells), bicarbonate at this location decreased during November and December 2005, but then started to increase during January 2006 – it continued to increase to a maximum concentration of 345 mg/L in April 2007 (since then it has fluctuated and it may be decreasing). The sharp increase starting in January 2006 represents an abrupt reversal of the long-term declining bicarbonate concentrations at this location since well monitoring started in October 2002 (Table 11).

Table 11 (and Figures 40 and 41) shows that long-term decreasing trends in bicarbonate concentrations have also abruptly reversed to increasing trends in Wells PB 2, PB 4, and NBL 1. In PB 4 and NBL 1, as with PB 3, the abrupt trend reversals started with increases in January 2006 – Well PB 2 had shown non-detects (zero values in Table 11) for an extended period and was not analyzed for field parameters during 2006 until June. The marked, synchronous improvement in groundwater quality at these tracking wells, starting in January 2006, is interpreted as due to the new pumping-well configuration drawing in non-impacted water from the west or northwest. Based on the monthly bicarbonate concentration data for 2006 (Table 11), the location of the full seepage-impact front shown near Well PB 2 during October 2006 (Figure 35) indicated the impact front has receded, under the influence of pumping, approximately 110 ft to the south from the former location along Well PB 3, one year earlier (see 2005 Annual Report, Figure 35).

Comparison of the pH changes measured from October 2005 to October 2007 at these tracking wells confirms the marked improvement in groundwater quality: PB 3 increased from 6.00 to 6.64; and PB 4 increased from 4.99 to 6.51 (however the maximum value of 7.05 occurred in December 2006). Field pH data from Well PB 2 were not measured during September and October 2005; however, from August 2005 to October 2007 the pH increased from 3.39 to 6.39.

The groundwater quality improvement is expected to be temporary. Pumping rates have begun to decline and this is expected to continue because this has been the case for all other pumping wells in the past.

Until the cessation of mine water discharge in 1986, seepage impacts in Zone 3 migrated to the east and northeast, due to groundwater mounding in the alluvium recharge area to the west. As the hydraulic head in the alluvium recharge area has decreased, migration has been toward the north (in relatively southern locations) and northeast (in more northerly locations), subparallel to the eastern edge of saturation and the bedrock dip direction.

As predicted in the EPA's *First Five-Year Review Report* (EPA, 1998) and discussed in the Technical Memorandum (General Electric, 2000), continued pumping of the downgradient Stage II extraction wells caused the seepage-impacted waters to migrate to the northwest and north toward the pumping locations. For example, until May 2000, Wells 708 and 711 had pH values greater than 4.0, but after that time they dropped below 3.0.

The acidic "core" of the impacted water is shown in Figure 35 with the closed dashed red lines indicating the pH value of 4.0. The other red line shows the approximate location where the pH values are 5.0.

During 2007, Well EPA 14 continued to show impacted water quality (Appendix B). For example, high concentrations were measured for manganese, aluminum, combined radium, and gross alpha. The EPA's *Second Five-Year Review Report* (EPA, 2003, Figure 6-7) presented Stiff diagrams for Well EPA 14 in annual "snapshots" of water quality from October 1998 through October 2002. Before October 2000, the calcium-to-magnesium (Ca/Mg) ratio was greater than one and the bicarbonate concentrations were elevated; from October 2000 to October 2002, the Ca/Mg ratio was less than one and bicarbonate was depleted. Modest exceedances of the aluminum and cobalt standards in Well EPA 14 began in 2000, when the bicarbonate concentration decreased suddenly and sharply. Figure 41 shows that the bicarbonate at this location fell sharply to nondetect (zero) in July 2001, then increased to 188 mg/L in October 2004, and then fell to nondetect again in October 2006. When the bicarbonate "comes off the floor" for either a short or extended period of time, this indicates flux in the geochemical conditions and a temporary (or extended) recovery in the groundwater systems' buffering capacity.

The EPA (2003, Figure 6-8) also presented Stiff diagrams for ten Zone 3 wells based on October 2002 sampling. The following discussion refers to the Stiff diagrams shown in EPA's (2003) Figure 6-8, while also providing updates on specific changes in water quality through October 2007.

Well NBL 1, to the north of the present edge of the seepage impact, contains a calcium-sulfate type of water and is representative of background water quality that appears transitional to early-stage impact. The latter interpretation is based on the gradual reduction of the Ca/Mg ratio from 2001 through October 2005 (Appendix B) and the beginning of decreasing bicarbonate concentrations during approximately April 2004 (Appendix B, based on laboratory determinations of bicarbonate) and June 2004 (Table 11, based on field kit determinations of bicarbonate). However, as noted earlier, the multiyear decreasing trend in bicarbonate appears to have reversed starting in October 2006 (Appendix B) and January 2006 (Table 11). Table 11 shows that the field bicarbonate concentration reached a maximum of 345 mg/L in April 2007; however, the laboratory bicarbonate data (Appendix B) indicate that the concentrations during 2007 ranged from 207 to 222 mg/L, which are the highest values since 2004.

Well 420, located along the western edge of the impacted area in Figure 35, contains a calcium-sulfate type of background water. Combined radium in this well has fluctuated above and below the Site standard from 1989 through October 2007 – this may reflect the flux of geochemically heterogeneous background water or impacted water (e.g., N.A. Water Systems, 2005b). Since October 2001, bicarbonate concentrations have fluctuated from 508 mg/L to (in April 2006) 781 mg/L (Appendix B). During the four quarters of 2007, the range in values was unusually large (237 to 749 mg/L). These observations are interpreted as indicating that the seepage-impacted region is nearby.

Well 717, near the western edge of the seepage-impacted area in Figure 35, provides a third example of a calcium-sulfate type of water that was interpreted as predominantly background (largely non-impacted) in 2002, but has subsequently become increasingly impacted. Starting during 2006, exceedances for cobalt, nickel, and gross alpha have also occurred. Bicarbonate concentrations attained a maximum of 740 mg/L in July 2002, and subsequently decreased to 92 mg/L in October 2007 (Appendix B). The bicarbonate at this location is showing a sharp decline similar to that which occurred in Well EPA 14 (see Figure 41), and it appears likely that the bicarbonate concentration in Well 717 will decline to non-detect (zero) values within approximately the next year or two (as the local buffering capacity becomes exhausted).

The other seven wells depicted with Stiff diagrams (EPA, 2003, Figure 6-8) contain impacted magnesium-sulfate types of waters. For example, in October 2007 (see Appendix B) Well 613 (in the southwestern part of the impacted area shown in Figure 35) showed very high sulfate, a Ca/Mg ratio less than one, a non-detect for bicarbonate, a chloride concentration of 146 mg/L, a pH of 2.93, and exceedances for most parameters except several metals, lead, and some of the major ions. Well 613 is the most impacted of any of the wells. Although some of the downgradient wells show significant impacts (e.g., Wells 708 and 719), they also show indications that neutralization accompanies migration from the waters' source area.

3.3.3 Rate of Seepage Migration

Table 12 summarizes the key factors, locations, and criteria underpinning the calculations of seepage travel times for Zone 3. As discussed earlier, the new pumping configuration in the northern part of Zone 3 has caused a marked improvement in the water quality along the northern tracking wells. This improvement indicates that the seepage-impact front had, for the first time, receded southward during 2006.

For this reason, a new component was added to Table 12 in the 2006 annual report: the lower part of this table provides the calculation for the rate of southward recession of the seepage-impact front (versus the upper part of this table, which provides calculations of the rates of former northward advances of the seepage-impact front). The rate of recession from Well PB 4 to PB 2 extrapolated to a minimum of 156 ft/yr (the minimal nature of this value reflects the temporary absence of water quality monitoring at PB 2 until June 2006), as a result of the new pumping. The recession is interpreted as a consequence of dilution resulting from pumping of RW 11, RW 12, RW 13, and PB 2.

During 2007, the location of the northern edge of seepage impact is inferred to be unchanged for the following reasons (refer to Tables 11 and 12): (1) the bicarbonate concentration in PB 4 continued to increase through October 2007; (2) bicarbonate concentrations in PB 2 have been fluctuating since April 2007, but attained the highest value in September 2007 (note that well pair PB 2 and PB 4 are the travel-time calculation endpoint wells in the lowest row in the top block of Table 12, and the single row comprising the lower (recession) block of Table 12); and (3) the declines from the bicarbonate concentration highs in PB 3 (starting in April 2007) and NBL 1 (starting in May 2007) through October 2007 are not very large given the fluctuating values and ranges.

3.3.4 Natural Attenuation System Performance Evaluation

The Zone 3 natural attenuation system comprises the hydro-geochemical interactions between the bedrock matrix, the anthropogenic background waters (derived from former mine water discharge), and the tailings fluids. The natural system is attenuating the seepage impacts by the processes of neutralization, precipitation, adsorption, and mixing with the background waters.

Natural geochemical processes slow the migration of constituents associated with the acidic seepage in Zone 3 (as in the Southwest Alluvium and Zone 1). These processes neutralize the acidic seepage, which causes the precipitation and adsorption of metals and radionuclides. Evidence of this neutralization process includes: (1) increase in pH and corresponding decrease in concentrations of metals and radionuclides with increasing distance from the source area; and (2) gradual increase in bicarbonate for a few years followed by dramatic decreases in wells such as EPA 14, 420, and 717, when acidic seepage begins migrating into a previously non-impacted (background water) area (Earth Tech, 2002d) and eventually overcomes the available buffering capacity. Shutoff of the remaining Stage II wells in 2000 has enhanced the effectiveness of the natural attenuation processes in many parts of the impacted area. Although Zone 3 has not yet fully stabilized, the long-term northward advance of the seepage-impact front has been arrested (in the vicinity of the northern tracking wells) and reversed during 2006, due to the new pumping configuration. Within the interior core region of Zone 3, seepage impacts continued to change water quality to that of fully impacted water (for example, Well 717); however, it appears that the reconfigured pumping has contained, or nearly contained, the overall area affected by seepage impacts.

A summary of constituents detected in Zone 3 in October 2007 is provided in Table 13. Historic data are provided in Appendix B. These data indicate that the following constituents exceeded the Site standards in Zone 3:

- Sulfate and TDS;
- Metals (aluminum, arsenic, beryllium, cadmium, cobalt, manganese, molybdenum, and nickel);
- Radionuclides (uranium, combined radium-226 and –228, thorium, vanadium, and gross alpha); and
- Total trihalomethanes (of which only chloroform was detected).

The geochemical processes influencing the migration of these constituents are discussed below.

Sulfate and TDS

Figure 42 is a graph of sulfate concentrations from 1989 through 2006. Concentrations are relatively high where seepage impacts have been greatest. However, as in the Southwest Alluvium, sulfate concentrations are controlled by geochemical equilibrium with gypsum (or anhydrite) and calcite. Although very high sulfate concentrations were present in the tailings fluids, such "primary" sulfate impact very rapidly attenuated downgradient. For example, compare the relatively elevated sulfate concentration in upgradient Well 613 (upper right, light blue line in Figure 42) with the much lower concentrations in all the other Zone 3 wells (grouped together in the lower part of Figure 42). Over the entire monitoring history since 1989, sulfate concentrations overall have remained within a range of approximately 5,000 to 1,800 mg/L (excluding Well 613). The upper part of this range is lower than the average background sulfate concentration in Well SBL 1 in the Southwest Alluvium (Figure 16).

Natural attenuation has reduced sulfate concentrations substantially from those reported in the tailings source area. Earth Tech (2002d, Figure 3-13) demonstrated that sulfate concentrations decreased by about 85 percent between the North Cell and the seepage-impacted water at Well 613. A similar comparison can be made using October 2007 sample data from the current northern portion of the impacted area: sulfate concentrations decreased 68 percent from Well 613 (8,300 mg/L) to the early-stage impacted water at Well NBL 1 (2,660 mg/L).

However, neither natural attenuation nor active remediation will reduce sulfate concentrations below the Site standard because the concentrations are controlled by groundwater equilibrium with the mineral gypsum (as in the Southwest Alluvium and Zone 1). For example, from 1989 through 1997, Well EPA 1 consistently had sulfate concentrations in the range of 2,500 mg/L to 3,000 mg/L. This well is located approximately 800 ft downgradient of the current northeastern edge of the seepage-impacted water (see Figure 35) and showed background water quality until this part of Zone 3 lost saturation. TDS also will continue to exceed the Site standard because sulfate comprises most of the TDS (as in the Southwest Alluvium and Zone1).

Metals

Figures 43a and 43b are graphs of metals concentrations (from 1989 through 2007) that exceeded the Site standards: aluminum, arsenic, beryllium, cadmium, cobalt, manganese, molybdenum, and nickel (the metals uranium and vanadium are discussed later with the radionuclides). Arsenic, beryllium, and cadmium have MCLs under the federal Safe Drinking Water Act; aluminum and manganese have SMCLs and are non-hazardous; and cobalt, molybdenum, and nickel have neither MCLs or SMCLs. *UNC requests revision of the ROD background concentrations for arsenic, molybdenum, cobalt, and nickel (similar to the NRC revision in 1996 for the background standards for sulfate, nitrate, and TDS).* The bases for this request are discussed below.

Arsenic and molybdenum exceed Site standards primarily in the background water. These two constituents have historically shown elevated concentrations in background Wells EPA 1 (now dry) and NBL 1, while very low to non-detect concentrations are found in most impacted wells, including Well 613 (see Table 13 and Figure 43b). Molybdenum has also shown long-term exceedances in impacted Wells 504 B and EPA 13, but such occurrences may represent the local influence of background water that is mixed with impacted water.

The persistent exceedances of arsenic in NBL 1 (Figure 43b) ranged from 0.4 to 2.5 mg/L in 2007.

N.A. Water Systems (2007b; SWSFS Part I) recently performed a statistical analysis of historic arsenic concentrations in Zone 3. The summary statistics indicate the 95th-percentile concentration for background wells (0.572 mg/L; n = 268 samples) is significantly higher than for impacted wells (0.317 mg/L; n = 549 samples). The range for the background wells (0.0005 to 2.30 mg/L) is approximately three times higher than for the impacted wells (0.0005 to 0.82 mg/L). (The highest concentration reported in that document was subsequently exceeded by the concentration of 2.50 mg/L from NBL 1 during July 2007.)

Many of the other metals exceeded the Site standards in at least one background well, usually EPA 1. The changing water quality at Well NBL 1 is again instructive on this count. During 2005 nickel and cobalt both trended upward in NBL 1, from "baseline" background water concentrations equal to or slightly exceeding the Site standard for cobalt (Figure 43a) and concentrations slightly above the standard for nickel. Concentrations of nickel decreased from 2006 to 2007, while the fluctuating concentrations of cobalt remained approximately stable over the same time period. Therefore, although neutralization of the acidic seepage will continue to reduce metals concentrations at many of the impacted wells, the natural Site conditions (i.e., background) may prevent them from being reduced below the current Site standards (Earth Tech, 2002d).

The metals exhibit a consistent pattern of higher concentrations in wells such as 613, 517, and 719, which have an acidic pH, and much lower concentrations where the pH is more neutral. This difference in concentrations is due to attenuation as the acidic seepage is neutralized along the groundwater flowpath.

Figures 43a and 43b show that attenuation occurs throughout the seepage-impacted area, including areas where the pH is less than 4.0. Well 613 is located near the center of the impacted area, closest to the source area, where pH has ranged from 2.77 to 3.24 since this well was first monitored in 2000. On graphs for five of the eight constituents, this well shows the highest metals concentrations during October 2007. The effectiveness of natural attenuation and seepage impact mitigation is shown by the metals concentrations at Well 719. In October 2007, this well had a pH (4.17) that was moderately higher than that measured in Well 613 (2.93); however, the concentrations of metals are generally much lower in Well 719. In October 2007 arsenic, cadmium, beryllium, and aluminum were below the standards in Well 719. Since 2001, aluminum, nickel, arsenic, beryllium, cobalt, and manganese have shown decreasing trends in this well, suggesting that since the Stage II pumping wells were shut off, the downgradient migration of seepage-impacted water is slowing and the natural system is accomplishing more effective attenuation. Figure 44 illustrates that the October 2007 distribution of aluminum exceedances was restricted to the southwestern part of the impacted area.

During October 2007, all wells within the seepage-impacted area continued to show exceedances of manganese, cobalt, and nickel, except Well 420 near the northwestern edge. It is important to realize that background water quality is associated with metals exceedances. For example, from installation in August 2001 through mid-2004 (background water quality), tracking Well NBL 1 exceeded the standards for molybdenum, nickel, and manganese.

Uranium, Vanadium, and Radionuclides

Figure 45 presents graphs of the concentrations of uranium, vanadium, combined radium, and thorium-230 from 1989 through 2007. Combined radium concentrations exceed the Site standard for Zone 3 (5 pCi/L) in the background water; consequently, radium concentrations in Zone 3 are never expected to reach the standard. This is exemplified by combined radium concentrations at well NBL 1 (Figure 45). Well NBL 1 is to the north of the present edge of the seepage impact and contains a calcium-sulfate type of water representative of background water quality. Since well installation, the combined radium at NBL 1 has fluctuated but consistently exceeded the Site standard, indicating the presence of the constituent radionuclides at this location is unrelated to seepage impact (though increasing radium concentrations since January 2005 may represent early-stage impact). The license amendment request to change the combined radium standards (UNC, 2006), and the related NRC license amendment (NRC, 2006b), addressed only the Southwest Alluvium and Zone 1. However, the central fact underpinning the statistical analysis of background and impacted water quality (N.A. Water Systems, 2006a; technical analysis report in support of the license amendment request) is that background water, derived from the former mine water discharge into the alluvium, frequently exceeds the Site standard for radium. This fact also applies to Zone 3, which derived its background quality groundwater from the same source.

Historically, uranium, vanadium, and thorium-230 are typically present above the standards in Well 613, which has the most acidic pH (2.93 in October 2007). Downgradient toward the northeast, natural attenuation reduces the concentrations of these three radionuclides in Well 708 (pH of 3.78 in October 2007) to nondetect (vanadium and thorium-230) or below the standard (uranium). Much lower concentrations are reported where the pH is more neutral. These reductions are due to attenuation by neutralization, adsorption, or possibly precipitation. In October 2007, the only exceedances of these three constituents were in samples collected from Well 613.

Most wells show uranium concentrations below the Site standard of 0.3 mg/L. However, the exceedance of the uranium standard continued in Well 613 during 2007 (the longer-term pattern shows fluctuating to approximately steady concentrations above the standard). The "spikey" uranium concentrations at Well EPA 14, which started during April 2003, reduced to below the Site standard during April 2005 (Figure 45 and Appendix B); in October 2007 the uranium concentration was 0.0108 mg/L.

The historic amounts of gross alpha within the Zone 3 groundwater indicate that this parameter tends to fluctuate by approximately one order of magnitude in most of the impacted wells (except Well 613, which shows smaller fluctuations). The gross alpha Site standard of 15 pCi/L was exceeded in October 2007 in the following wells: 613 (long-term fluctuations), 717; and EPA 14. Since October 2004, Well 719 has remained below the standard. During 2006, Well EPA 14 concentrations fluctuated by a factor of approximately three. Well EPA 14 has demonstrated a distinctive pattern of gross alpha concentrations compared to all other impacted wells (see Appendix B). Since 1989, the values have consistently been below the standard until the last two quarters of 2003, when the values spiked upward by a factor of approximately ten. During these same two last quarters of 2003, the combined radium concentrations in this well also showed sharp upward spikes. The unusual (and singularly large) value for uranium in this well during July 2003, and the relatively large range in combined radium since July 2003, indicate that a slug of radioactive water migrated into this well location during approximately mid-year 2003. The geochemistry of the background water (of post-mining/pre-tailings age) that seeped into the ground was heterogeneous, and it is often inherently difficult to unequivocally infer that impacted water, rather than a high-concentration-bearing slug of background water, is responsible for the pattern of exceedances at many locations.

Although neutralization of acidic seepage will continue to attenuate the radionuclides, the natural conditions will most likely prevent combined radium and gross alpha from being reduced to concentrations below the current Site standards.

Total Trihalomethanes (TTHMs)

The Site standard is no longer for chloroform per se, but rather for TTHMs pursuant to NRC license amendment 37 (NRC, 2006b). TTHMs (comprising only chloroform in all Site groundwater analyses) were detected above the Site standard in only Well 613 during October 2007 (see Figure 46). The concentrations in Well 613 have exceeded the TTHMs Site standard of 80 ug/L since October 2002, consistent with this well's proximity to the North Cell (see Figure 35). Well 613 concentrations have shown long-term fluctuations but increased by approximately four times from July to October 2002 (166 ug/L). Since then the concentration has fluctuated between 99 and 168 ug/L (118 ug/L in October 2007).

The only other Zone 3 locations with detected TTHMs are Wells 517 (6.76 ug/L chloroform in October 2007) and EPA 14 (2.29 ug/L in October 2007). Well 518 also consistently showed chloroform detections until it ceased being sampled in 2000 (Appendix B). All other Zone 3 wells have shown historic non-detects for chloroform and, since the fourth quarter of 2006, TTHMs. This indicates that groundwater to the northeast of Well 517 rapidly attenuates chloroform.

Chloroform is locally detected but never far from the original, former tailings source. The impounded north cell is no longer draining and there is no on-going source (USFilter, 2004b).

Section 4
Zone 1

4.1 Corrective Action Summary

Zone 1 corrective action consisted of source remediation (neutralization and later dewatering of Borrow Pit No. 2) and pumping of a series of extraction wells from 1984 through 1999 (Earth Tech, 2002d). Well productivity in this hydrostratigraphic unit had always been very low. Earth Tech (2002d, Figure 4-1) summarized the pumping program for Zone 1, including the well systems pumped, the number of wells operating for each system, and the combined annual pumping rates. A maximum combined pumping rate of 14 gpm was achieved by the 17 East and North Cross-Dike Pump-Back wells. The productivity declined steadily over time, and by July 1999, when the system was decommissioned, the three remaining wells were yielding a combined annual average of 0.65 gpm. The three remaining Zone 1 wells (615, 616 and 617) were decommissioned at the end of July 1999 in accordance with a letter from NRC dated July 30, 1999 (Earth Tech, 2002a), with the concurrence of EPA.

4.2 Mass of Chemical Constituents Removed

The mass of chemical constituents removed was calculated for the 10-year period from July 1989 through July 1999. These calculations were presented in the previous annual reviews, and the final summary was presented in the *1999 Annual Review* (Earth Tech, 1999).

4.3 Performance Monitoring Evaluation

The Zone 1 performance monitoring program is summarized in Table 14. The program consists of quarterly monitoring of water levels in 15 wells and water quality in eight wells and has been in effect since the second quarter of the 2000 operating year.

4.3.1 Water Level Evaluation

Historic water level data for Zone 1 wells through October 2007 are presented in Appendix C. Water levels for the fourth quarter of 2007 are shown on the potentiometric surface map in Figure 47. Water levels through time are shown on Figure 48. Saturated thicknesses calculated from the October 2007 measurements in Zone 1 are presented in Table 15. This table shows that the Zone 1 hydrostratigraphic unit remains completely saturated in most of the downdip wells: 505 A, 502 A, and 412 (in Section 36), and (TWQ)142 and (TWQ)143 (along the northern boundary of Section 36) (see Figure 47). However, during 2007, most of the wells continued to show overall decreasing piezometric elevations (usually with small fluctuations), indicating that the Zone 1 potentiometric field continues to become lower as the groundwater further dissipates into unsaturated parts of this bedrock stratigraphic unit.

Changes of piezometric elevations in updip and downdip wells indicate the broad pattern of the shift in the potentiometric field caused by groundwater drainage to the northeast in Zone 1. Groundwater levels in Well 504 A have risen gradually and may become fully saturated as groundwater migrates to this portion of the confined Zone 1 hydrostratigraphic unit (see Table 15; Figures 47 and 48; and Appendix C). Similarly, the slowly rising groundwater levels at downdip Wells 142, 143, and 412 represent increasing potentiometric levels within these 100-percent saturated parts of the fully confined Zone 1 hydrostratigraphic unit. Long-term decreasing water levels updip to the south-southwest, at locations under less than fully saturated conditions, represent the slow dissipation of head levels there as groundwater continues to flow downdip toward the fully saturated parts of the system.

Earlier groundwater flow in Zone 1 was approximately eastward, reflecting groundwater mounding and recharge within the alluvium to the west. Since the dewatering of Borrow Pit No. 2 and termination of mine water discharge into Pipeline Arroyo, the former mounding has dissipated. Consequently, water levels in updip areas of Zone 1 have dropped significantly, though the rate of decline has reduced with the dissipation of recharge-induced mounding (see Figure 48). The rate of groundwater drainage is also limited by the unit's relatively low transmissivity, and the very low transmissivity of the underlying aquiclude.

4.3.2 Water Quality Evaluation and Current Extent of Seepage-Impacted Water

In the absence of naturally occurring groundwater in this part of Zone 1, the temporary saturation created by the infiltration of former mine water discharges is considered the background water for Zone 1 (EPA, 1988b; 1998). This anthropogenic groundwater was later impacted by acidic seepage from Borrow Pit No. 2 in the Central Cell (compare Figure 2 and Figure 49). These seepage fluids contained elevated concentrations of metals, radionuclides, and major ions, including sulfate and chloride.

Source remediation (neutralization and subsequent dewatering of the borrow pit), continued neutralization of the seepage by natural geochemical processes, and mixing with the background water have reduced concentrations of most constituents below the Site clean-up standards. However, as discussed below, exceedances of some constituents still occur in Zone 1. Appendix C provides historic constituent concentration data through October 2007. Table 16 summarizes the constituents detected in Zone 1 during October 2007.

It is important to realize that exceedances of Site standards in some wells represent background water quality. For example, since 1989 background Well EPA 4 (in Section 1) has persistently shown exceedances of sulfate, has generally shown exceedances of manganese, and has shown concentrations of combined radium that have fluctuated above and below the former Site standard of 5 pCi/L (revised in 2006 to 9.4 pCi/L; NRC, 2006b). Background water quality is discussed further in the subsequent section entitled Natural Attenuation System Performance Evaluation.

Water quality has continued to improve since shutoff of the pumping wells, indicating that the degree of seepage impact is stable to diminishing. Zone 1 seepage impacts have been delineated by chloride concentrations greater than 50 mg/L (Earth Tech, 2000a). Figures 6 and 49 show the extent of seepage impacts in October 2007. The zone of seepage impact has migrated predominantly toward the northeast. Further eastward components to migration are limited by the proximity of the eastern edge of saturation.

The acidic "core" of the impacted zone is approximated by the area where pH is inferred to be less than 4.0 (orange area in Figure 49). Figure 50 shows historic pH values for Zone 1 wells through October 2007. Well 604 has persistently shown the lowest pH; as discussed below, it also is the most highly impacted well. However, this well shows a long-term increasing trend in pH values (Figure 50). Figure 50 shows that starting in approximately 1993, acid neutralization and buffering resulted in substantial pH increases in Wells 515 A, 516 A, and EPA 7.

The following constituents continue to exceed the Site standards outside the property boundary in Section 1:

- TDS – Wells EPA 5 and EPA 7
- Sulfate – Wells EPA 4, EPA 5, and EPA 7
- Manganese – Well EPA 4

TDS, sulfate, and manganese are non-hazardous constituents. All of these constituents have generally exceeded standards at the cited wells since 1989. As discussed earlier, during August 2006 the NRC groundwater protection standard for combined radium was revised to 9.4 pCi/L (NRC, 2006b). There were no exceedances of this standard in October 2007.

Within the Site property, the standards were exceeded for TDS, sulfate, and manganese (Table 16). Other constituents whose standards were exceeded onsite in October 2007 were: cobalt (Well 604), nickel (Wells 515 A and 604), aluminum (Well 604), and TTHMs (Wells 515 A and 614). During October 2007, Wells 614 and 515 A exceeded the chloride standard, as has frequently occurred since the start of monitoring here during 1989.

The extent of seepage impacts, as delineated by a chloride concentration greater than 50 mg/L, has not changed perceptibly in the past nine years, including the period since the shutoff of the extraction wells. Nonetheless, many aspects of water quality have continued to improve since shutoff, indicating that the degree of seepage impact is stable to diminishing. Natural attenuation processes include acid neutralization by (1) reaction with the Zone 1 bedrock (which has a calcite (calcium carbonate) fraction of 0.03 percent (Canonie, 1987, Table 4.5)); (2) mixing with the neutral background water; (3) precipitation of metals and radionuclides; and (4) adsorption of metals (excluding manganese) and radionuclides. These processes attenuate pH, metals, and other seepage constituents. The relatively low transmissivity of Zone 1 slows migration and increases residence time for the attenuation processes.

Outside the UNC property boundary in Section 1, the post-pumping groundwater quality continues to improve overall (Tables 16 and 17). *The October 2007 concentration of cobalt in Well EPA 5, 0.05 mg/L (exactly equal to the Site standard), means that there are no exceedances of hazardous constituents outside the UNC property boundary within seepage-impacted groundwater – in fact and more broadly, this is the case for all three hydrostratigraphic units.* The exceedances of sulfate and TDS in Wells EPA 5 and EPA 7 reflect geochemical equilibrium of the groundwater with gypsum; these constituents are also non-hazardous. All of these constituents are discussed more below.

4.3.3 Natural Attenuation System Performance Evaluation

The Zone 1 natural attenuation system comprises the hydro-geochemical interactions between the bedrock matrix, the anthropogenic background waters (derived from former mine water discharge), and the tailings fluids. The natural system is successfully attenuating the seepage impacts by the processes of neutralization, precipitation, adsorption, and mixing with the background waters. However, some constituents will remain at above-standard concentrations because of the inherent geochemical characteristics of the Zone 1 background water.

Table 17 shows the predicted geochemical performance of the Zone 1 natural attenuation system (Earth Tech, 2002d). In summary, sulfate and TDS concentrations are not expected to meet Site standards because gypsum equilibrium in the groundwater prevents any further reduction in sulfate concentration. Manganese may meet the Site standards if sufficient bicarbonate is available for attenuation. The remaining metals and radionuclides are expected to meet the standards through attenuation by neutralization and adsorption. The individual constituents of concern are discussed below.

Sulfate and TDS

Sulfate concentrations exceed the Site standard in both the seepage-impacted water and the background water in Zone 1. Figure 51 shows historic sulfate concentrations through October 2007; Figure 52 shows the extent of sulfate exceedances during October 2007. The time-series indicate that the operation of extraction wells prior to July 1999 did not have a discernable influence on sulfate and TDS, because sulfate concentrations in Zone 1 are controlled by the system's equilibrium with gypsum. Based on the overall stable concentrations and the results of the geochemical investigation presented by Earth Tech (2000a), sulfate is not expected to meet the clean-up standards within Section 1. As in the Southwest Alluvium and Zone 3, most of the TDS comprises sulfate. Accordingly, TDS concentrations are not expected to meet the clean-up standards in Section 1, although they should gradually decrease to background levels.

Manganese

Manganese concentrations exceed the Site standard in both the seepage-impacted water and the background water (Well EPA 4) in Zone 1. Concentrations in the seepage-impacted water are usually higher (an exception being impacted well EPA 5). These concentrations have decreased over time as the acidic seepage has been neutralized, but the magnitude of the decrease is largely controlled by the bicarbonate concentrations (Earth Tech, 2000a). Historic manganese concentrations through October 2007 are shown on Figure 53 and tabulated in Appendix C. The extent of manganese that exceeded the Site standard during October 2007 is shown on Figure 54. Figure 53 shows that the long-term decreasing trend in manganese in Well EPA 7, which started in January 1998, for the first time fell below the standard in 2006 (concentration of 1.96 mg/L in October 2007).

Bicarbonate concentrations in impacted wells are related to the waters' degree of neutralization of acidic seepage. Figure 55 shows historic bicarbonate concentrations through October 2007. As discussed above regarding Zone 3, marked declines of bicarbonate concentration are indicative of (sometimes temporary) exhaustion of the local neutralization capacity of the natural geochemical system. The plunge of bicarbonate concentration in Well EPA 5 from January 2000 to May 2000 is such an example. By contrast, Well 614 (Figure 55) has never shown such a falloff in bicarbonate concentrations, which is consistent with its side-gradient location with respect to former Borrow Pit No. 2. A third example of historic bicarbonate trends is provided by Well EPA 7 (Figure 55), where formerly very low bicarbonate concentrations have increased step-wise beginning in July 1990, with additional upward steps in January 1994, again in October 1998, and again in May 2000. The rising concentrations indicated that the natural attenuation neutralization capacity has recovered in a similar step-wise manner at this location, and although the rate of recovery has slowed since July 2002 it is still increasing and the historically highest bicarbonate concentration in EPA 7 was measured in October 2007 (598 mg/L).

The seepage-impacted wells that have had bicarbonate concentrations greater than 1,000 mg/L (Wells 614, 516 A, and EPA 5) either have never had manganese exceedances or have had a decrease in manganese concentration to below the standard. In contrast, impacted wells with lower bicarbonate concentrations, such as Wells 515 A, 604 and EPA 7, have historically had manganese exceedances (including 515 A and 604 in October 2007). However, even among these wells the effect of bicarbonate on manganese concentrations is well illustrated by EPA 7. Since July 1991, increasing bicarbonate concentrations in Well EPA 7 (in Section 1) have exceeded 500 mg/L (Figure 55), and the manganese concentration has steadily declined (Figure 53). The decreasing manganese trend continued through October 2007 and, as noted earlier, during 2006 manganese in this well fell to levels below the standard.

In contrast to seepage-impacted wells, long-term manganese exceedances at Well EPA 4 represent background water quality. Similarly, Well EPA 8, located beyond the tailings-impacted zone in background water to the east of EPA 4, also showed persistent manganese exceedances through the termination of groundwater quality monitoring in January 2000. Most of the other constituents at EPA 8 have been fluctuating to steady since 1989 (Appendix C).

In summary, exceedance of the manganese standard within the property boundary will continue except where there is sufficient neutralization capacity to reduce the manganese concentrations. It is also important to realize that manganese exceeds the standard in the background water quality. Manganese is a non-hazardous constituent.

Cobalt and Nickel

Excluding manganese, there are no exceedances of metals outside the property boundary in Section 1. Other metals were attenuated within the property boundary. Exceedances of cobalt and nickel are now limited to the area within the property boundary where the acidic seepage has not been fully neutralized. Historic concentrations for these two constituents through October 2007 are presented graphically in Figure 56. The extent of cobalt and nickel exceeding the Site standard during October 2007 is shown in Figure 57.

Nickel has shown a continuous decline in Well EPA 5 since January 2002 (Figure 56). During the last two quarters of 2007 the concentrations reduced to non-detects. Cobalt has shown a continuous decline in Well EPA 5 since April 2003 (Figure 56). During the last two quarters of 2007 the concentrations reduced to exactly the Site standard (0.05 mg/L). It is likely that cobalt will decline to below the standard during the next year or two.

Cobalt and nickel typically do not adsorb sufficiently to reduce their concentrations below their standards until the pH is approximately 6.5 or more (Earth Tech, 2002d). For example, cobalt and nickel concentrations in Well EPA 7 historically have fluctuated around the Site standard as the pH has increased to above 6.0. Continued neutralization in Well EPA 7 has been the geochemical impetus for reductions in concentrations to levels below the standards for cobalt in April 2002, and nickel in January 2003.

Combined Radium-226 and Radium-228

Similar to the metals, combined radium is attenuated by neutralization, precipitation, and adsorption. The highest concentrations of combined radium are within the property boundary where the pH is more acidic (Table 16). Historic concentrations for combined radium through October 2007 are presented in Figure 58. During October 2007, the NRC combined radium Zone 1 Site standard of 9.4 pCi/L (NRC, 2006b) was not exceeded in any well (Table 16).

Total Trihalomethanes (TTHMs)

Exceedances of the Site standard (80 ug/L; see NRC, 2006b) for TTHMs in October 2007 occurred only in two wells, both within the property boundary: 515 A and 614. Wells 515 A and 614 have long-term chloroform concentrations in the low hundreds of μg/L. UNC will submit an ACL application for TTHMs in POC Well 614.

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Section 5
Conclusions and Recommendations

This annual review evaluated the performance of the natural systems in all three Site hydrostratigraphic units and the active remediation in Zone 3. In the Southwest Alluvium and Zone 1, the natural systems have functioned as effectively as when active remediation took place. During 2007, part of Zone 3 underwent extraction well pumping that started during the hydrofracture program in 2005. The conclusions and recommendations of this evaluation are provided below.

5.1 Conclusions

- *There are no exceedances of hazardous constituents outside the UNC property within seepage-impacted groundwater – this is the case for all three hydrostratigraphic units.*
- *UNC is in full compliance with the NRC groundwater protection standards in the Southwest Alluvium.*
- Groundwater levels in the Southwest Alluvium continued to decline in 2007, indicating that the artificially-recharged zone of saturation continues to become naturally dewatered as the groundwater drains down the arroyo.
- Hydraulic containment is not a necessary feature of the corrective action program in the Southwest Alluvium because of the geochemical attenuation that occurs naturally. Furthermore, former pumping of extraction wells did not contain the constituents and would not do so in the future.
- Mapping of bicarbonate isoconcentration contours is the most meaningful method of delineating seepage-impacted water in the Southwest Alluvium.
- Evaluation and prediction of constituent concentrations in the Southwest Alluvium is 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. 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 offsite will tend to have sulfate and TDS levels approximately equal to, or lower than, those in the background water due to equilibration with the mineral gypsum. 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.

- Concentrations of uranium in the Southwest Alluvium are an indicator that natural attenuation is at least as effective a remedy as pumping. The uranium concentrations and concentration-time trends have either stabilized (e.g., Wells GW 1, GW 2, and GW 3) or shown decreasing trends (e.g., Well 802) since the pumps were turned off. The range of uranium concentrations in the background water has been empirically shown to be the same as the range within impacted water (GE, 2006). Uranium and bicarbonate concentrations are covariant in the Southwest Alluvium groundwater, i.e., when the concentration of the bicarbonate parameter changes, uranium changes with it. This observation has held for both the 11 years of active pumping and the 6 years of post-pumping monitoring. This means that uranium concentrations in the Southwest Alluvium are not related to the migration of uranium in tailings fluids. In fact, tailings solutions are far more depleted in uranium than are natural background solutions. This is an important consideration for the Site-Wide Supplemental Feasibility Study (SWSFS, in preparation by UNC) because it means the following: (1) uranium in tailings-impacted water is not degrading the water quality, and (2) there is no further improvement in alluvial water quality that can be made with respect to uranium concentrations.
- *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.

- Groundwater levels in the Zone 3 continued to decline in 2007, indicating that the articially-recharged zone of saturation continues to diminish as the groundwater drains down the dip of the bedrock layers.
- Starting in approximately January 2006, the new pumping-well configuration in Zone 3 (initiated in 2005 during the hydrofracture program) has caused the following three beneficial effects: (1) interception of northward-advancing impacted water (i.e., partial or possibly complete hydrodynamic control); (2) marked groundwater quality improvement (of water evading capture) and recession of the northern seepage-impact front to the south; and (3) dewatering. The pumping well array has been supplemented by the addition of a new extraction well in September 2007. The groundwater quality improvement is expected to be temporary. Pumping rates have begun to decline and this is expected to continue because this has been the case for all other pumping wells in the past.
- Based on the monthly bicarbonate concentration data in the northern Zone 3 tracking wells through October 2007, the location of the full seepage-impact front has remained unchanged during the last year and is near Well PB 2. The reconfigured pumping appears to have contained, or nearly contained, the overall area affected by seepage impacts.
- The in-situ alkalinity stabilization pilot study was terminated in 2007 because of unexpectedly low injection and extraction well flow rates. This was interpreted to have been caused by clogging of pores by clay created from the interaction of acidic tailings seepage with feldspar minerals. Based on these results, the use of alkalinity rich solutions to remediate the Zone 3 impacted groundwater in-situ is not feasible.
- The degree of seepage impact in Zone 1 is stable to diminishing. Groundwater elevations in Zone 1 continued to decline in 2007, causing the saturated thickness that accommodates groundwater flow and constituent migration to diminish in parts of this bedrock stratigraphic unit.
- Outside the UNC property boundary in Zone 1, the post-pumping groundwater quality continues to improve overall (Tables 16 and 17). The exceedances of sulfate and TDS in Wells EPA 5 and EPA 7 reflect geochemical equilibrium of the groundwater with gypsum; these constituents are non-hazardous.
- In Zone 1, the continuing improvement in offsite water quality, combined with the stability of onsite concentrations, leads to the conclusion that the Zone 1 groundwater corrective action program has achieved success. However, closure will depend on meeting the groundwater protection standards, which

will require that ACLs be established for POC Wells 604 (aluminum, manganese, and nickel) and 614 (TTHMs and chloride).

5.2 Recommendations

5.2.1 Recommendations for Closure of Southwest Alluvium Remedial Action

Predicted performance of the Southwest Alluvium natural attenuation system is summarized on Table 6. The continuing assessment of natural attenuation in this annual report is the basis for the following recommendations for the Southwest Alluvium corrective action system:

1. Decommission the pumping wells. Attenuation via natural geochemical processes has been shown to be at least as effective as pumping. Implement a No Further Action remedial alternative.
2. Continue to perform monitoring on an annual basis because the seepage-impacted water quality is largely stable, the offsite impacted water quality is not hazardous, and a yearly frequency is sufficient for tracking the migration of the seepage-impact front (estimated to be moving southwestward toward Well SBL 1 at an average rate of 34 ft per year).
3. EPA should consider adopting the recently revised NRC standards (NRC, 2006b) for chloroform (revised to a total trihalomethanes (TTHMs) Site-wide standard of 80 ug/L) and combined radium (revised to 5.2 pCi/L standard for the Southwest Alluvium). EPA should also consider (a) revising their current ROD uranium standard of 5 mg/L and adopting the NRC Site-wide standard of 0.3 mg/L (based on the review of dissolved uranium occurrences in the Southwest Alluvium presented by UNC (GE, 2006)), and (b) adopting the NRC (1996) standards for sulfate, TDS, and nitrate (throughout all three Site hydrostratigraphic units). Sulfate, TDS and manganese should be waived as constituents of concern based on NRC's (1996) background water quality analysis report and multiple reports by UNC (all of which are summarized in the SWSFS Part I; N.A. Water Systems, 2007b).
4. The Southwest Alluvium is in full compliance with the NRC groundwater protection standards. The EPA must consider granting a TI Waiver for sulfate and TDS; there are no known groundwater analyses anywhere in the Southwest Alluvium, seepage-impacted or not, that meet the New Mexico Standards for sulfate and TDS. In lieu of eliminating sulfate and TDS concentrations as ARARs, a TI Waiver for sulfate and TDS could best be applied in a non-traditional sense in that there would not be a classic TI zone. Instead, UNC proposes that the projected 200-year seepage front (as extrapolated during 2004) be used, which we understand to be compatible

with NRC guidance. Background water quality has shown modest exceedances of manganese, cobalt, and nickel; it is appropriate that the EPA consider revising the ROD to recognize the historic background water quality for these constituents in the Southwest Alluvium.

5. As first put forth by the NRC (1996), and further developed in several geochemistry (Earth Tech, 2000d and 2002c) and annual reports (Earth Tech, 2002d; N.A. Water Systems, 2004, 2005b, 2007a), there is quite simply no method to achieve the standards for sulfate, TDS and manganese -- short of dewatering the alluvium. The last drop of water left in the alluvium would exceed the standards for these parameters. *UNC once again requests approval of a TI Waiver for sulfate and TDS in the year 2204 extrapolated, downgradient impact zone shown in Figure 59.* The ongoing development of a SWSFS will formally evaluate and prioritize the most appropriate remedial course of action.

5.2.2 Recommendations for Zone 3 Remedial Action

Continue Zone 3 remediation using the natural system to stabilize the seepage impacts, in conjunction with the current pumping system that (1) provides capture of most if not all of the downgradient migration of seepage-impacted water, (2) maintains the marked improvement in groundwater quality that occurred during 2006 within the water near the seepage-impact front, and (3) dewaters and removes constituent mass.

Declining yields from the current extraction-well array indicate that such hydraulic control is temporary. This has always been the case for pumping in Zone 3. Zone 3 saturated thicknesses are quite low, and any future pumping to reduce the pressure head will obtain only limited short-term results. Because the bedrock slope drives groundwater flow to the north, there is an irreducible elevation head that cannot be decreased by pumping. Counteracting this force is clogging of the bedrock pore spaces by the seepage-induced chemical alteration of feldspar to clay. This clogging reduces the bedrock permeability, which retards the migration of the seepage. Eventually, there will be a balance developed between the irreducible elevation head and the trapping of the seepage-impacted groundwater due to the diminished bedrock permeability. Although the timing and location of such a balance cannot be predicted, such a development is likely. UNC recommends that consideration be given to other regulatory tools to manage the inherent physical limitations to the Zone 3 bedrock-groundwater system. As with Zone 1 and the Southwest Alluvium, the tools might include: ACLs, TI Waivers, monitored natural attenuation, and ICs.

EPA should consider revision of the ROD background concentrations for the following metals in Zone 3: arsenic, molybdenum, nickel, cobalt and manganese.

Uranium should also be addressed unless EPA adopts the NRC standard for uranium.

Sulfate, TDS and manganese should be waived as constituents of concern based on NRC's (1966) background water quality analysis report.

5.2.3 Recommendations for Closure of Zone 1 Remedial Action

Predicted performance of the Zone 1 natural attenuation system is summarized on Table 17. Implement the following recommendations toward closure of the Zone 1 corrective action system:

1. EPA should consider adopting the current NRC Site-wide groundwater protection standard of 80 ug/L for TTHMs (this group of compounds includes chloroform). This value is the current MCL.
2. EPA should consider adopting the current NRC standard of 9.4 pCi/L for combined radium in Zone 1. This value is based on background water quality statistical analysis.
3. The Zone 1 seepage-impacted area has attained ALARA goals. To complete the corrective action program for Zone 1 UNC will submit an ACL application for TTHMs (Well 614), aluminum (Well 604), manganese (Well 604), nickel (Well 604), and chloride (Well 614). With the vast amount of spatial and temporal monitoring data in Zone 1, it is a straightforward exercise to empirically demonstrate that chloroform (the only detected TTHM compound) attenuates to below the proposed standard everywhere off of UNC property. The other cited constituents are (a) associated with wells inside the UNC property that have monitoring histories indicating longstanding ALARA concentrations, and (b) non-hazardous constituents in the context of the federal Safe Drinking Water Act.
4. As first put forth by the NRC (1996), and further developed in several geochemistry (Earth Tech, 2000c) and annual reports (Earth Tech, 2000e; N.A. Water Systems, 2004, 2005b, 2007a), there is no method to achieve the standards for sulfate and TDS, and Zone 1 has already been dewatered to the extent that is feasible (all pumping wells were decommissioned in 1999 because their yields were less than the decommissioning limit). It is not appropriate to tie remediation progress to sulfate or TDS concentrations. Even the last drop of water left in Sections 1 and 2 of Zone 1 would exceed the standards for these parameters. The EPA should approve a TI Waiver for sulfate and TDS in the TI zone shown in Figure 59. Remedial alternatives to be presented in the final, complete SWSFS should be closely coordinated with the necessary TI Waiver(s), ACL applications, and other potentially appropriate changes in Site remediation standards.

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Church Rock Site, Church Rock, New Mexico
Section 6
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TABLE 1

Southwest Alluvium Performance Monitoring Program, 2007 Operating Year
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Well	Use[1]	Water Level	Water Quality	NRC POC	Purpose
509 D	Monitor	X	X	Y	Seepage extent
624	Monitor	X	X		Downgradient background, seepage extent
627	Monitor	X	X		Downgradient background, seepage extent
632	Monitor	X	X	Y	Seepage extent
801[2]	Pumping (idled)	X	X		Seepage and saturation extent
802	Pumping (idled)	X	X		Seepage and saturation extent
803	Pumping (idled)	X	X		Seepage and saturation extent
805	Monitor	X			Water level only
807	Monitor	X			Water level only
808[3]	Pumping (idled)	X	X		Seepage extent
EPA 23	Monitor	X	X	Y	Problematic completion
EPA 25	Monitor	X	X		Downgradient background, seepage extent
EPA 28	Monitor	X	X	Y	Seepage extent
GW 1	Monitor	X	X	Y	Seepage extent
GW 2	Monitor	X	X	Y	Seepage extent
GW 3	Monitor	X	X	Y	Downgradient background, seepage extent
	Total	16	14		

Eliminated From Monitoring					Reason for Elimination
GW 4	X	X			Dry
EPA 22A				Y	Dry
29A					Dry
639					Dry
642					Dry
644					Dry
645					Dry
804					Not needed, use 632
806					Not needed, use 805
EPA 27					Dry

Notes:

1 Pumping wells turned off in January 2001 after final baseline samples were collected. Well 801 is the exception, see Note 2.

2 Well 801 was turned off at the end of July 1999 because it met decommissioning criteria. Sample collection ceased after the first quarter 2000. Well 801 water quality is included in the test program, therefore sampling recommenced January 2001 and has continued through 2003.

3 Well 808 was not included in the Performance Monitoring Program prior to the NA Test, therefore no data are available prior to January 2001.

TABLE 2

Detected Constituents in Southwest Alluvium, October 2007
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Chemical Name	**Action Level**	**Unit**	**0509 D**	**0624**	**0627**	**0632**	**0801**	**0802**	**0803**	**0808**	**EPA 23**	**EPA 25**
ALUMINUM	5	mg/l										
AMMONIA (AS N)		mg/l	0.62		0.18	0.61	3.37		1.64		5.8 D	0.08
BICARBONATE (HCO3)		mg/l	2340	1430	593	1970	1490	2260	1880	1840	1300	1010
CALCIUM		mg/l	826 D	626 D	486 D	568 D	514 D	593 D	635 D	681 D	608 D	679 D
CHLORIDE	250	mg/l	352 D	188 D	63 D	259 D	223 D	209 D	169 D	187 D	108 D	120 D
COBALT	0.05	mg/l										
GROSS ALPHA	15	pci/l	1.5			2.4	1.3	1.1	1.3			
MAGNESIUM		mg/l	334 D	385 D	244 D	774 D	661 D	923 D	700 D	609 D	424 D	215 D
MANGANESE	2.6	mg/l	3.55	0.1		2.35	4.25	0.91	2.13	0.69	4.67	2.48
NICKEL	0.05	mg/l										
NITRATE (NO3)	190	mg/l	12.4	74 D	107 D	70 D	0.8	101 D	47.7 D	122 D	22.7	90 D
PH (FIELD)		su	6.41	6.50	6.87	6.29	6.46	6.49	6.44	6.49	6.56	6.82
PH (LAB)		su	6.75	6.91	7.26	6.62	6.65	6.57	6.62	6.69	6.76	7.19
POTASSIUM		mg/l	13.1	6.9	6.2	10.9	13.5	7	12.9	5.3	12.5	8.8
RADIUM-226		pci/l				0.7	0.5					
RADIUM 226 & 228	5	pci/l				0.7	0.5					
SODIUM		mg/l	334 D	246 D	469 D	388 D	338 D	348 D	276 D	300 D	162 D	168 D
SULFATE (SO4)	2125	mg/l	1720 D	1990 D	2270 D	3210 D	3200 D	3490 D	3080 D	2610 D	2350 D	1650 D
THORIUM 230	5	pci/l				1.6	1.5					
TOTAL DISSOLVED SOLIDS	4800	mg/l	5180	5030	4710	7350	6470	8080	6670	6620	4850	4100
TOTAL TRIHALOMETHANES	80	ug/l				3.57	2.96	13.5	3.9	6.88		
URANIUM	0.3	mg/l	0.246	0.0341	0.0243	0.0819	0.0431	0.152	0.129	0.128	0.0342	0.114

TABLE 2

Detected Constituents in Southwest Alluvium, October 2007
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Chemical Name	Action Level	Unit	EPA 28	EPA 28 Dup	GW 1	GW 2	GW 3	SBL-01
ALUMINUM	5	mg/l						0.2
AMMONIA (AS N)		mg/l			0.36			0.32
BICARBONATE (HCO3)		mg/l	795	719	1660	2400	1580	429
CALCIUM		mg/l	506 D	493 D	645 D	654 D	812 D	470 D
CHLORIDE	250	mg/l	141 D	139 D	255 D	238 D	176 D	102 D
COBALT	0.05	mg/l						0.03
GROSS ALPHA	15	pci/l	1.2				1.2	1.1
MAGNESIUM		mg/l	465 D	460 D	593 D	868 D	267 D	988 D
MANGANESE	2.6	mg/l	0.7	0.55	0.04	1.27	1.68	2.7
NICKEL	0.05	mg/l						0.08
NITRATE (NO3)	190	mg/l	36 D	29 D	96 D	4.8	94 D	49 D
PH (FIELD)		su	6.67	6.70	6.67	6.42	6.50	6.54
PH (LAB)		su	6.88	7.06	6.70	6.54	6.67	6.92
POTASSIUM		mg/l	13.3	12.8	7.7	14.2	10	14
RADIUM-226		pci/l						
RADIUM 226 & 228	5	pci/l						
SODIUM		mg/l	211 D	221 D	377 D	382 D	280 D	296 D
SULFATE (SO4)	2125	mg/l	2600 D	2650 D	2720 D	3700 D	1970 D	4960 D
THORIUM 230	5	pci/l			1			2
TOTAL DISSOLVED SOLIDS	4800	mg/l	5040	5000	6610	7990	5150	8670 H
TOTAL TRIHALOMETHANES	80	ug/l			0.84	0.64		
URANIUM	0.3	mg/l	0.0506	0.0399	0.101	0.117	0.136	0.0259

Table 3

Southwest Alluvium Saturated Thickness, October 2007

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

Well	Water Level Measurement Date	SW Alluvium Unsaturated Thickness	SW Alluvium Saturated Thickness	SW Alluvium Percentage Saturated
509-D	10/1/07	74.30	35.70	32%
624	10/2/07	49.49	25.51	34%
627	10/2/07	57.26	13.74	19%
632	10/2/07	41.42	25.58	38%
801	10/1/07	46.56	13.94	23%
802	10/1/07	44.54	36.96	45%
803	10/1/07	59.38	58.62	50%
805	10/11/07	46.55	73.45	61%
807	10/11/07	52.04	47.96	48%
808	10/1/07	46.10	85.90	65%
EPA-23	10/1/07	49.47	70.53	59%
EPA-25	10/2/07	49.72	20.28	29%
EPA-28	10/2/07	59.25	18.75	24%
GW-1	10/1/07	58.47	18.53	24%
GW-2	10/1/07	52.24	37.76	42%
GW-3	10/2/07	50.70	6.30	11%
SBL-01	10/2/07	47.38	17.62	27%

TABLE 4

Summary of Operational Data
Southwest Alluvium Extraction Wells 1989 to 2001
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

Well No.	**Annual Average Pumping Rate (gallons per minute)**												
	1990 (1)	**1991 (2)**	**1992 (3)**	**1993 (4)**	**1994 (5)**	**1995 (6)**	**1996 (7)**	**1997 (8)**	**1998 (9)**	**1999 (10)**	**2000 (11)**	**2001 (12)**	**1990-2001**
801 (13)	1.2	0.5	0.4	0.2	0.2	0.1	0.1	0.1	0.08	0.08	0.00	0.00	0.25
802	11.1	12.5	11.9	9.0	9.8	9.7	9.1	10.1	11.02	9.62	9.31	5.80	9.91
803	2.0	2.6	2.5	3.0	3.2	3.5	3.1	2.9	3.84	3.56	3.83	3.68	3.14
808 (14)		10.0	15.5	19.9	15.6	12.3	12.2	7.2	4.34	3.50	2.50	3.35	9.67
Total Pumping Rate	14.3	25.6	30.3	32.1	28.8	25.6	24.5	20.3	19.29	16.76	15.64	11.94	22.98
Volume Pumped (millions of gallons) (15)	7.4	12.4	17.2	18.1	15.7	12.9	12.2	9.2	9.0	7.5	7.7	1.7	131.0

Notes:

1. Average pumping rate calculated for the period between October 13, 1989, and October 12, 1990.
2. Average pumping rate calculated for the period between October 13, 1990, and October 11, 1991, except Well 808, which calculated for the period between June 26, 1991 (i.e., well startup) and October 11, 1991.
3. Average pumping rate calculated for the period between October 12, 1991, and October 8, 1992.
4. Average pumping rate calculated for the period between October 9, 1992, and October 8, 1993.
5. Average pumping rate calculated for the period between October 9, 1993, and October 14, 1994.
6. Average pumping rate calculated for the period between October 15, 1994, and September 29, 1995.
7. Average pumping rate calculated for the period between September 30, 1995, and September 27, 1996.
8. Average pumping rate calculated for the period between September 28, 1996, and September 26, 1997.
9. Average pumping rate calculated for the period between September 27, 1997, and September 25, 1998.
10. Average pumping rate calculated for the period between October 02, 1998, and September 27, 1999.
11. Average pumping rate calculated for the period between September 28, 1999, and September 29, 2000.
12. Average pumping rate calculated for the period between September 30, 2000, and January 12, 2001.
13. Well 801 decommissioned at the end of July 1999.
14. Well 808 began operation on June 26, 1991.
15. Data obtained from system flowmeter.

Source: Earth Tech, December 2002, Figure 2.1

TABLE 5

Southwest Alluvium Groundwater Velocities, October 2007
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Well Pair 805 and 624

Groundwater Elevations: 6863.50 (Well 805) and 6848.67 (Well 624) ft amsl
Separation Distance: 1902 ft
Average Linear Horizontal Hydraulic Gradient: 0.0078
Velocity 1 = 60 ft/yr
Velocity 2 = 47 ft/yr
Average Velocity = 54 ft/yr

Well Pair 805 and 627

Groundwater Elevations: 6863.50 (Well 805) and 6834.55 (Well 627) ft amsl
Separation Distance: 3203 ft
Average Linear Horizontal Hydraulic Gradient: 0.0090
Velocity 1 = 69 ft/yr
Velocity 2 = 53 ft/yr
Average Velocity = 61 ft/yr

Well Pair 624 and SBL 1

Groundwater Elevations: 6848.67 (Well 624) and 6846.21 (Well SBL 1) ft amsl
Separation Distance: 500 ft
Average Linear Horizontal Hydraulic Gradient: 0.0049
Velocity 1 = 38 ft/yr
Velocity 2 = 29 ft/yr
Average Velocity = 34 ft/yr

Darcy seepage velocity calculation input values:
Mean hydraulic conductivity used = 2×10^{-3} cm/s (USFilter, 2004b).
Range of effective porosities = 27% (velocity 1) to 35% (velocity 2) (Canonie, 1989b; Earth Tech, 2002c).

TABLE 6

Predicted Performance of Southwest Alluvium Natural Attenuation, 2007
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Constituent	Will Standards Be Met? Section 2	Section 3	Section 10	Remarks
Manganese	No	Yes?	No	Section 2 includes onsite seepage impact; Section 3 includes offsite seepage impact with Mn attenuated and known background water with Mn below standard; Section 10 includes advancing front of seepage impact with Mn below standard but Mn slightly above standard occasionally in background Well SBL 1 (see Table 2 and Table A.1 in Appendix A)
Sulfate	No	No	No	Seepage impact areas limited by calcium availability; background waters characterized by exceedances unrelated to seepage impact; highest sulfate concentrations occur in background Well SBL 1 (see Figures 9 and 14)
TDS	No	No	No	Governed by sulfate concentration; highest TDS concentrations occur in background Well SBL 1 (see Figure 17)
Metals	Yes	Yes?	No	Attenuation by neutralization and adsorption. Section 2 includes onsite seepage impact with no exceedances; Section 3 includes offsite seepage impact and known background water with no exceedances; Section 10 includes advancing front of seepage impact with no exceedances but small exceedances of nickel in background Well SBL 1 continued during 2007 (see Table 2)
Radionuclides	Yes	Yes	Yes	Attenuation by neutralization and adsorption

TABLE 7

Change in Zone 3 Saturated Thickness Over Time

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

Well Number[1]	Saturated Thickness		Change (feet)	Change
	3rd Quarter 1989	4th Quarter 2007		
402	--	21.89	--	--
411	62.5	--	--	--
420	56.3	11.61	-44.7	-79%
424	--	24.25	--	--
446	--	7.20	--	--
501 B	20.2	--	--	--
502 B	48.5	--	--	--
504 B	40.1	8.15	-32.0	-80%
517	42.7	11.90	-30.8	-72%
518[2]	37.2	--	--	--
613[3]	67.2	19.34	-47.9	-71%
EPA 01	14.7	--	--	--
EPA 03	8.3	--	--	--
EPA 09	8.1	3.55	-4.5	-56%
EPA 11	30.8	--	--	--
EPA 12	10.7	--	--	--
EPA 13	24.8	9.95	-14.9	-60%
EPA 14	76.3	29.77	-46.5	-61%
EPA 15	60.8	--	--	--
EPA 17	1.4	--	--	--
EPA 18	2.5	--	--	--
701	46.1	16.04	-30.1	-65%
702	24.1	9.50	-14.6	-61%
703	32.6	--	--	--
705	--	--	--	--
706	--	17.62	--	--
707	58.8	16.40	-42.4	-72%
708	49.8	17.10	-29.8	-60%
709	56.1	--	--	--
710	45.5	14.42	-31.1	-68%
711	43.7	19.68	-24.0	-55%
712	39.1	7.21	-31.9	-82%
713	34.2	10.55	-23.6	-69%
714[4]	50.1	16.63	-33.5	-67%
715[4]	47.6	--	--	--
716[4]	58.3	--	--	--
717[4]	57.6	23.62	-34.0	--
718[4]	51.1	--	--	--
719[4]	39.9	11.10	-28.8	-72%
720[4]	33.1	--	--	--
NBL-01[5]	--	17.05	--	--
Average	37.3	14.98	-30.3	-68%

Notes:

[1] Wells 9 D and 106 D were not included because they appear to be completed above the bottom of Zone 3. Measurements of saturated thickness in these wells may be less than actual conditions. Well 126 was not included because it was completed above the bottom of Zone 3. Measurements of saturated thickness in this well are less than actual conditions.
Wells 600, 610 and 672 were not included because they were used solely as pumping wells, therefore no water level data are available.
Well 608 was not included because no water level data were available in 1989 and the last water level measurement was in February 2000

[2] Water level for Well 518 last measured in January 2000.

[3] Water level for Well 613 measured in 1983 before pumping started. Water level data for 1989 are not available because the well was pump

[4] Water levels for the Stage II wells were measured June 1991 when wells were installed. Not included in 1989 average saturated thickness calculation.

[5] Well NBL-01 installed in July 2001and first water level measured in August 2001.

Shading indicates saturated thickness greater than 25 feet.

"--" indicates that no data is available.

TABLE 8

Estimated Mass Removal by Extraction Well Pumping in Zone 3, December 2006 Through November 2007
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Well	Water Pumped (gallons)	SO4 (kg)	NO3 as N (kg)	Chloroform (g)	Al (kg)	As (g)	Be (g)	Co (g)	Pb (g)	Mn (kg)	Mo (g)	Ni (g)	U (g)	Total Radium (mci)	Pb-210 (mci)	Gross Alpha (mci)
RW-11	362,876	3,510	9	2	15	130	13	318	34	10	824	322	80	25	0.69	10
RW-12	173,152	1,984	3	1	6	75	5	161	16	5	580	171	30	13	0.33	5
RW-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0
RW-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0
RW-16	221,892	2,503	17	1	9	13	8	315	21	12	104	242	27	30	0.42	13
RW-17	249,873	3,003	6	2	14	53	10	293	24	9	307	276	42	19	0.47	8
PB-2	481,035	5,263	3	2	8	991	12	417	46	13	3,372	536	86	34	0.91	14
EW-1/2	28,243	446	0	0	1	3	4	71	4	1	1	87	0	3	0.05	5
RW-A	48,694	566	1	0	2	35	2	45	5	1	162	48	11	4	0.09	1
Total	1,517,071	16,709	37	7	52	1,264	53	1,575	145	50	5,188	1,634	265	125	3	56

Notes:

RW-series wells are located on Figure 38 of the *2007 Annual Review Report*.

Wells RW-13 and RW-15 became fouled with sediment and were not pumped.

Units for radionuclides (mci) are not mass units proper; mci are milli-Curies, or thousandths of Curies.

In developing this table, analytical nondetects were assigned values of one-half the detection limit.

TABLE 9

Zone 3 Performance Monitoring Program, 2007 Operating Year
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Well	Water Level	Water Quality	NRC POC	Purpose
Continue Monitoring				
420	X	X		Postmining-pretailings background, track plume.
711	X	X	Y	Track saturation and plume, replace 502 B based on results of low flow purge testing performed in January 2000.
504 B	X	X		Track saturation and plume, extensive data set.
517	X	X	Y	Track plume, extensive data set.
EPA 9	X			Extent of saturation, water quality not necessary.
EPA 13	X	X		Extent of saturation. Water quality added 2nd quarter 2001.
EPA 14	X	X		Postmining-pretailings background, track plume.
702	X			Water level only, track saturation.
710	X			Water level only.
712	X			Water level only.
713	X			Water level only.
714	X			Water level only.
613	X	X	Y	Extensive data set, track saturation and source.
701	X			Water level only (decommissioned pumper).
706	X			Water level only (decommissioned pumper).
707	X			Water level only (decommissioned pumper).
708	X	X	Y	Added to program 2nd quarter 2001.
717	X	X		Water level. Water quality added 2nd quarter 2001.
719	X	X		Water level. Water quality added 2nd quarter 2001.
Additional Wells, Not Included In Original Performance Monitoring Program				
402	X			Long-term water level for migration path.
424	X			Long-term water level for migration path.
446	X			Long-term water level for migration path.
NBL-01	X	X		Well drilled and installed June 2001. Water level and water quality to track downgradient extent of seepage.
Total	23	11		

Eliminated From Monitoring				**Reason For Elimination**
9 D				Dry
106 D				Dry
411				Oil, cannot get water level or sample.
501 B			Y	Dry
EPA 1				Dry
EPA 3			Y	Dry
EPA 11				Unuseable since 1990 - water level below pump, pump cemented in well.
EPA 12				Dry
EPA 15				Dry
EPA 17				Dry
EPA 18				Dry
126				Dry
502 B				Failed low-flow test, use 711
518			Y	Failed low-flow test, use 517
608				Not needed (formerly water level only)
703				Not needed (formerly water level only)
715				Not needed (formerly water level only)
709				Not needed (decommissioned pumper)
716				Not needed (pumper)
718				Not needed (pumper)
720				Not needed (decommissioned pumper)

Notes:
NRC POC = Nuclear Regulatory Commission Point of Compliance well
Source: Earth Tech, December 2002, Table 3.2

TABLE 10

Zone 3 Saturated Thickness, October 2007

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

Well	Water Level Measurement Date	Zone 3 Unsaturated Thickness	Zone 3 Saturated Thickness	Zone 3 Percentage Saturated
402	10/11/07	41.11	21.89	35%
420	10/9/07	39.39	11.61	23%
424	10/11/07	48.75	24.25	33%
446	10/11/07	57.80	7.20	11%
504-B	10/9/07	57.85	8.15	12%
517	10/8/07	50.10	11.90	19%
613	10/8/07	48.66	19.34	28%
701	10/11/07	47.96	16.04	25%
702	10/11/07	71.50	9.50	12%
706	10/11/07	60.38	17.62	23%
707	10/11/07	71.60	16.40	19%
708	10/8/07	67.90	17.10	20%
710	10/11/07	66.58	14.42	18%
711	10/8/07	65.32	19.68	23%
712	10/11/07	78.79	7.21	8%
713	10/11/07	62.45	10.55	14%
714	10/11/07	21.37	16.63	44%
717	10/9/07	47.38	23.62	33%
719	10/9/07	33.90	11.10	25%
EPA-09	10/9/07	46.45	3.55	7%
EPA-13	10/9/07	54.05	9.95	16%
EPA-14	10/9/07	43.23	29.77	41%
NBL-01	10/9/07	16.95	17.05	50%
PB-03	10/9/07	27.29	21.71	44%
PB-04	10/9/07	20.06	16.94	46%

TABLE 11
Zone 3 Field Parameter Measurements of Tracking Wells, Through October 2007
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

	Bicarbonate (mg/L)					Conductivity (umhos/cm)					pH (s.u.)					Chloride (mg/L)				
Date	**0504 B**	**PB-02**	**PB-04**	**PB-03**	**NBL-01**	**0504 B**	**PB-02**	**PB-04**	**PB-03**	**NBL-01**	**0504 B**	**PB-02**	**PB-04**	**PB-03**	**NBL-01**	**0504 B**	**PB-02**	**PB-04**	**PB-03**	**NBL-01**
Oct-02	*0*	*58*	*194*	*224*	*330*	*5,010*	*4,040*	*3,730*	*3,670*	*3,160*	*5.06*	*7.09*	*7.10*	*7.10*	*7.18*	*NA*	*25.3*	*23.8*	*113.0*	*NA*
Nov-02	0	41	188	299	285	4,930	3,080	2,860	2,510	3,120	5.30	5.95	6.47	6.60	6.51	14.0	26.5	24.3	23.8	21.0
Dec-02	22.9	57	178	283	NA	5,040	4,120	3,950	3,330	NA	5.40	5.75	6.40	6.68	NA	22.9	26.2	23.2	25.7	NA
Jan-03	0	34	148	239	311	5,180	3,930	3,716	3,460	3,300	5.54	4.97	6.92	6.41	6.43	NA	NA	22.9	22.8	NA
Feb-03	0	58	193	324	328	3,620	2,910	2,660	2,570	2,300	3.52	5.57	6.96	6.92	6.53	26.7	30.1	30.4	28.5	21.5
Mar-03	NA	60	188	311	326	4,000	3,090	2,890	2,680	2,500	3.49	5.59	6.71	6.95	6.73	26.4	30.1	29.7	29.7	22.1
Apr-03	NA	34	172	310	321	4,210	4,460	4,220	3,820	2,650	5.14	5.46	5.94	6.26	6.87	26.6	30.5	30.0	30.1	21.6
May-03	0	34	167	293	322	5,510	4,460	4,210	3,820	3,390	5.01	5.36	5.99	6.31	6.37	28.0	31.0	30.2	31.9	32.7
Jun-03	0	21	129	267	316	5,470	4,480	4,060	3,820	3,380	4.28	5.15	6.17	6.20	6.36	27.7	30.8	29.6	30.6	28.0
Jul-03	NA	32	126	257	311	5,480	4,560	4,330	3,920	3,500	5.35	5.28	5.85	6.32	6.29	26.5	30.6	29.7	31.1	25.8
Aug-03	NA	5	100	234	307	5,210	4,280	3,960	3,630	3,230	5.14	5.18	5.76	6.18	6.28	27.0	30.4	29.7	31.1	23.1
Sep-03	NA	7	91	218	295	5,260	4,400	4,160	3,770	3,340	4.68	5.23	5.79	6.28	6.39	28.0	30.5	29.3	31.5	26.7
Oct-03	NA	0	65	211	295	5,360	4,450	4,210	3,860	3,410	5.48	5.18	5.81	6.34	6.41	27.7	21.0	30.0	32.7	26.8
Nov-03	NA	0	73	197	285	5,290	4,510	4,210	3,880	3,490	5.09	5.25	5.81	6.24	6.42	27.3	30.6	30.2	32.1	24.8
Dec-03	NA	NA	41	166	265	5,370	4,540	4,290	3,910	3,510	4.41	5.14	5.77	6.76	6.48	27.7	30.2	29.8	31.5	25.2
Jan-04	NA	NA	73	194	327	5,340	4,610	4,310	4,030	3,550	5.39	5.16	5.82	7.51	6.50	32.5	30.5	29.5	32.6	26.8
Feb-04	NA	NA	50	190	323	5,410	4,630	4,260	3,970	3,590	3.40	3.81	5.99	6.25	6.40	28.0	30.1	30.3	32.7	26.6
Mar-04	NA	15	48	179	316	5,560	4,730	4,500	4,130	3,780	3.89	4.75	5.70	6.31	6.29	27.5	30.1	30.2	33.3	25.9
Apr-04	NA	15	48	174	315	5,370	4,560	4,380	4,010	3,630	5.36	5.08	5.52	6.03	6.34	28.1	32.1	32.3	36.2	31.1
May-04	NA	0	27	166	312	6,190	4,390	4,160	3,870	3,510	3.26	5.02	5.34	5.88	6.23	28.4	33.2	32.8	38.1	31.9
Jun-04	NA	0	22	152	294	5,510	4,530	4,400	4,040	3,750	4.48	4.92	5.46	6.05	6.40	28.2	32.6	32.9	37.7	34.1
Jul-04	NA	0	20	140	274	5,450	4,510	4,420	4,000	3,740	5.48	5.04	5.58	6.05	6.45	27.8	31.9	32.8	36.9	34.1
Aug-04	NA	0	17	124	272	5,500	4,450	4,380	4,040	3,710	3.77	4.26	5.45	5.98	6.39	28.3	31.0	32.3	36.2	33.7
Sep-04	0	0	20	117	251	5,480	4,500	4,430	4,030	3,790	4.04	4.46	5.48	6.05	6.45	28.5	30.9	32.5	36.0	34.0
Oct-04	0	0	18	102	245	5,520	4,540	4,560	4,110	3,940	5.56	5.15	5.62	6.08	6.47	27.8	31.5	32.0	30.2	33.2
Nov-04	0	0	17	98	245	5,370	4,400	4,340	3,950	3,840	4.46	4.23	5.47	5.99	6.37	27.8	31.4	32.3	35.6	32.0
Dec-04	0	0	13	87	207	5,290	4,340	4,290	3,920	3,790	4.46	4.28	5.44	5.95	6.36	27.8	31.2	31.0	34.0	30.0

TABLE 11

Zone 3 Field Parameter Measurements of Tracking Wells, Through October 2007
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

	Bicarbonate (mg/L)					Conductivity (umhos/cm)					pH (s.u.)					Chloride (mg/L)				
Date	0504 B	PB-02	PB-04	PB-03	NBL-01	0504 B	PB-02	PB-04	PB-03	NBL-01	0504 B	PB-02	PB-04	PB-03	NBL-01	0504 B	PB-02	PB-04	PB-03	NBL-01
Feb-05	0	0	7	68	196	5,680	4,720	4,550	4,130	3,980	3.92	3.24	5.31	5.98	6.37	28.0	31.5	31.3	33.4	30.0
Mar-05	0	0	0	60	169	5,540	4,510	4,350	3,990	3,960	3.84	3.72	5.32	5.93	6.27	24.5	31.3	32.0	33.7	35.2
Apr-05	8	0	29	70	154	5,350	4,300	4,340	3,980	3,890	4.46	4.25	5.56	5.88	6.31	27.8	32.4	32.2	34.0	35.1
May-05	0	0	0	67	150	5,300	4,290	4,170	3,840	3,810	4.33	3.78	4.53	5.85	6.30	28.5	32.6	30.6	33.4	34.6
Jun-05	0	0	0	65	138	5,400	4,330	4,280	3,980	3,910	4.06	3.93	4.63	5.77	6.15	28.1	32.1	31.0	33.6	34.7
Jul-05	0	0	0	67	123	5,020	4,150	4,100	3,780	3,640	5.10	3.55	4.04	5.58	5.88	27.9	31.2	31.9	33.1	34.3
Aug-05	0	0	0	57	122	5,270	4,320	4,360	3,880	3,730	3.40	3.39	3.29	5.89	6.62	28.4	31.5	31.6	34.2	34.2
Sep-05	0	NA	0	54	111	5,430	NA	4,230	3,920	3,830	3.58	NA	4.15	5.80	6.24	28.4	NA	31.3	33.2	34.1
Oct-05	0	NA	0	51	107	5,630	NA	4,410	4,220	4,030	5.45	NA	4.99	6.00	6.26	28.3	NA	31.3	33.6	34.0
Nov-05	0	NA	5	48	96	5,550	NA	4,180	4,080	3,940	3.75	NA	5.45	5.76	6.25	28.7	NA	33.0	34.2	34.2
Dec-05	0	NA	22	44	77	5,670	NA	4,190	4,060	3,950	3.38	NA	5.92	5.97	6.43	33.3	NA	35.6	34.1	31.6
Jan-06	0	NA	28	89	128	5,720	NA	4,110	4,330	4,250	5.22	NA	6.30	6.36	6.47	29.4	NA	45.0	35.2	32.2
Feb-06	0	NA	101	117	126	5,670	NA	4,350	4,250	4,040	3.83	NA	6.19	6.14	6.38	27.5	NA	41.3	37.5	49.0
Mar-06	0	NA	190	133	132	5,850	NA	4,290	4,310	4,060	4.14	NA	6.19	6.18	6.18	27.6	NA	43.7	39.9	38.8
Apr-06	0	NA	244	139	119	5,710	NA	4,280	4,310	5,710	5.21	NA	6.24	6.17	6.10	28.9	NA	44.3	41.0	34.0
May-06	0	NA	246	138	112	5,740	NA	4,180	4,290	4,130	4.12	NA	6.16	6.02	6.01	28.3	NA	45.1	42.0	33.9
Jun-06	0	104	249	138	130	5,680	4,280	4,160	4,450	4,080	4.12	5.86	6.14	6.08	6.02	29.0	44.3	45.8	42.0	32.8
Jul-06	0	134	230	217	138	5,140	4,020	3,750	4,060	3,810	5.06	5.90	6.13	6.14	6.06	29.4	40.7	45.0	50.5	37.0
Aug-06	0	160	232	227	137	5,340	4,050	3,860	4,140	3,850	3.89	6.04	6.17	6.34	6.24	27.6	43.1	47.2	50.0	37.8
Sep-06	0	137	235	278	155	5,350	3,960	3,740	3,980	3,870	3.41	6.00	6.16	6.45	6.49	27.8	38.7	27.8	50.5	41.2
Oct-06	0	141	279	323	133	5,230	4,040	3,810	4,000	4,000	5.11	6.02	6.24	6.42	6.21	29.9	39.0	47.3	51.4	35.0
Nov-06	0	159	229	304	155	5,390	4,180	3,840	4,020	4,020	3.64	6.01	6.96	6.46	6.59	27.8	38.7	46.2	53.1	44.0
Dec-06	0	151	233	328	183	5,680	4,290	4,090	4,230	4,360	3.42	6.18	7.05	6.67	6.44	28.6	38.8	47.1	54.0	48.3
Jan-07	0	149	243	335	196	5,310	4,170	3,920	4,010	4,220	5.23	6.13	6.70	6.56	6.36	29.0	37.0	48.0	53.0	49.0
Feb-07	0	144	205	272	178	5,340	4,150	3,800	3,900	4,160	4.16	6.50	6.64	6.62	6.43	28.0	37.0	49.0	53.0	51.0
Mar-07	0	NA	258	310	210	5,500	NA	3,970	4,120	4,200	3.84	NA	6.99	6.92	6.56	29.0	NA	50.0	53.0	50.0
Apr-07	0	161	302	345	217	5,210	3,990	3,830	3,950	4,060	5.25	6.01	6.33	6.44	6.18	28.0	38.0	46.0	44.0	52.0
May-07	0	173	288	317	223	5,260	3,980	3,750	3,850	3,860	3.91	6.05	6.48	6.52	6.61	28.0	36.0	48.0	52.0	54.0
Jun-07	0	169	310	311	191	4,200	3,230	3,020	2,980	3,030	3.38	6.03	6.86	6.85	6.44	28.0	35.0	50.0	51.0	52.0
Jul-07	0	156	293	322	199	4,750	3,400	3,530	3,410	3,520	5.10	6.16	6.37	6.51	6.40	29.0	36.0	51.0	49.0	54.0
Aug-07	0	171	293	306	150	4,860	3,770	3,550	3,570	3,650	3.92	5.91	6.45	6.41	6.06	28.0	36.0	53.0	52.0	55.0
Sep-07	0	184	307	304	135	4,940	3,610	3,570	3,660	3,720	3.58	6.09	6.60	6.46	6.77	29.0	35.0	54.0	53.0	57.0
Oct-07	20	161	329	307	185	4,630	3,300	3,170	3,200	3,350	3.29	6.39	6.51	6.64	6.20	29.0	36.0	55.0	52.0	50.0

TABLE 12

Zone 3 Seepage Migration Travel Time Calculations
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

End Point Well	Starting Point	Distance Between Both Points (ft)	*Time for Onset of* Seepage Impacts at Starting Point (date)	Seepage Impacts at End Point (date)	Travel Time (ft/yr)	Basis for Determining Onset Date for Seepage Impacts At Selected Points
420	North Cell	2,100	1980	Oct-02	95	Bicarbonate concentration greater than 500 mg/L
504 B	North Cell	2,450	1980	Jul-92	204	Bicarbonate concentration less than 100 mg/L
EPA 14	North Cell	1,520	1980	Apr-96	95	Bicarbonate concentration greater than 500 mg/L
PB 2	North Cell	3,080	1980	Oct-02	140	Bicarbonate concentrations first declining to 50 mg/L at Well PB 2
PB 2	504 B	630	Jul-92	Oct-02	61	Bicarbonate concentrations first declining to 50 mg/L at each well
PB 4	PB 2	52	Apr-03	Feb-04	60	Bicarbonate concentrations first persistently at or below 50 mg/L at each well
			Geometric Mean		99	

End Point Well	Starting Point Well	Distance Between Both Points (ft)	Time for Recession of Seepage Impacts at Starting Point (date)	Seepage Impacts at End Point (date)	Travel Time (ft/yr)	Basis for Determining Recession Date for Seepage Impacts At Selected Points
PB 2	PB 4	52	Feb-06	No later than Jun-06	156	Abrupt upward bicarbonate concentration reversal started in Dec-05 in Well PB 4 and attained concentrations persistently above 50 mg/L in Feb-06. Nine month hiatus in monthly field geochemical monitoring of Well PB 2 until Jun-06 when bicarbonate concentrations above 50 mg/L were persistently attained. See monthly field bicarbonate measurements in Table 11.

From Oct-2006 to Oct-2007 the location of the northern edge of seepage impact is inferred to be unchanged (see Table 11)

TABLE 13

Detected Constituents in Zone 3, October 2007
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Chemical Name	Action Level	Unit	0420	0504 B	0517	0613	0708	0711	0711 DUP	0717	0719	EPA 13	EPA 14	NBL-01
ALUMINUM	5	mg/l		0.1	4.7	641	4.1	0.4	0.4	3.2	0.9		121	0.6
AMMONIA (AS N)		mg/l		0.73	10.9 D	247 D	1.41	0.48	0.52	63.6 D	0.62	0.43	74.9 D	7.1 D
ARSENIC	0.05	mg/l	0.005	0.02		0.001	0.002	0.03	0.03	0.001	0.001	0.27 D		0.61 D
BERYLLIUM	0.017	mg/l				0.16							0.07	
BICARBONATE (HCO3)		mg/l	476	6					6	92		79		220
CADMIUM	0.01	mg/l			0.007	0.029							0.01	
CALCIUM		mg/l	649 D	480 D	478 D	376 D	461 D	489 D	486 D	633 D	496 D	476 D	483 D	623 D
CHLORIDE	250	mg/l	43	29	47	146 D	28	18	18	79	29	41	79	50
COBALT	0.05	mg/l		0.24	0.8	1.79	0.37	0.4	0.4	0.5	0.19	0.07	0.78	0.25
GROSS ALPHA	15	pci/l	3.1	10.7	11.2	40	10.4	7.7	7.6	20.9	4.2	5.3	26.9	12.4
LEAD-210	1	pci/l			1.8	1.6								
MAGNESIUM		mg/l	137 D	657 D	463 D	651 D	604 D	512 D	505 D	448 D	371 D	781 D	558 D	280 D
MANGANESE	2.6	mg/l	2.05	7.52	8.98	50.6	11.4	7.09	7.06	17.2	4.49	8.13	17.3	6.97
MOLYBDENUM	1	mg/l	0.1	1				0.1	0.1			0.2		1.4
NICKEL	0.05	mg/l		0.26	0.76	1.82	0.34	0.34	0.34	0.34	0.22	0.16	0.76	0.26
NITRATE (NO3)	190	mg/l	2.8		0.2	10.6				31.1 D	0.1		24 D	
PH (FIELD)		su	7.11	3.29	4.05	2.93	3.78	4.46	4.68	5.73	4.17	6.12	4.31	6.20
PH (LAB)		su	7.13	4.81	3.93	2.95	3.49	3.80	4.91	6.10	4.40	6.58	4.36	6.53
POTASSIUM		mg/l	6.1	12.4	11.8	0.8	12.7	11.2	11.1	19.6	9.8	12.3	11.3	13.6
RADIUM-226		pci/l	6.1	12.4	11.8	0.8	12.7	11.2	11.1	19.6	9.8	12.3	11.3	13.6
RADIUM-228		pci/l	3.5	16.9	14.1		6.9	15.6	15.1	25.2	8.7	8.2	35.4	10.4
RADIUM 226 & 228	5	pci/l	5.2	25.1	19.7	17.2	12.5	19.5	18.6	39.5	10.7	11.6	49.2	20.8
SODIUM		mg/l	125	151	147	266 D	115	100	98.3	162	117	136	174	142
SULFATE (SO4)	2125	mg/l	1860 D	4050 D	3390 D	8300 D	4040 D	3470 D	3430 D	3440 D	2730 D	4280 D	4220 D	2660 D
THORIUM-230	5	pci/l				706								
TOTAL DISSOLVED SOLIDS	4800	mg/l	3340	6000	5130	12700	5910	5090	5140	5420	4250	6440	6420	4290
TOTAL TRIHALOMETHANES	80	ug/l			6.76	127							2.29	
URANIUM	0.3	mg/l	0.269	0.0195	0.0518	1.36	0.0226	0.024	0.023	0.0036	0.0103	0.0139	0.0108	0.0886
VANADIUM	0.1	mg/l				2.3								

TABLE 14

Zone 1 Performance Monitoring Program, 2007 Operating Year
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Well[1]	Water Level[2]	Water Quality[2]	NRC POC	Purpose
Continue Monitoring				
515 A	X	X		Track transition area
604	X	X	Y	Track center of seepage
614	X	X	Y	Track transition area
EPA 2	X	X		Postmining-pretailings background water quality
EPA 4	X	X	Y	Postmining-pretailings background water quality
EPA 5	X	X	Y	Track transition area
EPA 7	X	X	Y	Track transition area, edge of saturation
EPA 8	X			Track edge of saturation
142	X	X		Premining background
143	X			Water level only, use 142
Additional Wells, Not Included In Original Performance Monitoring Program				
505 A	X			Long-term water level for migration path
502 A	X			Long-term water level for migration path
501 A	X			Long-term water level for migration path
504 A	X			Long-term water level for migration path
412	X			Long-term water level for migration path
Total	15	8		

Eliminated From Monitoring				Reason For Elimination
141				No longer useable, plugged during arroyo flooding
516 A			Y	Failed low-flow testing
619				Anomalous water quality and water level
615				Decommissioned pumper, not needed - use 515 A
616				Decommissioned pumper, not needed - use 604
617				Decommissioned pumper, not needed

Notes:
1. No wells within the tailings reclamation cap were included.
2. Water level and water quality monitored on a quarterly basis.

Table 15

Zone 1 Saturated Thickness, October 2007

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

Well	Water Level Measurement Date	Zone 1 Unsaturated Thickness	Zone 1 Saturated Thickness	Zone 1 Percentage Saturated
TWQ-142	10/9/2007	0.00	55.00	100%
TWQ-143	10/11/2007	0.00	52.00	100%
412	10/11/2007	0.00	76.00	100%
501-A	10/11/2007	9.04	55.96	86%
502-A	10/11/2007	0.00	59.00	100%
504-A	10/11/2007	7.51	60.49	89%
505-A	10/11/2007	0.00	46.00	100%
515-A	10/3/2007	25.75	15.25	37%
604	10/3/2007	23.20	21.80	48%
614	10/3/2007	21.54	23.46	52%
EPA-02	10/8/2007	19.64	30.36	61%
EPA-04	10/8/2007	16.78	38.22	69%
EPA-05	10/2/2007	27.51	21.49	44%
EPA-07	10/8/2007	28.40	54.60	66%
EPA-08	10/8/2007	27.01	38.99	59%

TABLE 16

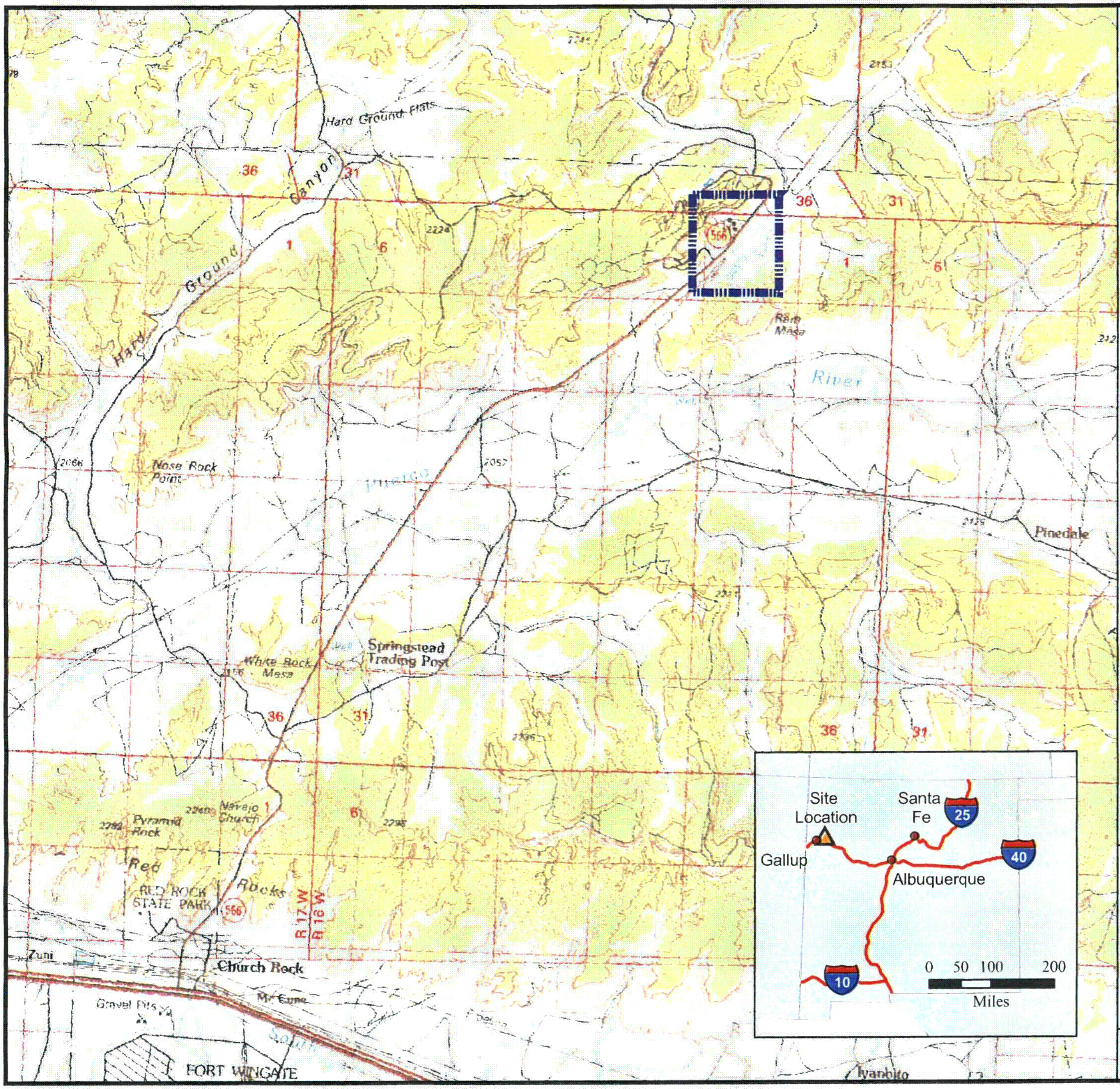
Detected Constituents in Zone 1, October 2007
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Chemical Name	Action Level	Unit	0142	0515 A	0604	0614	EPA 02	EPA 02 DUP	EPA 04	EPA 05	EPA 07
ALUMINUM	5	mg/l		0.5	5.7						0.5
AMMONIA (AS N)		mg/l	0.15	6.2 D	0.24	72.3 D	0.33	0.32	0.64	8.2 D	0.15
BICARBONATE (HCO3)		mg/l	250	217	5	1520	287	348	128	65	598
CALCIUM		mg/l	33.9	436 D	418 D	540 D	344 D	350 D	543 D	431 D	489 D
CHLORIDE	250	mg/l	16	255 D	82 D	378 D	20	20	36	69 D	200
COBALT	0.05	mg/l		0.04	0.26					0.05	0.02
GROSS ALPHA	15	pci/l		4.5	6.1	2.1	1.7	2.5	2.3	2.6	1.6
MAGNESIUM		mg/l	17	823 D	794 D	582 D	159 D	162 D	374 D	478 D	898 D
MANGANESE	2.6	mg/l	0.03	16.8	10.8	0.49	1.42	1.39	3.43	1.15	1.96
NICKEL	0.05	mg/l		0.21	0.29						
NITRATE (NO3)	190	mg/l	0.3	61 D	75 D	78 D				18.4 D	127 D
PH (FIELD)		su	7.14	5.40	4.86	6.43	6.85	6.78	6.67	5.93	6.19
PH (LAB)		su	7.53	5.96	5.11	6.87	7.39	7.15	6.91	6.34	6.70
POTASSIUM		mg/l	3.5	15.9	13.7	11.9	6.1	6.2	8.1	10.2	7.8
RADIUM-226		pci/l		1.3	1.7	0.7	1.1	1.4	0.9	1.3	
RADIUM-228		pci/l			2.9	2					
RADIUM 226 & 228	5	pci/l		1.3	4.6	2.7	1.1	1.4	0.9	1.3	
SODIUM		mg/l	305	445 D	287 D	455 D	185	188	170	119 D	334
SULFATE (SO4)	2125	mg/l	570	4440 D	4410 D	2910 D	1490 D	1470	2840 D	2960 D	4130 D
TOTAL DISSOLVED SOLIDS	4800	mg/l	1090	7880	7160	6490	2600	2670	4520	4880	7820
TOTAL TRIHALOMETHANES	80	ug/l		168	7.68	182	0.91				
URANIUM	0.3	mg/l		0.0006	0.0008	0.0508	0.0012	0.0012		0.0015	0.0019

TABLE 17

Predicted Performance of the Zone 1 Natural System
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Constituent	Will Standards Be Met? Section 1	Will Standards Be Met? Section 36	Remarks
Manganese	Maybe	Maybe	Dependent on bicarbonate availability
Sulfate	No	No	Limited by calcium availability
TDS	No	No	Governed by sulfate concentration
Metals	Yes	Yes	Attenuated by neutralization and adsorption
Radionuclides	Yes	Yes	Attenuated by neutralization and adsorption



N

LEGEND

▬ Approximate Site Location

NEW MEXICO INSET LEGEND

● Major City

△ Church Rock Site Location

— Interstate Highway

▭ State Boundary

Notes:

1. Topographic basemap taken from the United States Geologic Survey 30x60 minute, 1:100,000 scale, Gallup, New Mexico Topographic Map, 1981.
2. Data for New Mexico Inset map taken from ESRI Data & Maps 2002 CD-ROM set.

1 0.5 0 1

Miles

FIGURE 1

Site Location Map

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

N.A. Water Systems

Z:\databases\6209_GE_CR\GISDATA\arcmap_doc\2006_annual_report\f01_site_location.mxd; December 12, 2006

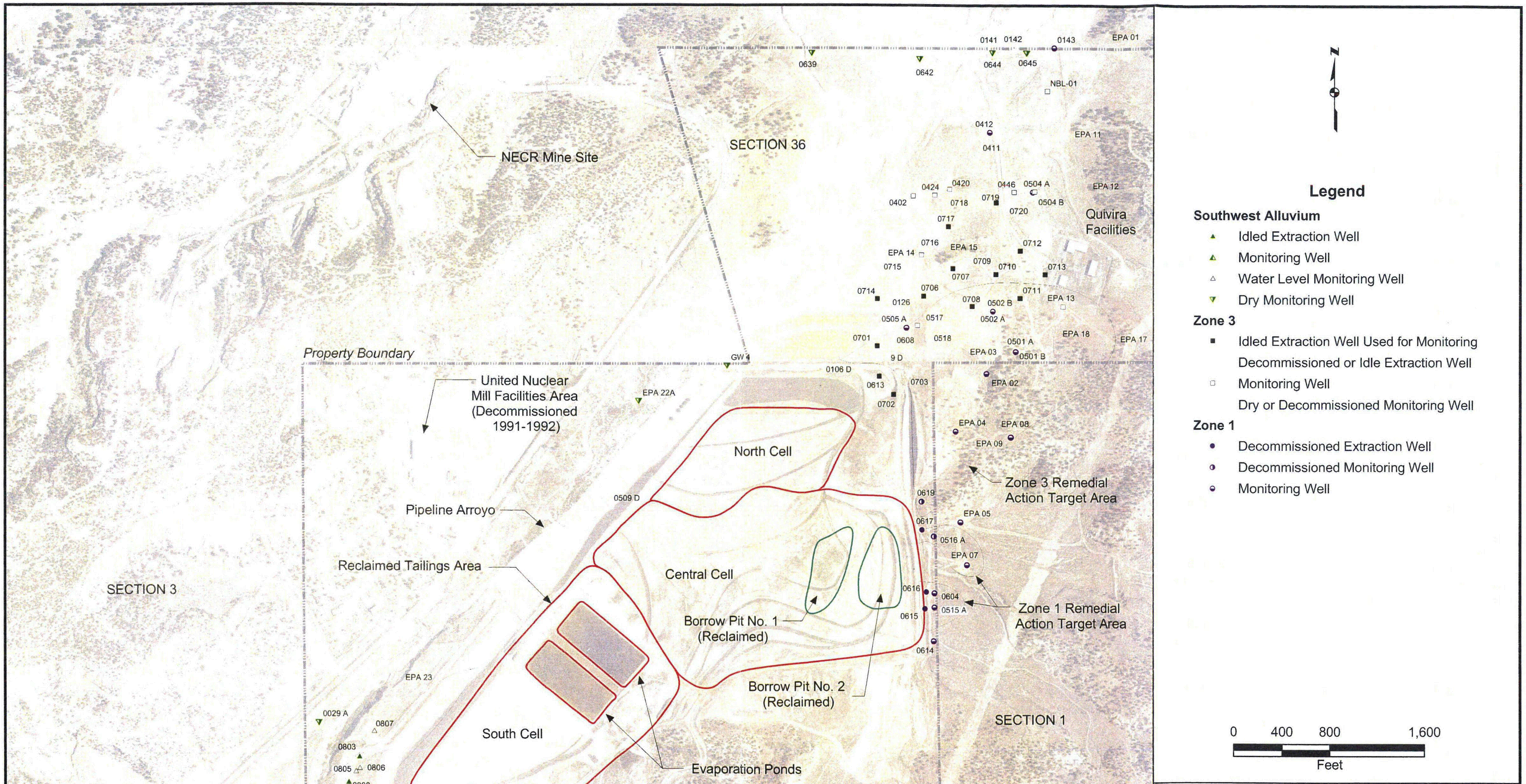


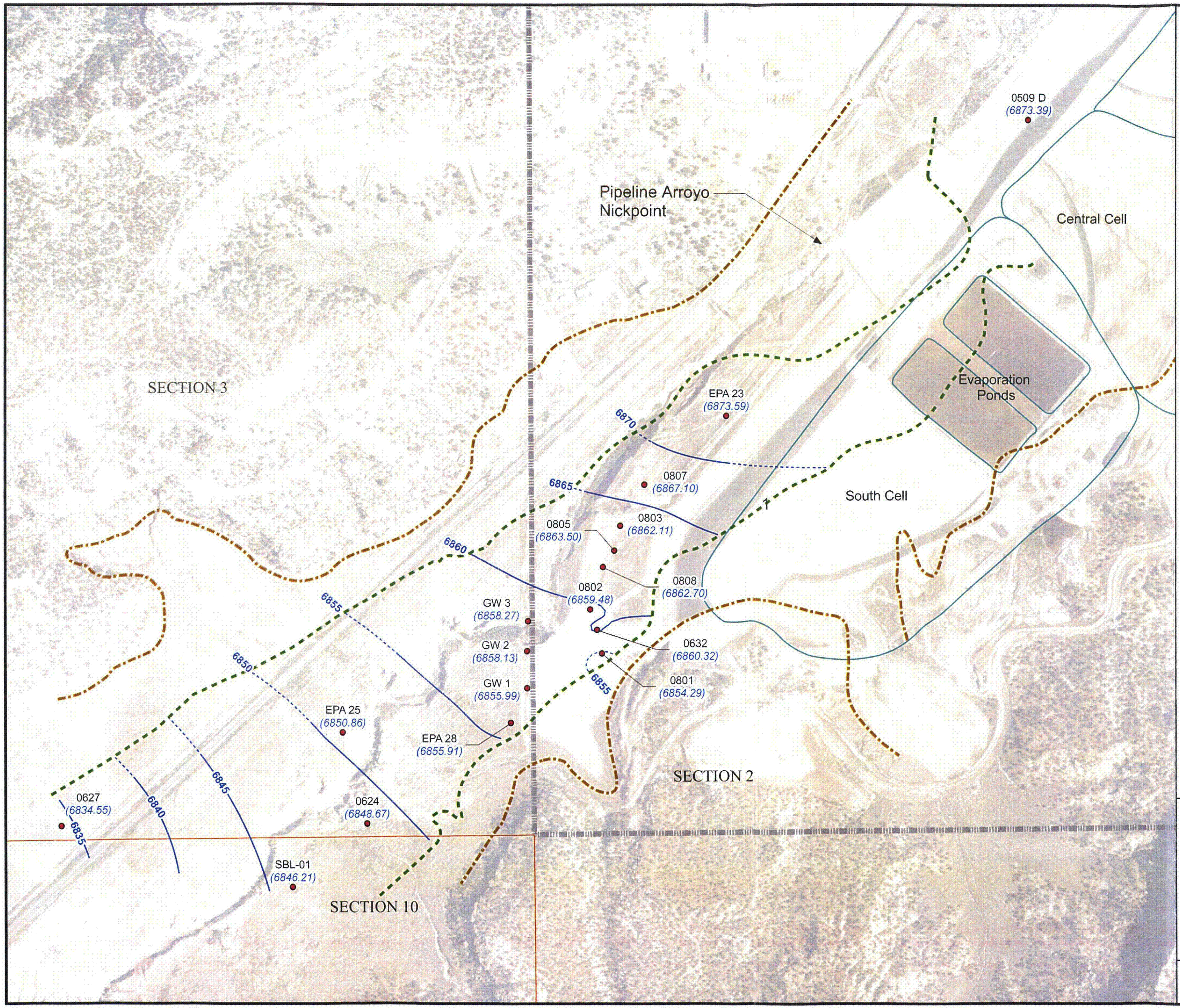
FIGURE 2

Site Layout and Performance
Monitoring Well Locations
2007 Operating Year

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

N.A. Water Systems

Z:\databases\6209_GE_CR\GISDATA\arcmap_doc\2007_annual_report\f02_site_layout.mxd; December 26, 2007



N

Legend

●	Southwest Alluvium Monitoring Well
—	Groundwater Elevation Contour
------	Inferred Groundwater Elevation Contour
-·-·-	Approximate Extent of Alluvium
- - -	Approximate Extent of Saturated Alluvium
▨	Property Boundary
—	Section Boundary
—	Cell Boundary

Notes:

1. Groundwater elevation values are displayed in feet above mean sea level.
2. Well names are displayed with black text.
3. Groundwater elevations are shown with blue text and enclosed in parentheses.
4. Aerial photo taken on August 1, 1996.

0 250 500 1,000

Feet

FIGURE 3

Southwest Alluvium Potentiometric Surface Map October 2007

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

N.A. Water Systems

Z:\databases\6209_GE_CR\GISDATA\arcmap_doc\2007_annual_report\f03_swa_piezo.mxd; December 18, 2007

FIGURE 4

Southwest Alluvium Water Levels Over Time
United Nuclear Corporation, Church Rock Site, Church Rock New Mexico

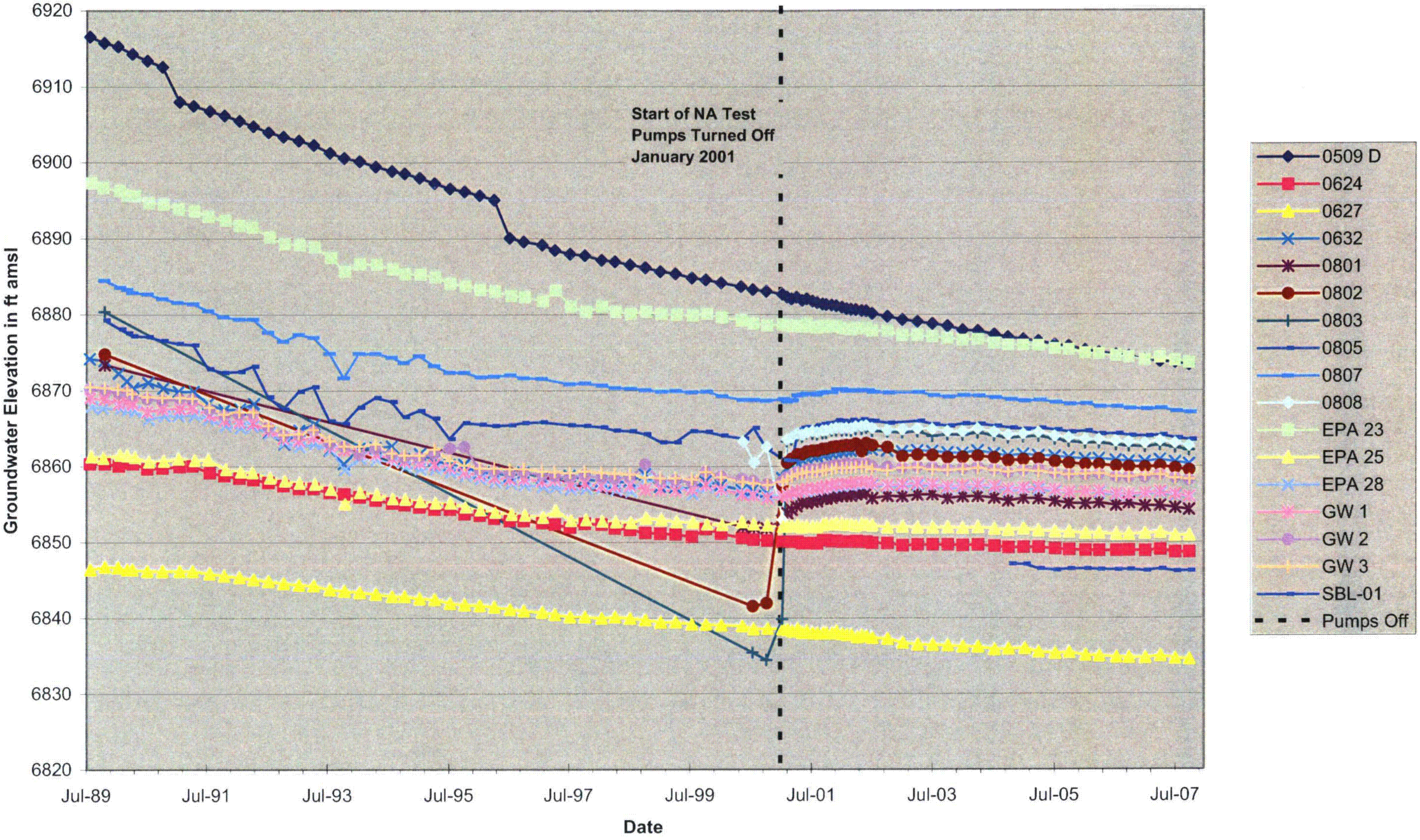
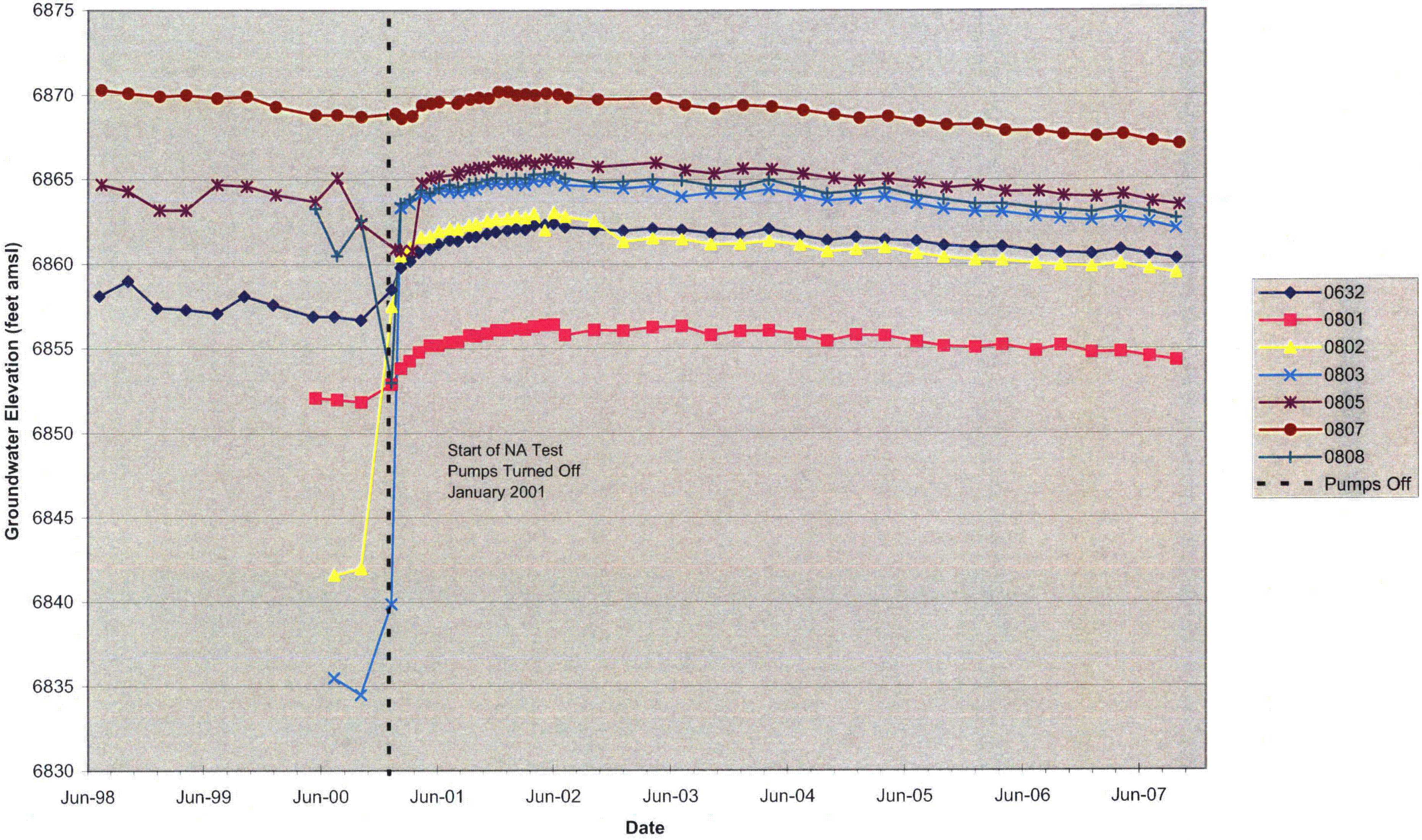
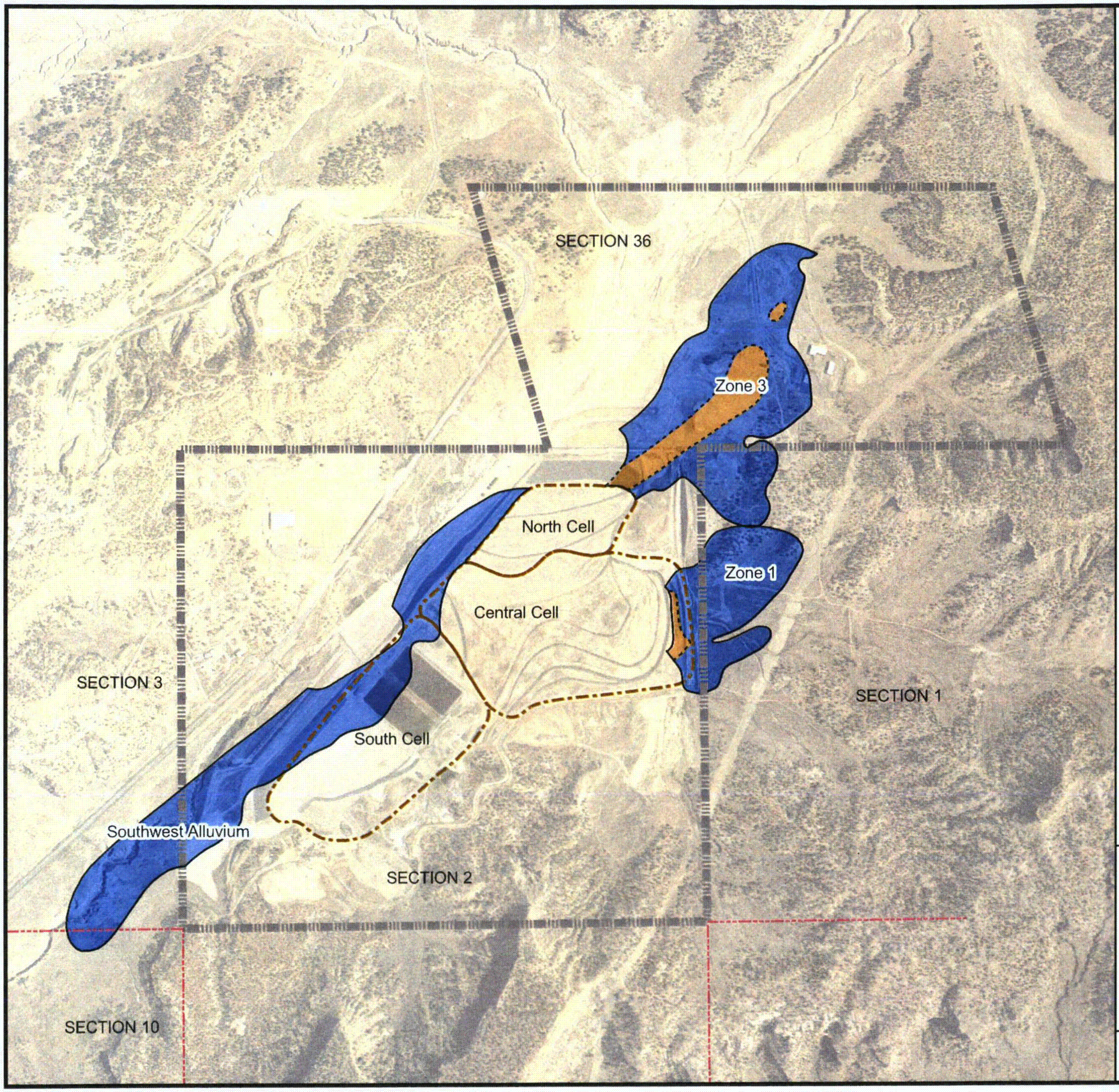


FIGURE 5

Southwest Alluvium Pumping Well Water Levels Over Time
United Nuclear Corporation, Church Rock Site, Church Rock New Mexico





Aerial photo taken on August 1, 1996.

FIGURE 6

Extent of Seepage-Impacted Groundwater October 2007

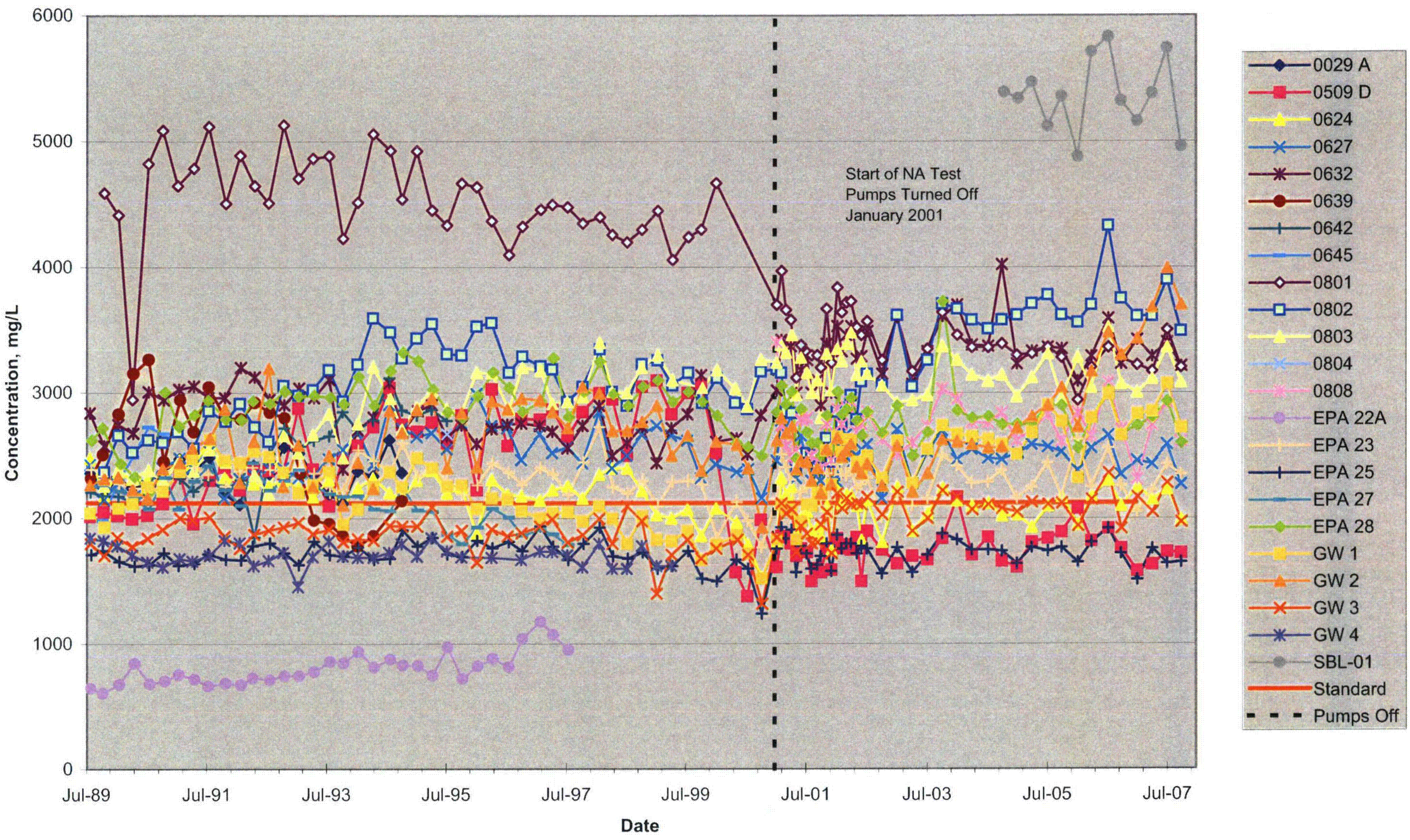
United Nuclear Corporation Church Rock Site
Church Rock, New Mexico

N.A. Water Systems

Z:\databases\6209_GE_CR\GISDATA\arcmap_doc\2007_annual_report\f06_seepage_extents.mxd; January 9, 2008

FIGURE 7

Southwest Alluvium Sulfate Concentrations Over Time
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico



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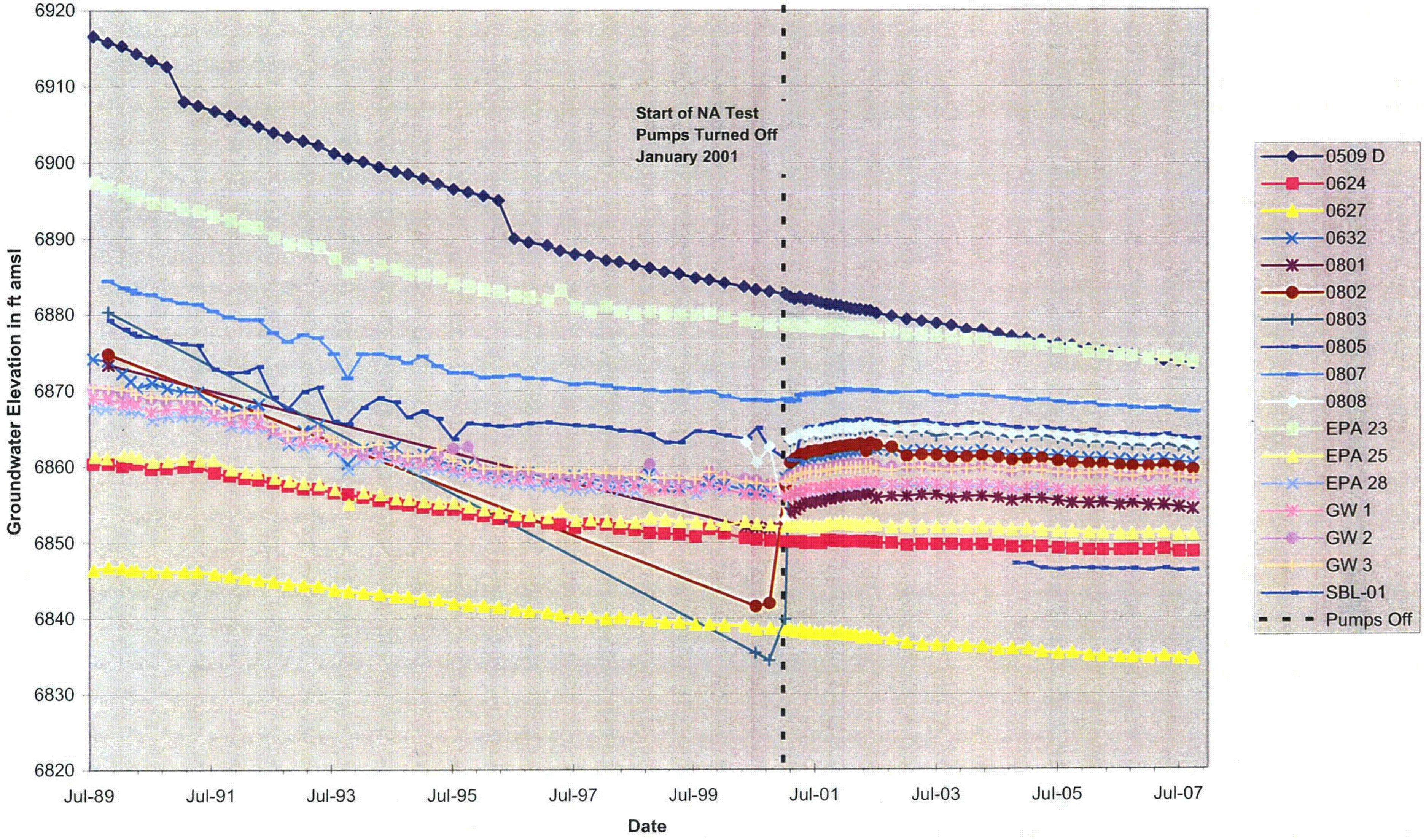
N.A. Water Systems

FIGURE 4

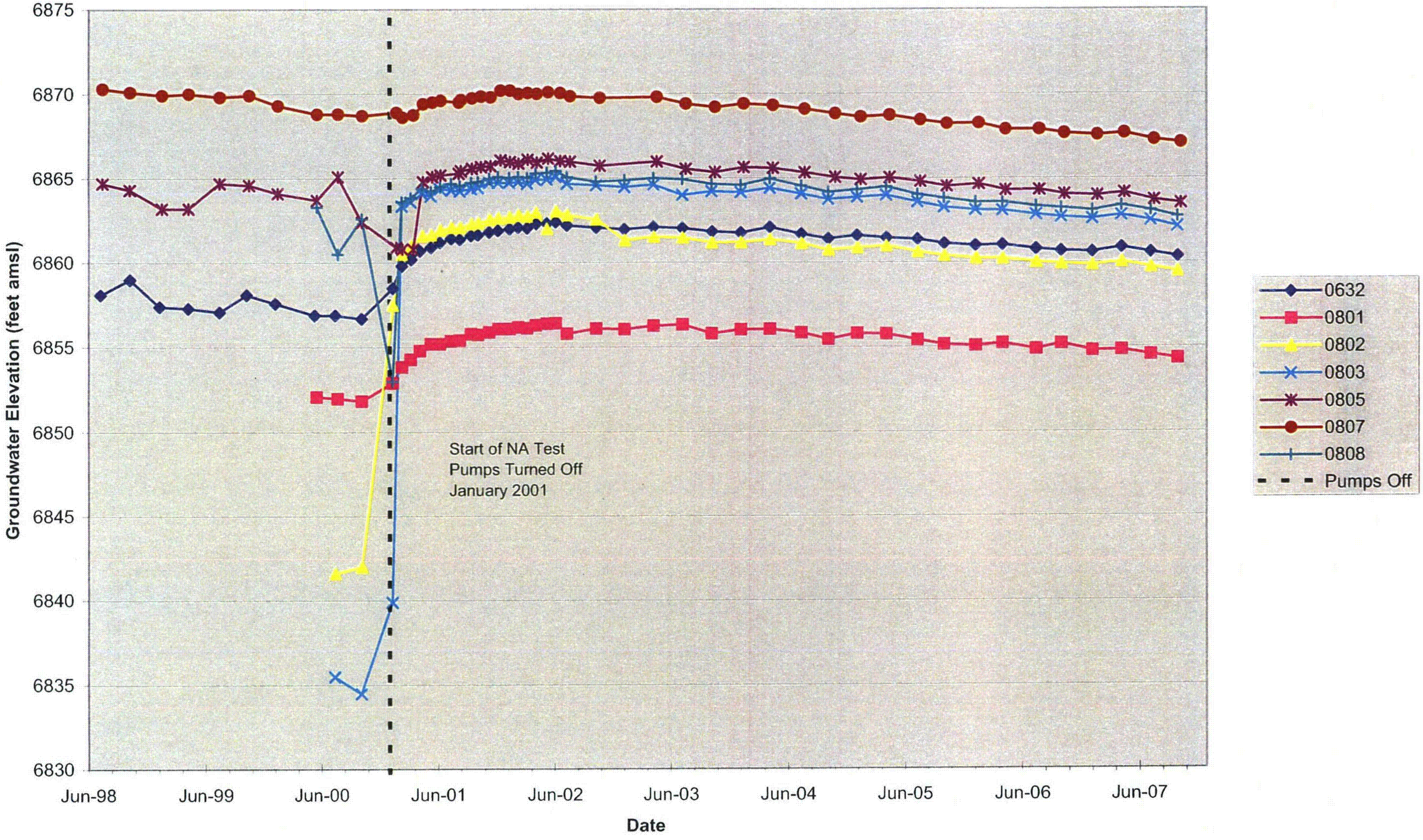
Southwest Alluvium Water Levels Over Time
United Nuclear Corporation, Church Rock Site, Church Rock New Mexico



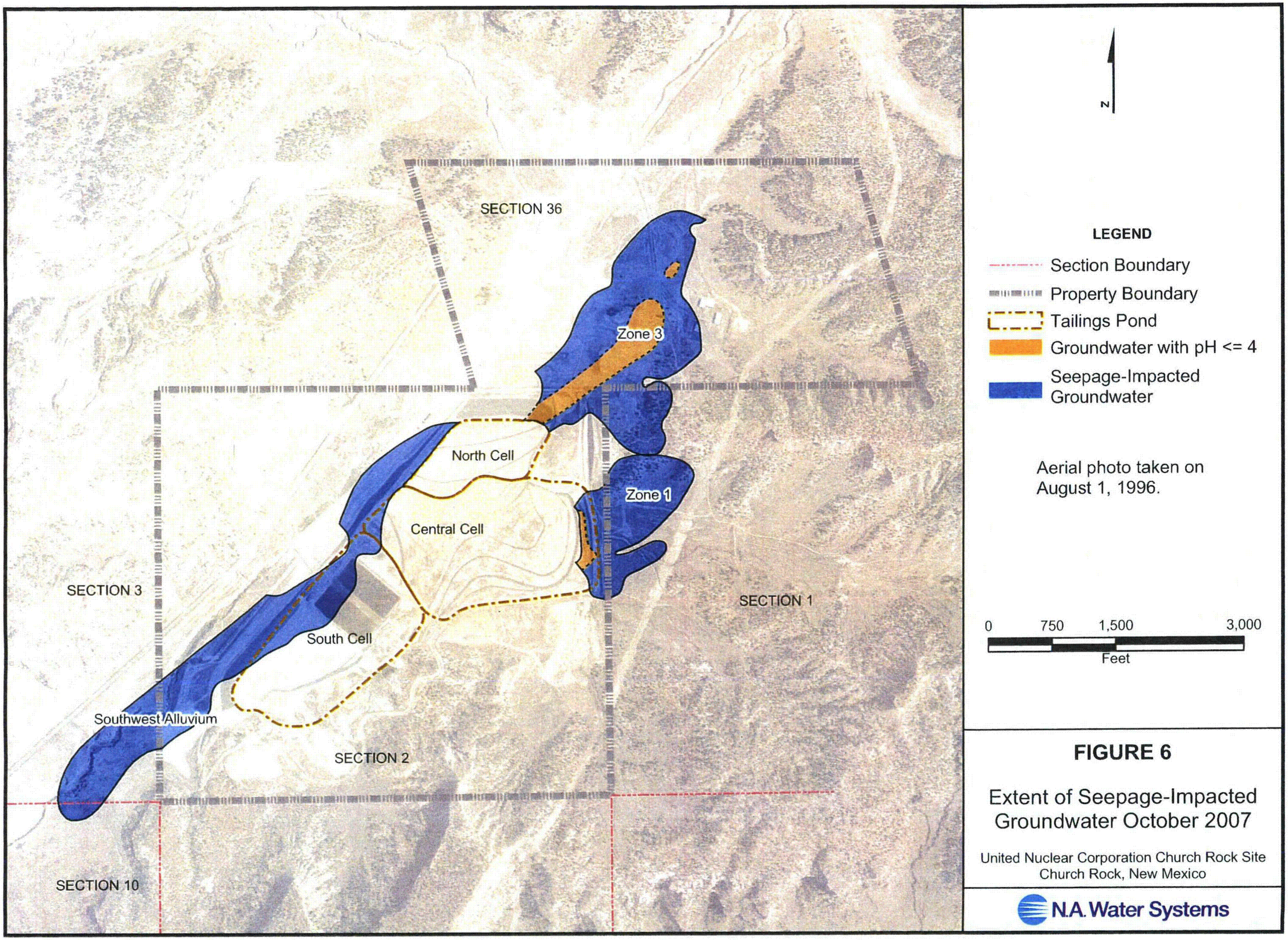
N.A. Water Systems

FIGURE 5

Southwest Alluvium Pumping Well Water Levels Over Time
United Nuclear Corporation, Church Rock Site, Church Rock New Mexico



N.A. Water Systems



Aerial photo taken on August 1, 1996.

FIGURE 6

Extent of Seepage-Impacted Groundwater October 2007

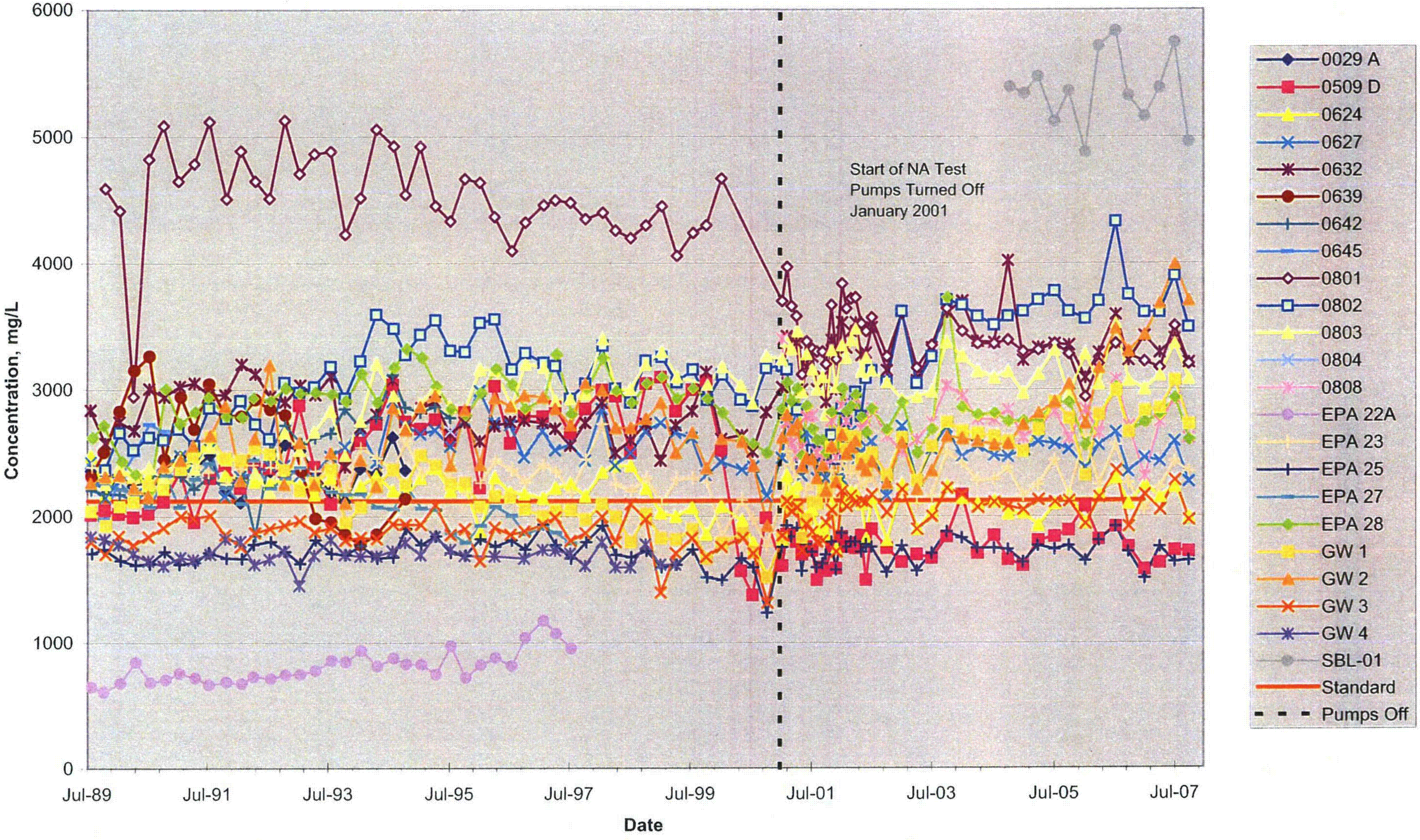
United Nuclear Corporation Church Rock Site
Church Rock, New Mexico

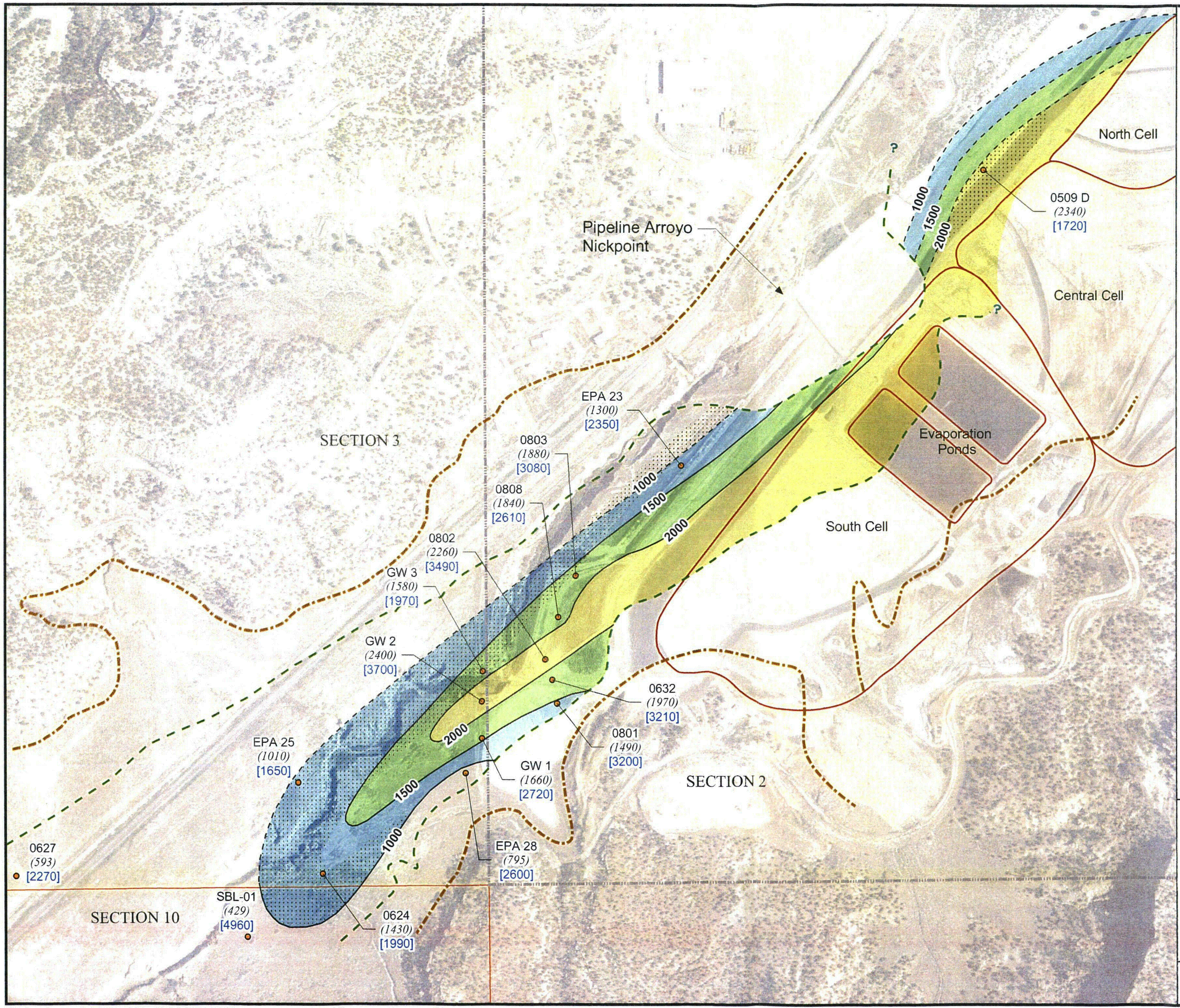
N.A. Water Systems

Z:\databases\6209_GE_CR\GISDATA\arcmap_doc\2007_annual_report\f06_seepage_extents.mxd; January 9, 2008

FIGURE 7

Southwest Alluvium Sulfate Concentrations Over Time
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico





N

Legend

● Southwest Alluvium Well

- - - Approximate Extent of Saturated Alluvium

-·-·- Approximate Extent of Alluvium

—— Bicarbonate Isoconcentration Contour in mg/L

- - - Inferred Bicarbonate Isoconcentration Contour in mg/L

Bicarbonate Concentrations (mg/L)

🟦 1000 - 1500

🟩 1500 - 2000

🟨 >2000

Property Boundary

—— Section Boundary

—— Tailings Pond

░ Sulfate Below 2125 mg/L

(2350) Bicarbonate result in mg/L

[3580] Sulfate result in mg/L

Notes:

1. Well names are displayed with black text.
2. Aerial photo taken on August 1, 1996.

0 250 500 1,000
Feet

FIGURE 8

Southwest Alluvium Bicarbonate Isoconcentration Map and Distribution of Sulfate Below 2125 mg/L, October 2007

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

N.A. Water Systems

Z:\databases\6209_GE_CR\GISDATA\arcmap_doc\2007_annual_report\f08_swa_sulfate.mxd; December 26, 2007

FIGURE 9

Primary Components of Total Dissolved Solids in the Southwest Alluvium, October 2007
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

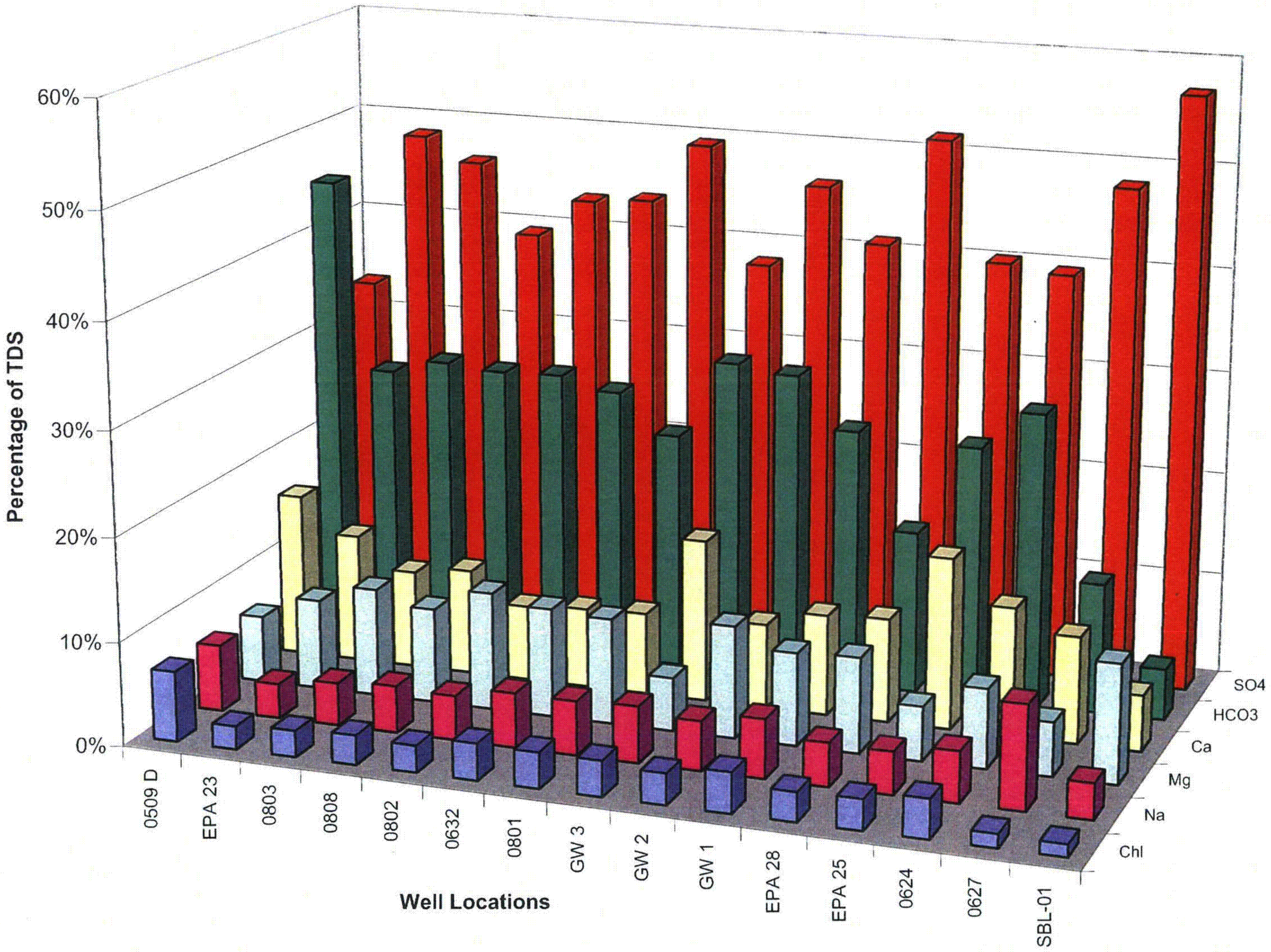


FIGURE 10

Southwest Alluvium Chloride Concentrations From 1999 Through October 2007
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

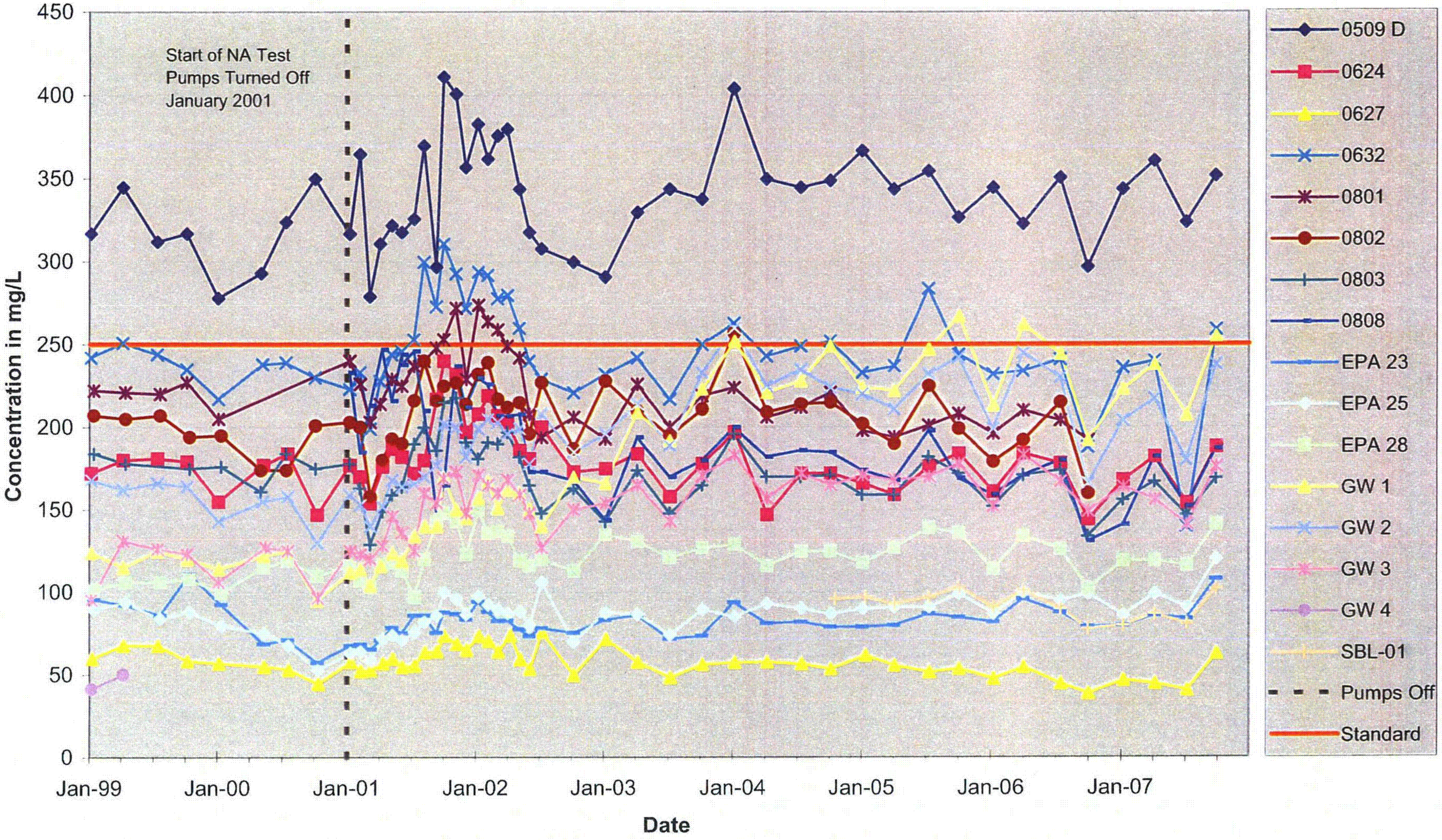


FIGURE 11

Southwest Alluvium Manganese Concentrations From 1999 Through October 2007
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

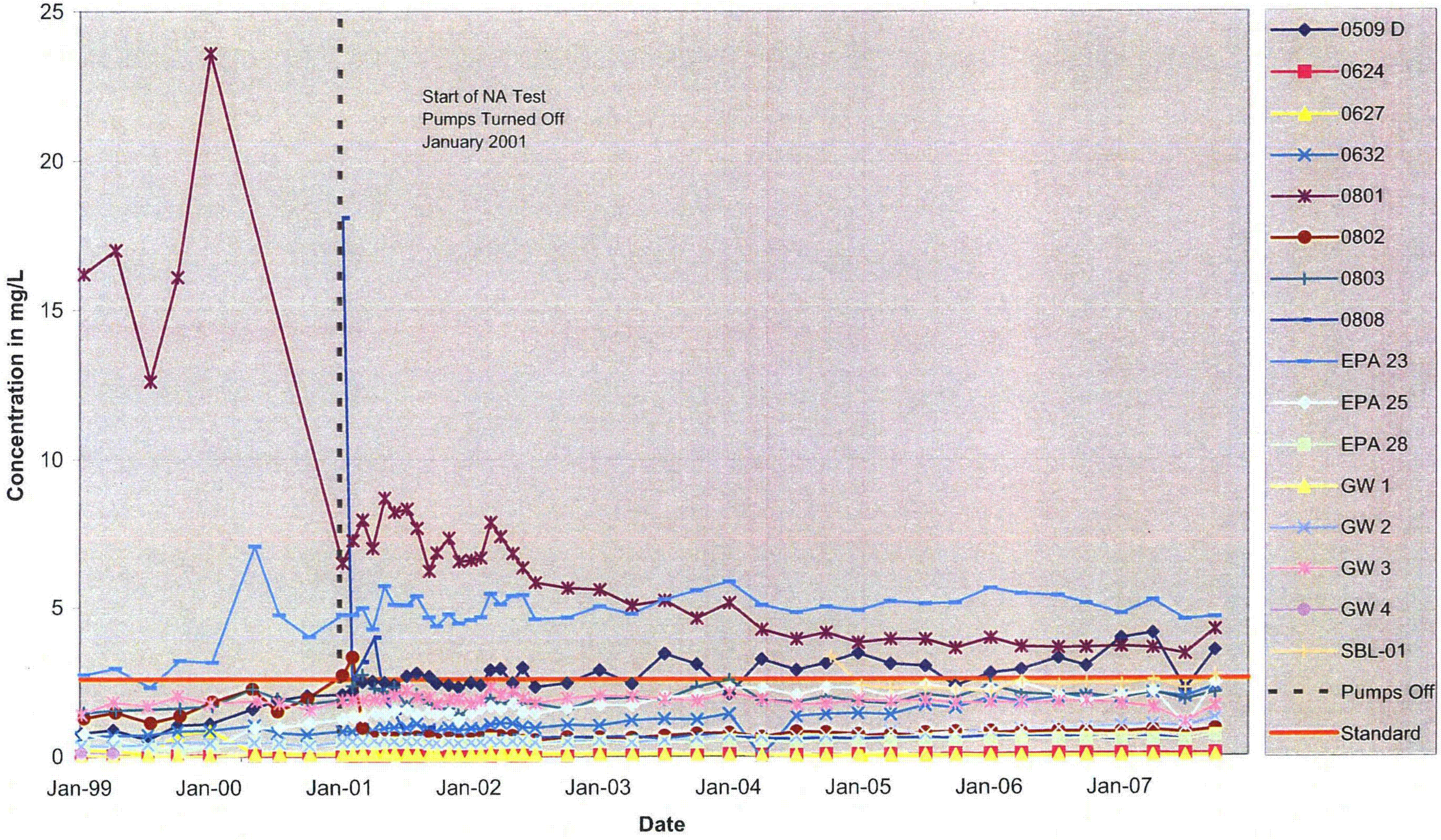


FIGURE 12

Southwest Alluvium Total Dissolved Solids Concentrations Over Time
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

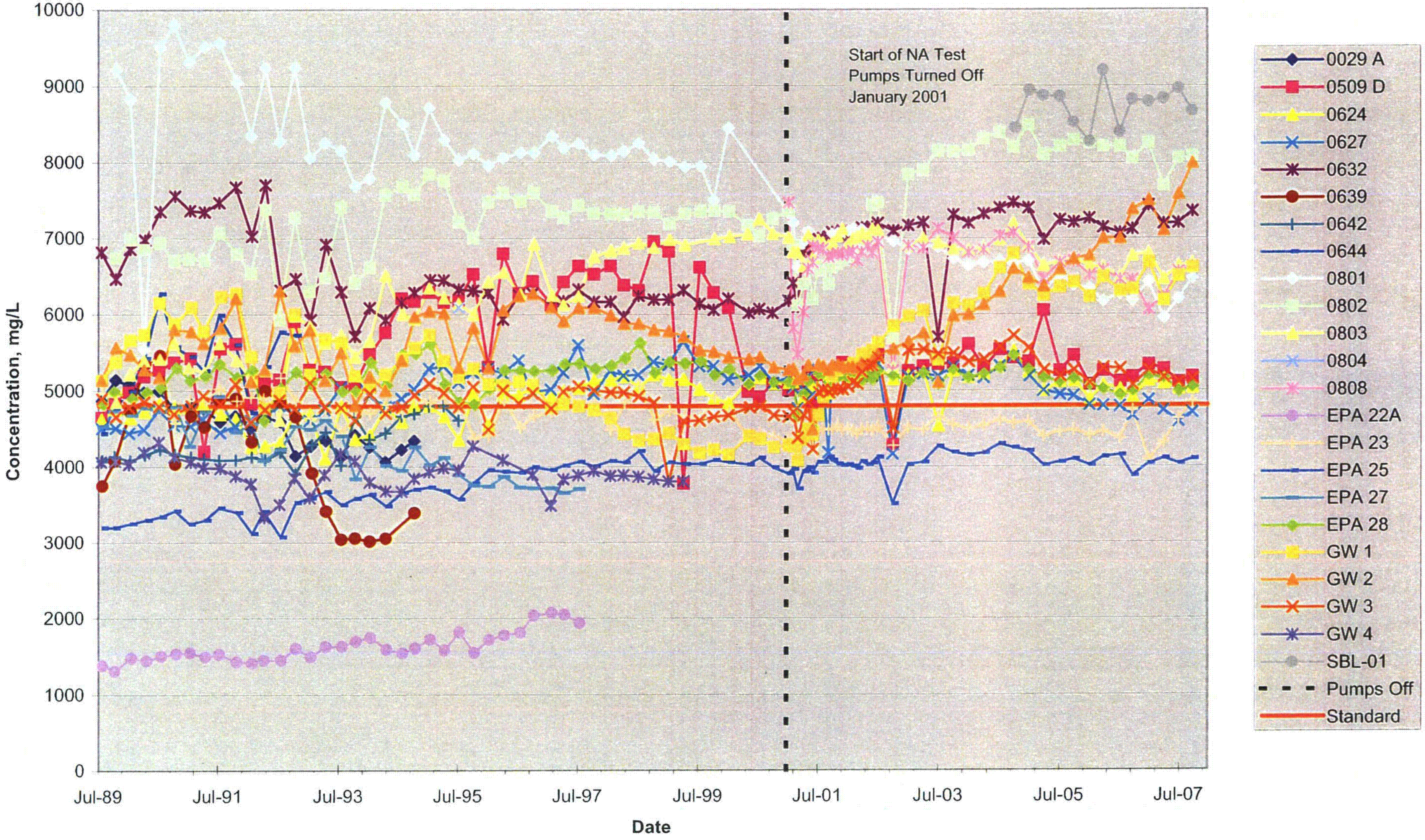


FIGURE 13

Calcium and Bicarbonate Concentrations in Selected Backgound and Seepage-Impacted Wells
United Nuclear Corporation Church Rock site, Church Rock, New Mexico

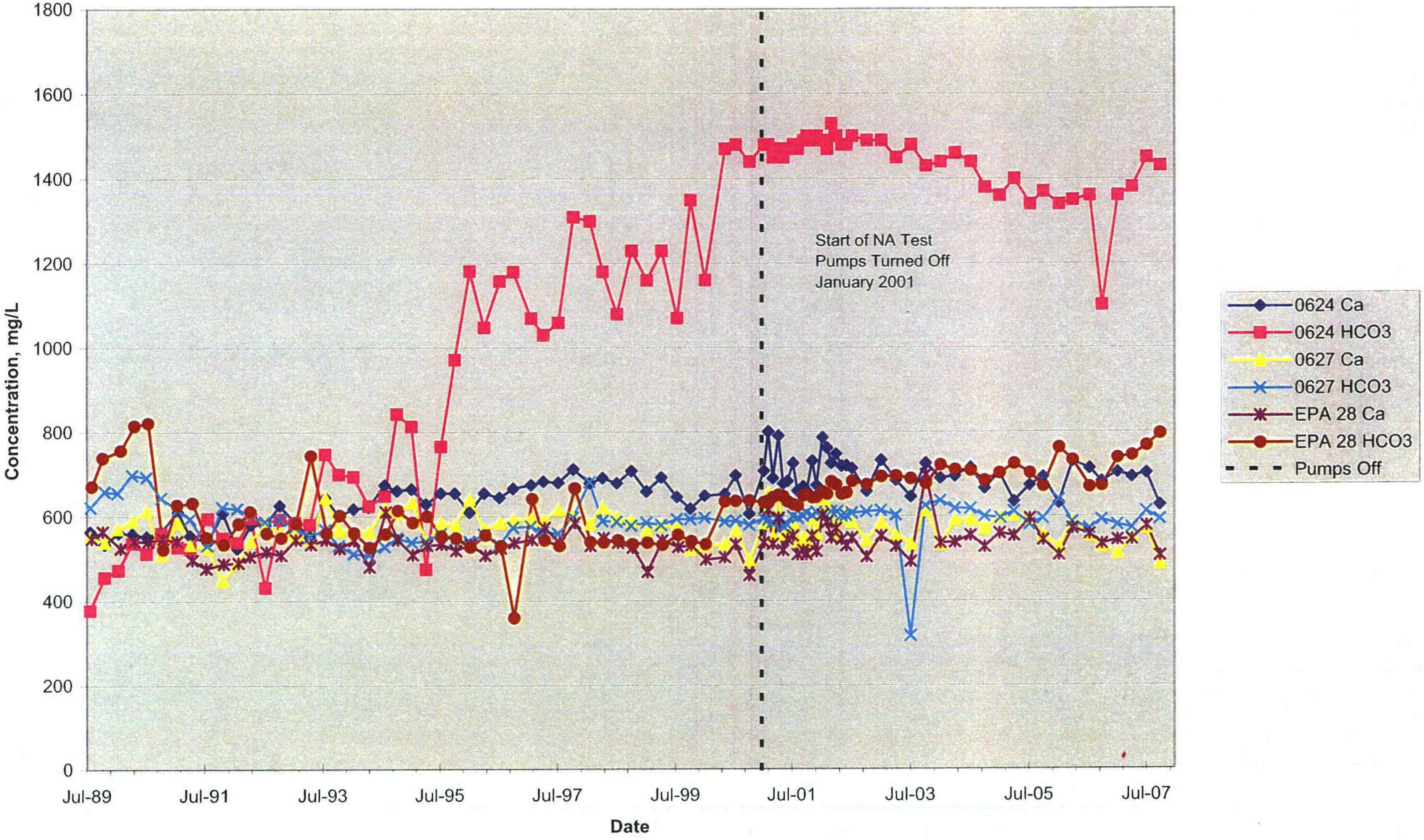


FIGURE 14

Southwest Alluvium Calcium Concentrations From 1999 Through October 2007
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

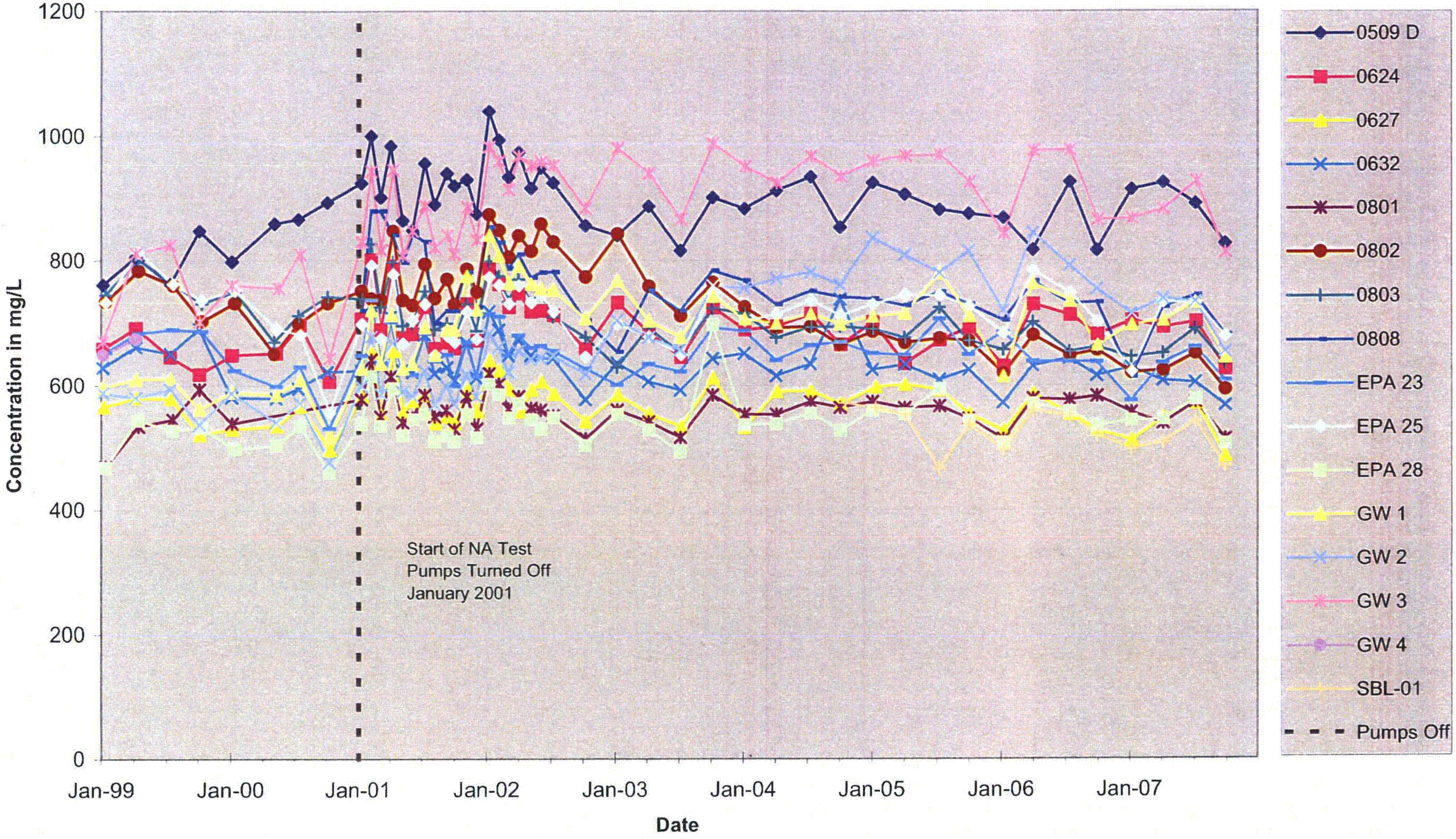


FIGURE 15

Southwest Alluvium Bicarbonate Concentrations From 1999 Through October 2007
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

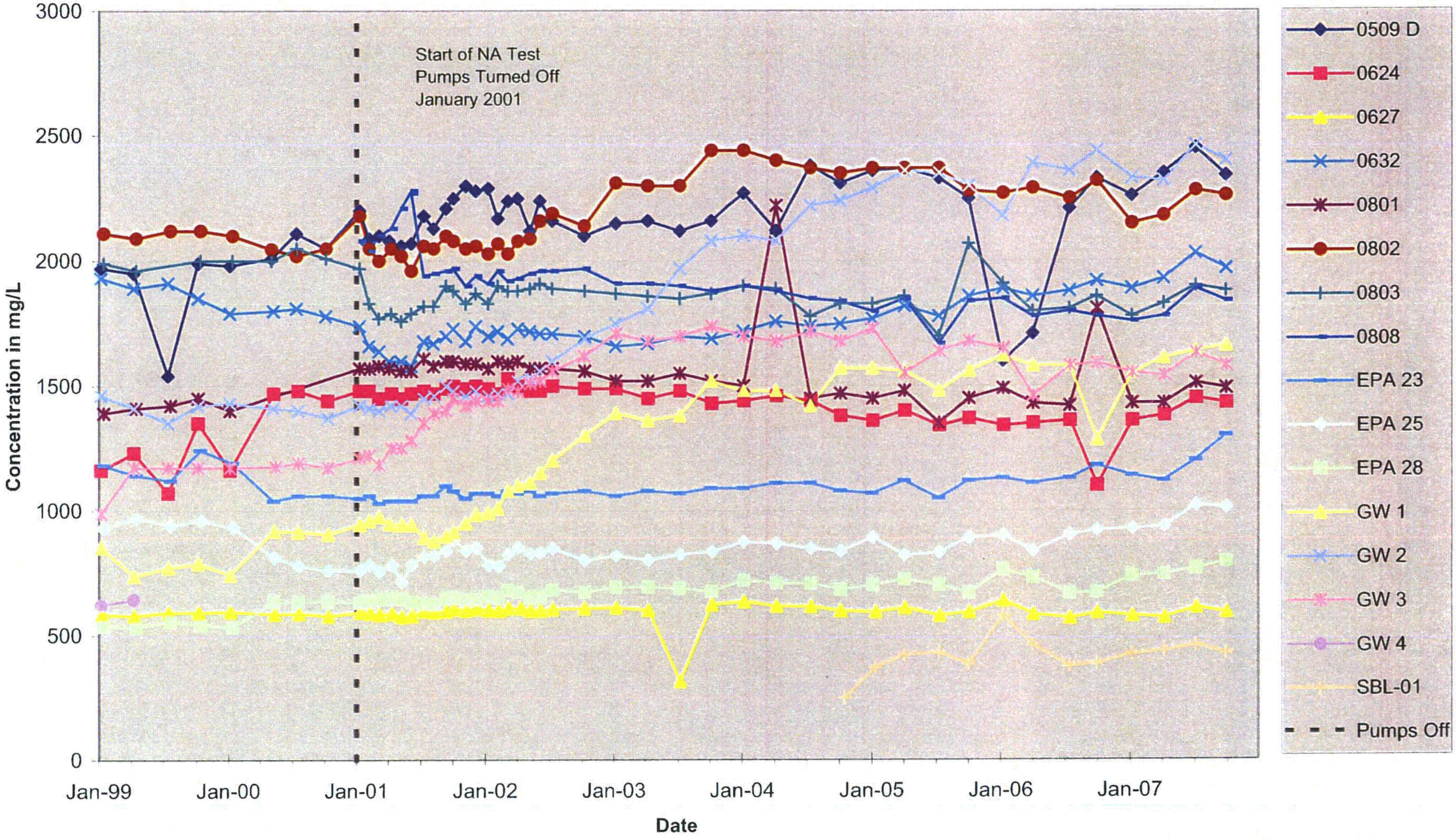


FIGURE 16

Southwest Alluvium Sulfate Concentrations From 1999 Through October 2007
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

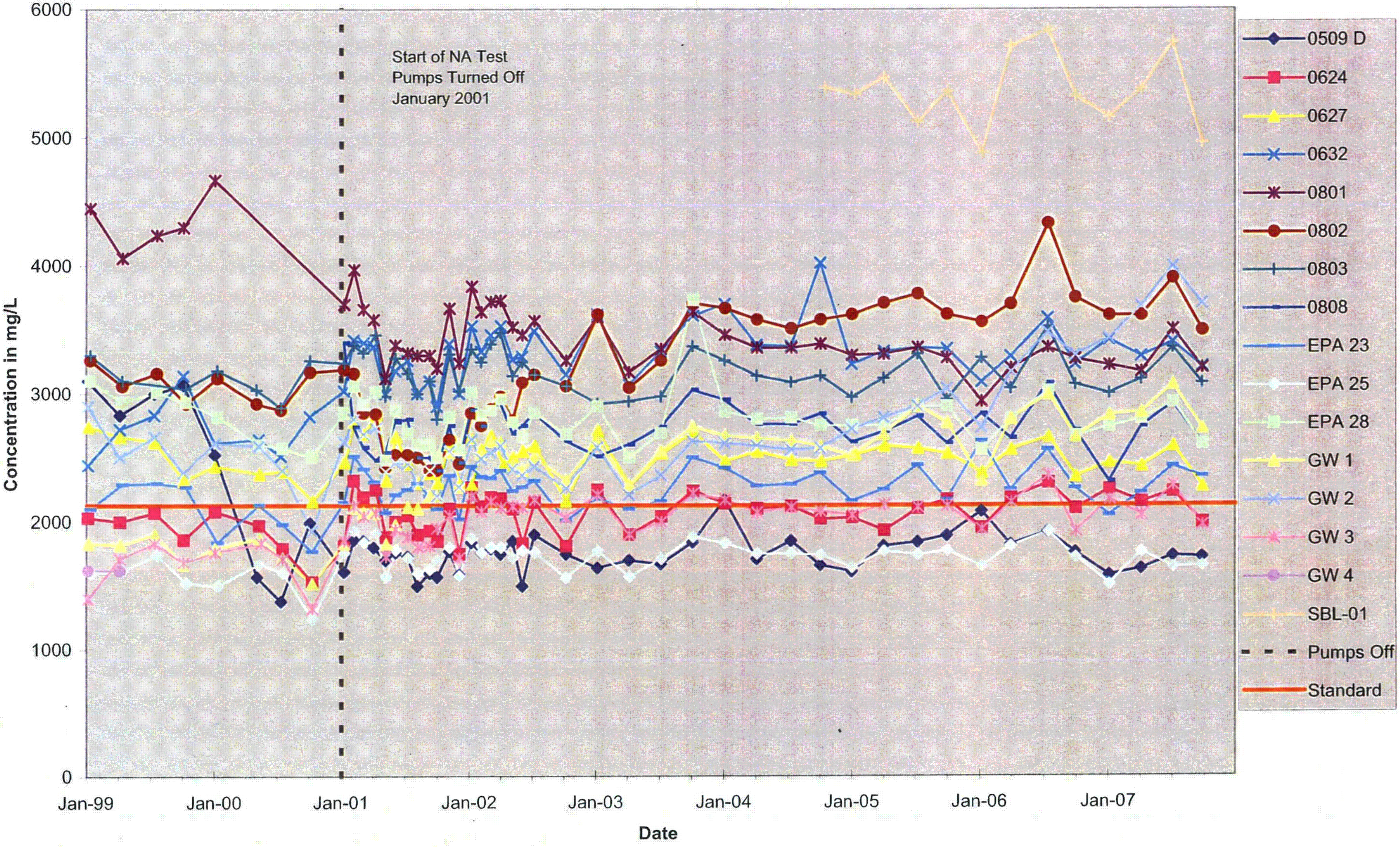


FIGURE 17

Southwest Alluvium Total Dissolved Solids Concentrations From 1999 Through October 2007
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

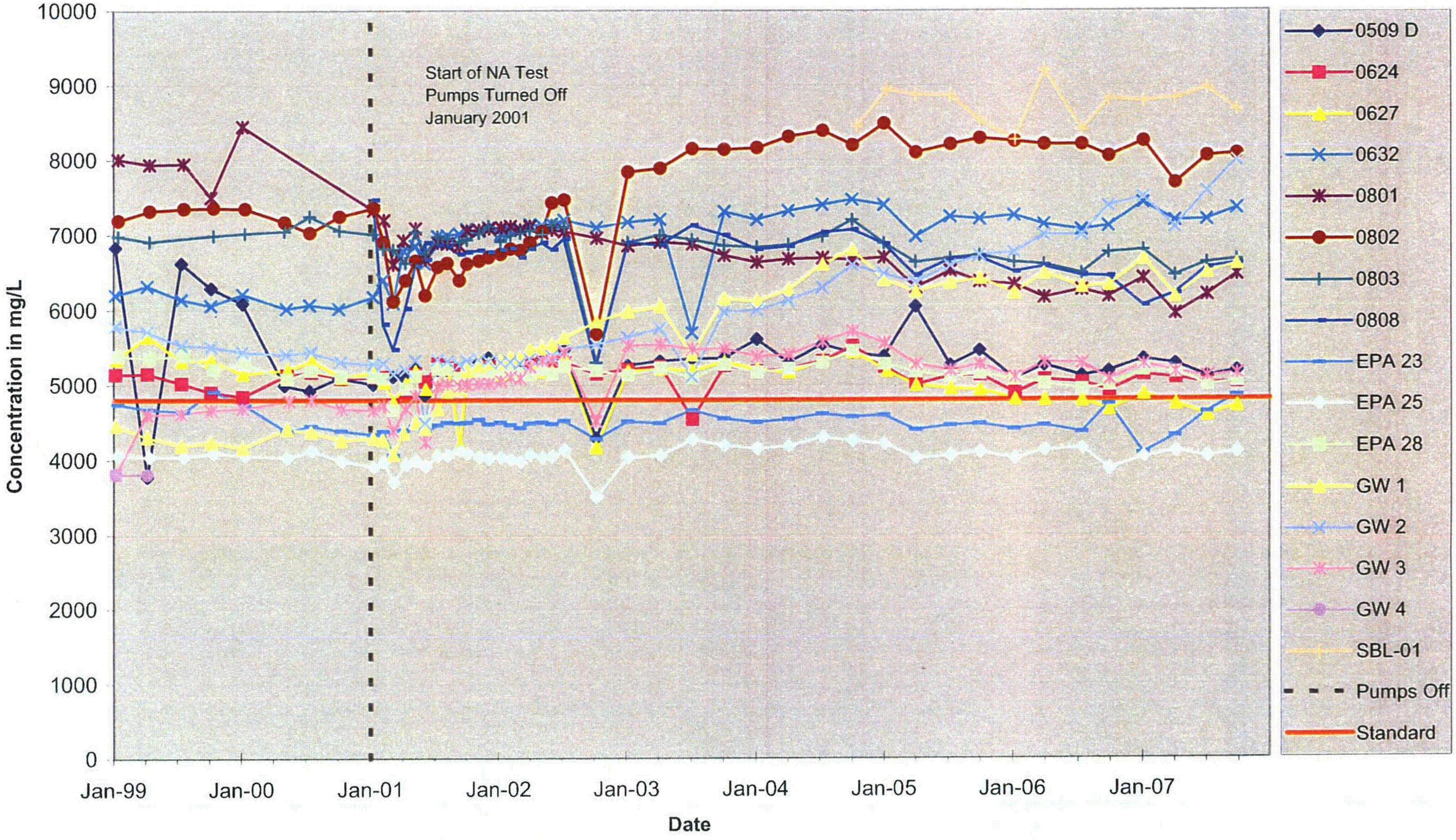


FIGURE 18

Uranium Concentrations in Selected Southwest Alluvium Wells
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

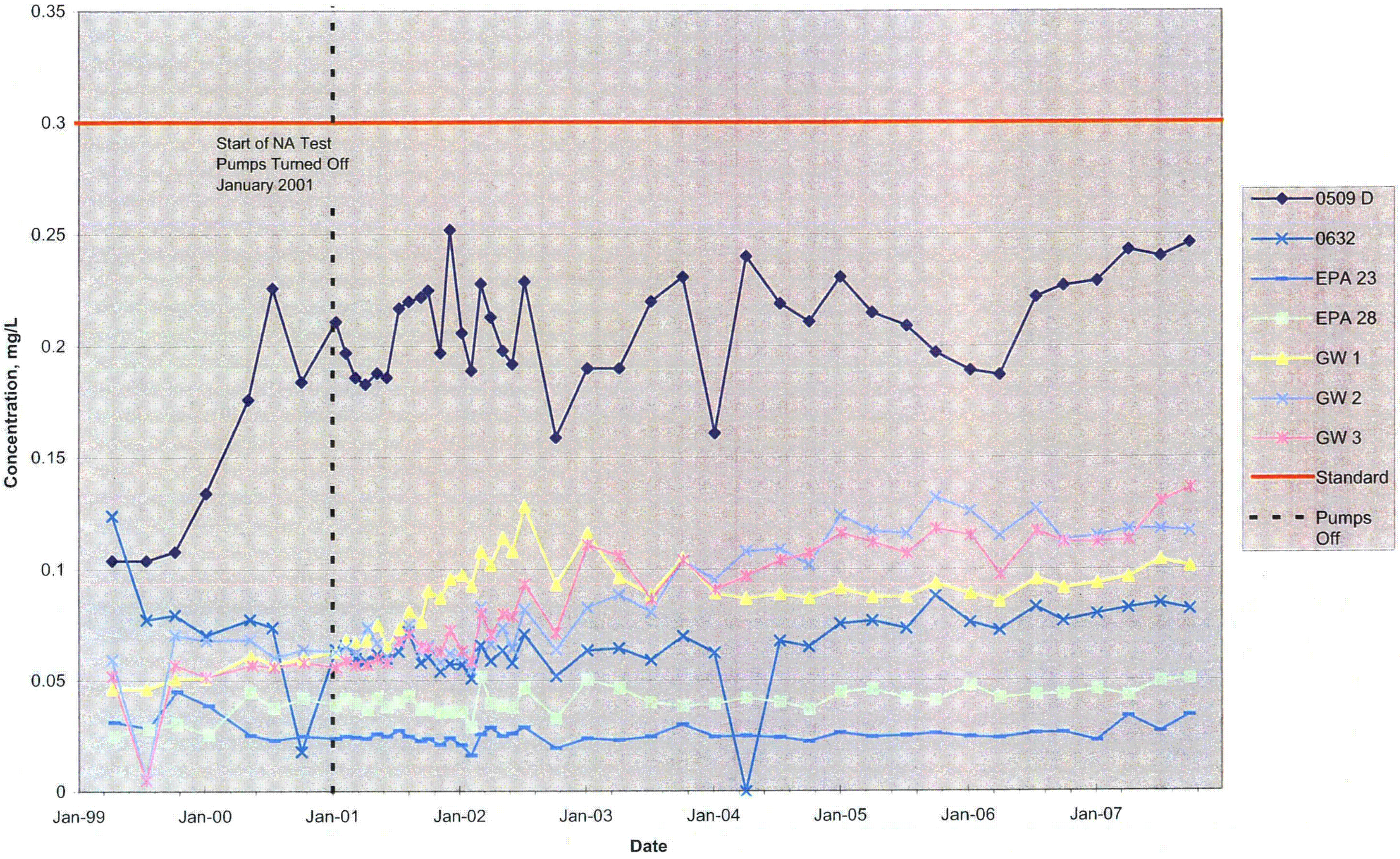


FIGURE 19

Uranium Concentrations in Selected Southwest Alluvium Wells
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

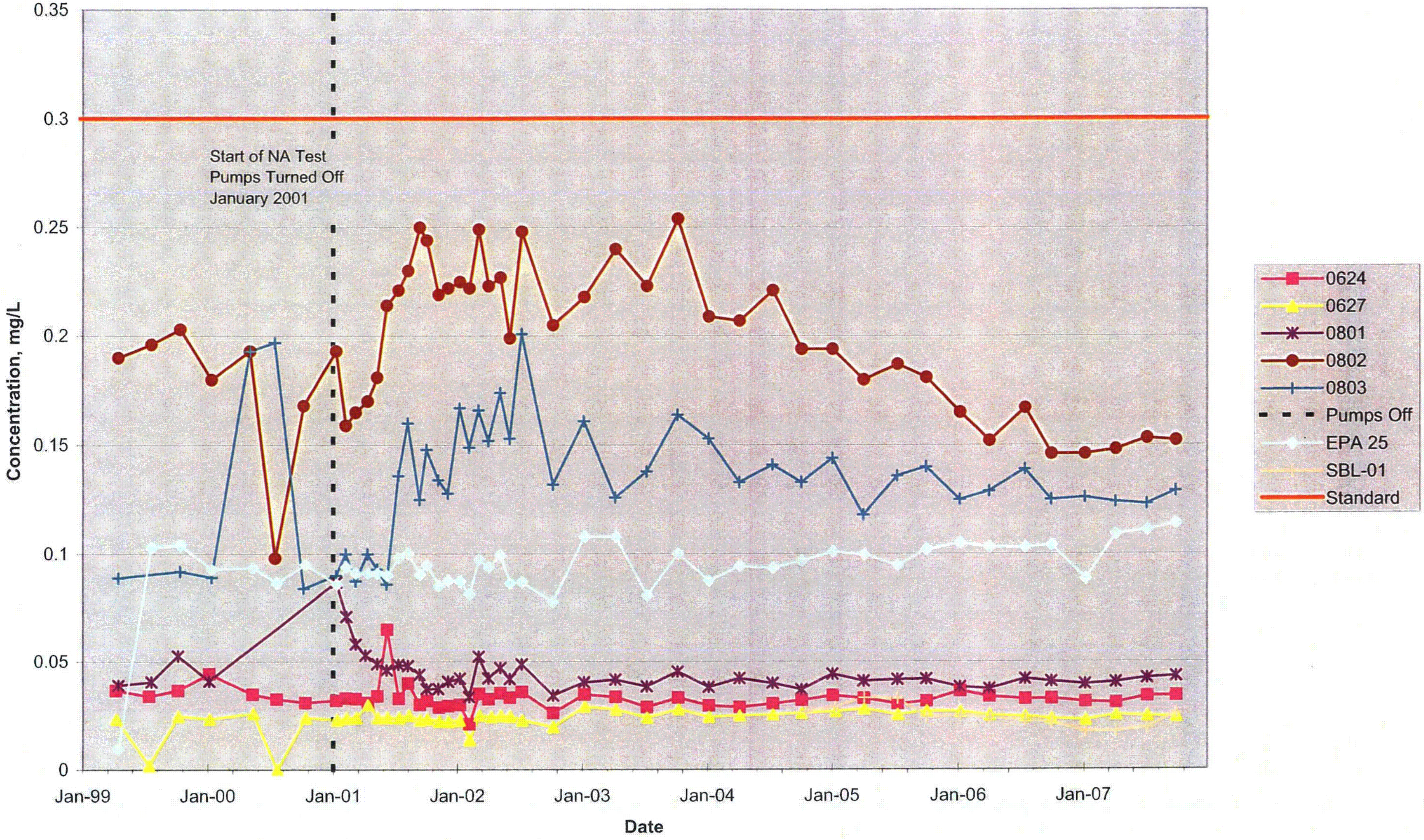
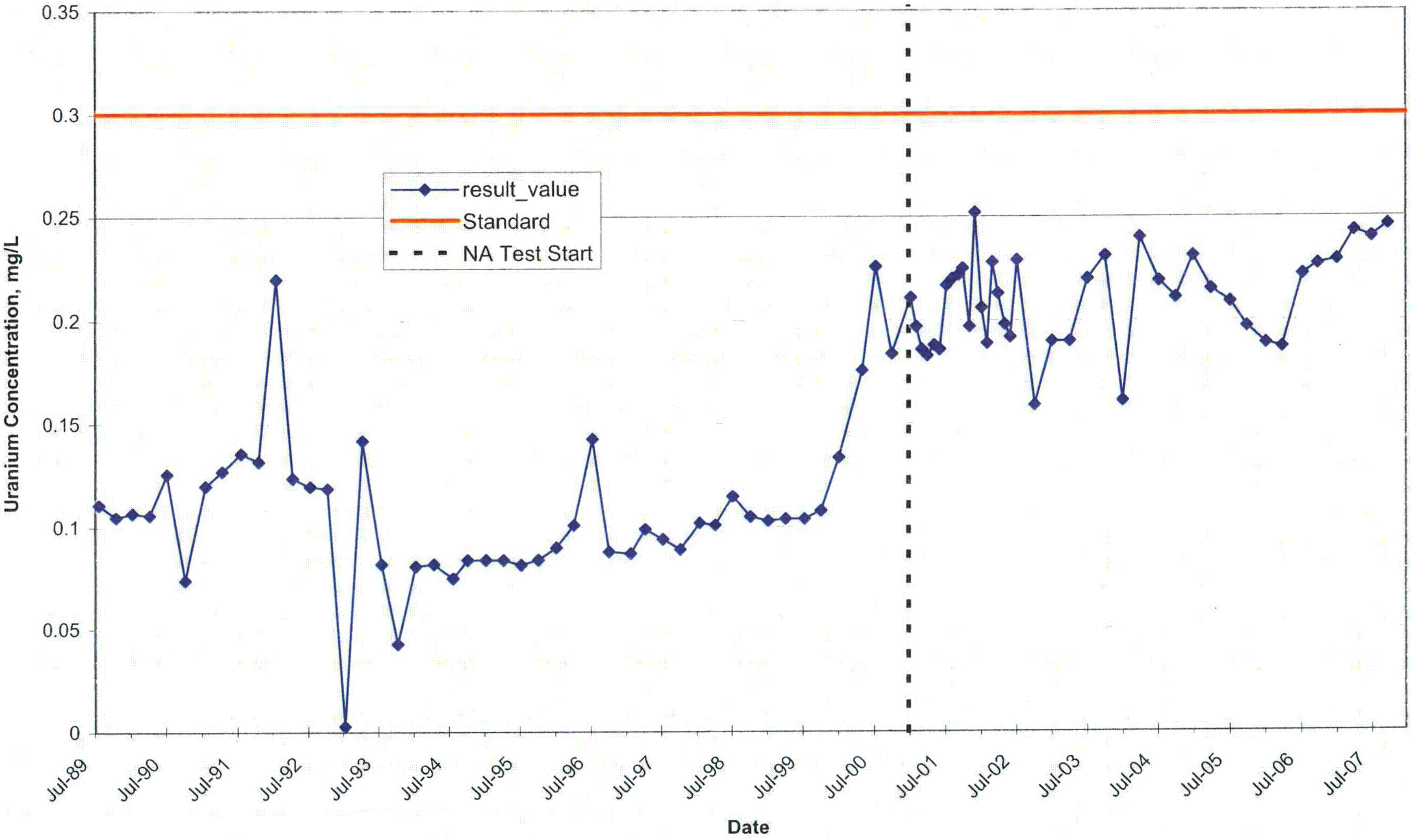


FIGURE 20

Uranium Concentration in Well 0509 D
United Nuclear Comporation Church Rock Site, Church Rock, New Mexico



Red line indicates uranium standard (0.3 mg/L).