



# Rio Algom

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April 11, 2003

*40-8905*

VIA OVERNIGHT MAIL  
ADRESSEE ONLY  
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**Subject: RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION FOR  
THE RIO ALGOM LLC'S APPLICATION FOR GROUND WATER  
ALTERNATE CONCENTRATION LIMITS DATED JANUARY 16,2003**

Dear Ms. Caverly:

Rio Algom Mining LLC is providing responses to the Request for Additional Information (RAI) dated January 16, 2003, and they are attached to this letter. The development of these responses required more time that expected as a result of supplemental modeling and research necessary to address the information requests.

Rio Algom greatly appreciative of the progress on the review of license amendment petitions for Alternate Concentration Limits. Rio Algom believes that these responses address all of the requests provided in the RAI, and if there is a need for additional detail, Rio Algom is prepared to respond promptly in order to expedite the completion of this review process.

If you have any questions, please call me at (405) 858-4807

Sincerely,

William Paul Goranson, P.E.  
Manager, Radiation Safety, Regulatory  
Compliance and Licensing

Enclosures

CC: Bruce Law, RAM  
Terry Fletcher, RAM  
Peter Luthiger, RAM  
Russell Jones, Kerr-McGee

*NMSSO1*

**Response to Request for Additional Information**

**Corrective Action Program and Alternate  
Concentration Limits Petition for  
Uppermost Bedrock Units  
Ambrosia Lake Uranium Mill Facility  
Near Grants, New Mexico**

**And**

**Application for Alternate Concentration Limits in  
the Alluvial Materials at the  
Quivira Mill Facility  
Ambrosia Lake, New Mexico**

**Prepared for  
Rio Algom Mining**

**Prepared by  
Maxim Technologies, Inc.**

**April 2003**

**Version 1.1**

## TABLE OF CONTENTS

COMMENT A.1 .....	1
RESPONSE TO COMMENT A.1 .....	1
COMMENT A.2 .....	2
RESPONSE TO COMMENT A.2 .....	2
COMMENT A.3 .....	3
RESPONSE TO COMMENT A.3 .....	3
COMMENT: A.4 .....	4
RESPONSE To Comment A.4 .....	4
COMMENT B.1 .....	4
COMMENT B.2 .....	6
RESPONSE TO COMMENTS B.1 and B.2 .....	6
Calibration to Chloride in the Dakota .....	6
Retardation Factors .....	7
Mobility of Uranium and Other Constituents .....	8
Uranium Source Concentration .....	11
Recent Trends At Well 36-06KD .....	11
COMMENT B.3 .....	12
RESPONSE TO COMMENT B.3 .....	12
COMMENT B.4 .....	13
RESPONSE TO COMMENT B.4 .....	13
COMMENT B.5 .....	14
RESPONSE TO COMMENT B.5 .....	14
COMMENT B.6 .....	16
RESPONSE TO COMMENT B.6 .....	16
COMMENT B.7 .....	16
RESPONSE TO COMMENT B.7 .....	16
COMMENT C.1 .....	17
RESPONSE TO Comment C.1 .....	17
Solubility of Radium .....	17
Radium Retardation .....	17
Source of Radium in Well 5-08 .....	17
Will Radium Exceed the ACL? .....	18
COMMENT C.2 .....	19
COMMENT C.3 .....	19
COMMENT C.4 .....	19
RESPONSE TO COMMENTS C.2, C.3, and C.4 .....	19
COMMENT C.5 .....	23
RESPONSE TO COMMENT C.5 .....	23
COMMENT C.6 .....	23
RESPONSE TO COMMENT C.6 .....	23
REFERENCES .....	24

## **LIST OF TABLES**

1. Dissolved vs. total study of radionuclide concentrations in ground water.
2. K<sub>d</sub> values (ml/g) summarized by Yu et al., (2001) showing the range of measured values taken from the literature and classified by aquifer matrix type. The geometric mean of the range is also shown
3. Results of additional well purging on Ra-226 concentrations in alluvial monitor well 5-08.
4. Modeled attenuation factor of 0.005 applied to background concentration of the constituents of concern and compared to health-based concentrations at the POE.
5. Proposed Alluvial ACLs.

## **LIST OF FIGURES**

1. Sensitivity analysis using the midrange of each parameter for initial model input and then varying each parameter across its range one parameter at a time.
2. Final optimized model for chloride transport in the Dakota.
3. Time Concentration Plots for Constituents of Concern in Monitor Well 36-06KD.
4. Eh-pH Diagrams for the Constituents of Concern in Groundwater from the Dakota Formation, Rio Algom Site, Ambrosia Lake, New Mexico. Diagrams from Brookins (1988).
5. Chloride Normalized Concentrations of Uranium and Nickel from Monitor Well 36-06KD.
6. Field-derived K<sub>d</sub> values for <sup>238</sup>U and <sup>235</sup>U from Serkiz and Johnson (1994) plotted as a function of porewater pH for contaminated soil/porewater samples. [Square and circle symbols represent field-derived K<sub>d</sub> values for <sup>238</sup>U and <sup>235</sup>U, respectively. Solid symbols represent minimum K<sub>d</sub> values for <sup>238</sup>U and <sup>235</sup>U that were based on minimum detection limit values for the concentrations for the respective uranium isotopes in porewaters associated with the soil sample.] (From EPA, 1999).
7. Effect of pH on K<sub>d</sub> for Nickel in core material from 28 sandy aquifers in Denmark (from EPA, 1998).
8. Final optimized model for uranium transport in the Dakota.
9. Simplified Geologic Map of the QMC Site Showing Location of Vent Holes and Subcrop of the Tres Hermanos B Sandstone Beneath the Alluvium.
10. Model for Uranium transport in the Tres Hermanos B.
11. Model for uranium transport in the Alluvium.
12. Groundwater Table Elevation Map, Ambrosia Lake Area, Near Grants, New Mexico.

## **RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION**

### **CORRECTIVE ACTION PROGRAM AND ALTERNATE CONCENTRATION LIMITS PETITION FOR UPPERMOST BEDROCK UNITS AMBROSIA LAKE URANIUM MILL FACILITY NEAR GRANTS, NEW MEXICO**

**AND**

### **APPLICATION FOR ALTERNATE CONCENTRATION LIMITS IN THE ALLUVIAL MATERIALS AT THE QUIVIRA MILL FACILITY AMBROSIA LAKE, NEW MEXICO**

#### **COMMENT A.1**

The exposure assessments of the ACL applications for the alluvial and uppermost bedrock units do not address the cumulative effects of human exposure to hazardous constituents for which ACLs are proposed.

**REQUIRED ACTION:** Provide additional analysis demonstrating that the cumulative effects of exposure to all hazardous constituents identified for an average individual at the POE will be maintained at a level adequate to protect public health.

#### **RESPONSE TO COMMENT A.1**

To address the potential for cumulative health risks from human exposure for the alluvial aquifer, health risk-based concentrations were recalculated for those constituents known or suspected to cause cancer to cumulatively approach the lifetime fatal cancer risk of  $1 \times 10^{-4}$  for groundwater consumption at a potential point of exposure (POE) location. The health risk-based concentrations, each of which individually achieves a lifetime cancer risk of  $1 \times 10^{-5}$  are presented below. The health-based concentrations for a hypothetical individual exposed to all the constituents in groundwater are as follows:

- Lead-210: 1.3 pCi/L
- Radium-226: 3.23 pCi/L
- Thorium-230: 13.9 pCi/L
- Natural uranium: 16.4 pCi/L
- Gross alpha: 8.57 pCi/L

Gross alpha was developed using the risk coefficient for polonium-210 as a toxicity surrogate as discussed in response to Comment A.2. If these constituents were present together at the proposed POE wells at these concentrations and ingested on a long-term

basis, the cumulative risk would not exceed  $1 \times 10^{-4}$ . However, that type of exposure is not now occurring or expected to occur. Table 2.4 in the ACL Application indicates that only Radium-226 is modeled to be present at the proposed POE wells at a measurable concentration. In summary, the hypothetical cumulative risk would not exceed  $1 \times 10^{-4}$  in the event exposure to these five constituents in groundwater at the health risk-based concentrations at the proposed POE wells occurred. To be health protective, and attain a cumulative risk less than  $10^{-4}$ , the constituents for which health-based concentrations have been developed should not be present at the proposed POE wells at concentrations greater than those presented above.

To address the potential for cumulative health risks from human exposure for the uppermost bedrock unit, health risk-based concentrations were recalculated for those constituents known or suspected to cause cancer to cumulatively approach the lifetime fatal cancer risk of  $1 \times 10^{-4}$  for groundwater consumption at a potential point of exposure (POE) location. The health risk-based concentrations, which individually achieve a lifetime cancer risk of  $1 \times 10^{-5}$  for a hypothetical individual exposed to all the constituents in groundwater were as follows:

- Lead-210: 1.3 pCi/L
- Radium-226: 3.2 pCi/L
- Thorium-230: 13.9 pCi/L
- Natural uranium: 16.4 pCi/L

#### **COMMENT A.2**

It is not clear that gross alpha contents of groundwaters can be accounted for predominantly by the considered individual radionuclides.

**REQUIRED ACTION:** Provide a technical basis for the assertion that gross alpha activities are accounted for by considering only those radionuclides for which compliance limits have been set, so that risk calculations involving only those radionuclides are sufficiently protective.

#### **RESPONSE TO COMMENT A.2**

Since no risk coefficient is available for gross alpha, a health risk-based limit for gross alpha has been calculated using the most recent risk coefficient for polonium-210 of  $4.05 \times 10^{-9} \text{ Bq}^{-1}$  (USEPA, 1999). Polonium-210 was chosen as a toxicity surrogate for gross alpha because the risk coefficient for polonium-210 is the most conservative risk coefficient other than that provided for lead-210. Assuming that the toxicity of gross alpha is equivalent to polonium-210 is a conservative approach that likely overestimates potential risks. The health risk-based limit for the alluvial aquifer for gross alpha that achieves a lifetime cancer risk of  $1 \times 10^{-4}$  is 85.7 pCi/L; the health risk-based limit for gross alpha that achieves a lifetime cancer risk of  $1 \times 10^{-5}$  is 8.57 pCi/L. The health risk-based concentration applicable at the proposed POE wells for gross alpha is 8.57 pCi/L.

### **COMMENT A.3**

It is not clear in all cases which water samples have been filtered.

**REQUIRED ACTION:** Provide specific information on whether groundwater samples were filtered prior to chemical and radiological analysis.

### **RESPONSE TO COMMENT A.3**

Radiochemical (U, Th-230, Ra-226, Ra-228, Pb-210, gross alpha) results for NRC CAP samples collected beginning in July 1999 are based on the dissolved fraction. Samples prior to that date were reported on a Total basis in any submittal to NRC.

Since the inception of the CAP in 1990, all groundwater results for radiological parameters have been reported as a TOTAL fraction. The sampling method (bailer) would disturb the water column in some of the wells so that the fines within the well would become suspended and be collected within the bailer. The bailer would continue collecting water until sufficient volume for the required parameters was collected from the well. This sample volume was then used to fill the individual bottles for the various parameters depending on preservation method. Although the non-radioactive metals (Se, Mo, etc.) were filtered, the radiological parameters were not. This resulted in the inclusion of suspended solids within the sample for radionuclides, which then was preserved (HNO<sub>3</sub> to pH < 2 s.u.) resulting in incorporating any residual material that was affixed to the sediment.

Some internal discussions were held regarding the analytical results as a result of initiating the ACL development process in early 1998. Specifically, the items of interest were:

- 1) inclusion of uranium and radon in the gross alpha result, and
- 2) reporting dissolved results versus total for radionuclides

At that time, a sampling program was initiated to obtain information on these data quality questions. To resolve Item 1, discussions with the laboratory resulted in the clarification of the gross alpha values that the lab reported. The gross alpha results were exactly that – gross alpha, with no adjustment to exclude uranium and radon as allowed within 10 CFR 40 Criterion 5. This resulted in Rio Algom adjusting of all reported gross alpha values to exclude uranium and radon beginning with the annual CAP report submitted in July 1998.

For Item 2, beginning in late 1998, total and dissolved water samples were sent to the laboratory to generate a database to support Rio Algom's contention that historical radionuclide concentrations were being reported as overly conservative concentrations due to the "total" analysis being performed. Data from this study, which involved several Dakota wells, confirmed that the water volume in wells, combined with the use of a sampling technique that resulted in the inclusion of sediment in the sample, resulted in the reporting of inappropriate results for ground water samples. Table 1 presents the total and dissolved data from the study.

As a result of this clear indication that sediments entrained in the 'total' water sample were influencing the actual ground water concentrations, beginning on July 1, 1999, all radionuclide water quality data reported to an agency has been reported on a dissolved basis, which is the appropriate mode for groundwater data.

As to the data included within Table 2-5 within the bedrock ACL submittal, this was most likely an oversight on Rio Algom's, Kerr-McGee's, and AVM's part. The 12/14/98 sample event was the first round of data collected from well 36-06 and was most likely used in the first draft of the report to support the argument that entrained sediments were influencing the results. Subsequent reviews of additional draft reports evidently did not catch this, so the data were never updated with more recent data prior to submittal in February 2000.

**COMMENT: A.4**

The risk coefficient used in both applications for Ra-226 is not consistent with the final federal guidance value.

**REQUIRED ACTION:** Recalculate health-based limits for Ra-226 using the current guidance in Federal Guidance Report 13 (EPA, 1999).

**RESPONSE TO COMMENT A.4**

The health risk-based limits for Radium-226 proposed for the uppermost bedrock units and the alluvial aquifer were recalculated using the most recent risk coefficient of  $7.17 \times 10^{-9} \text{ Bq}^{-1}$  (USEPA, 1999). The health risk-based limit for Ra-226 that achieves a lifetime cancer risk of  $1 \times 10^{-4}$  is 32.3 pCi/L for both the uppermost bedrock unit and the alluvial aquifer. The health risk-based concentration applicable at the proposed POE wells for Radium-226 is 32.3 pCi/L.

**COMMENT B.1**

Using the SOLUTE code (Beljin and van der Heijde, Version 2.00, 1993) transport model results to estimate attenuation factors between point of compliance (POC) and POE locations seems reasonable; however, the effect of parameter uncertainty on the calculated attenuation factor has not been evaluated.

**REQUIRED ACTION:** Rio Algom should provide an uncertainty analysis for the calculations used to estimate contaminant attenuation factors. Documentation of these analyses should include the range of attenuation factors that can be estimated from a set of transport calculations that can be reasonably calibrated to match observed chloride and U-nat concentrations, considering the uncertainty in groundwater velocity, dispersion lengths, uranium retardation factor, and source concentration variability. It should be shown, based on this uncertainty analysis that the attenuation factors used to calculate proposed health-based ACLs are reasonable and not overly optimistic. As part of this analysis, provide an explanation for the recent trends at well 36-06KD (i.e., rising chloride and U-nat, and descending pH).

well	Date	Pb-210		Ra-226		Ra-228		Th-230		U-nat		Gross Alpha		Lab
		D	T	D	T	D	T	D	T	D	T	D	T	
32-59	11/30/1998	1.2	5.5	0.9	1.4	0	3.9	0.4	1.3	0.25	0.26	139	233	Barringer
32-59	11/30/1998	-8.2	-1.9	0.65	1.78	1.4	3.6	0.13	3.4	0.25	0.262	134	172	ACZ
36-06	12/14/1998	0.42	8.5	16	13.55	14.7	15.3	0	400	0.509	0.426	194	1065	ACZ
36-06	5/10/1999	3.6	6.7	11	13	9.3	7.7	0.05	72			110	150	ACZ
31-66	5/24/1999	5.2	5.9	4.6	5.2	24	22	0.2	3.9	0.214	0.178	110	100	ACZ
31-66	5/24/1999	0	3.3	4.9	9.5	12	17	0.7	3.2	0.059	0.13	136	368	Barringer
36-06	5/26/1999	0.7	4.2	2.9	10.1	5.7	4.2	0.03	23.7	0.12	0.13	97	100	Barringer
36-06	5/26/1999	0.83	3.6	9.8	13	8.5	9.4	0.15	28	0.128	0.142	98	130	ACZ
30-48kd	6/22/1999	8.1	24	3	3.5	5.4	2.7	0.12	0.32	0.221	0.185		220	ACZ
30-48kd	6/22/1999	0	3	3.2	3.2	4.5	3.5	0.2	1.5	0.2	0.2	156	140	Barringer
36-06	7/26/1999	0.7	2.8	12.6	10.3	5.4	7.4	10.8	63.1	0.22	0.35	220	236	Barringer
36-06	7/26/1999	1.6		14		7.2		3		0.213		170		ACZ
31-66	7/26/1999	0.4	1.7	5.3	4.2	12	15	0.2	3	0.12	0.23	190	7	Barringer
31-66	7/26/1999	1.8		3.6		14		0.3		0.212		180		ACZ
30-48kd	7/27/1999	1.8	1.1	2.8	3.7	4.9	2.9	0	0.2	0.11	0.13	28	62	Barringer
30-48kd	7/27/1999	8.3		2.2		4.8		0.2		0.103		98		ACZ

U-nat in mg/l. All other constituents reported in pCi/l. D = dissolved. T = total

## **COMMENT B.2**

A basis is required for the assertion that applying the uranium attenuation factor to all other contaminants is conservative because uranium is the most mobile of the group.

**REQUIRED ACTION:** Provide the technical basis for the assertion that “U-nat is the most mobile of the hazardous constituents of concern” (bedrock aquifer application, p. 2-34).

## **RESPONSE TO COMMENTS B.1 AND B.2**

Key parameters in the Solute model of contaminant transport include the following parameters: source concentration and duration, the average groundwater velocity, longitudinal dispersivity, and retardation factor. This modeling approach first calibrates parameters to a chemical constituent that is not subject to chemical reactions and sorption/desorption interactions with the aquifer matrix, and acts as a tracer of groundwater flow. Chloride was chosen as a tracer of groundwater flow for this study. A retardation factor of 1 (no retardation) is commonly assumed for chloride in most systems allowing calibration to a system with a reduced number of variables. Uncertainty analysis was performed for the remaining variables (i.e., source concentration and duration, the average groundwater velocity, and longitudinal dispersivity), to insure that optimal values from the most reasonable ranges of values were chosen for predictive models of the constituents of concern.

### **Calibration to Chloride in the Dakota**

The NRC noted in its discussion of Comment B.1 that some parameters previously used in this modeling effort were outside the bounds of values that have been commonly reported in the literature. We concur with this assessment, and propose the following ranges of values for each important model parameter. These ranges are supported by the scientific literature and our experience with other similar hydrogeologic systems and uranium mill tailings site:

- **Source Concentration (chloride)** – 4,000 to 8,000 mg/L. Analysis of process solutions and tailings pore liquids report chloride concentrations of 1,540 mg/L and 2,300 mg/L, respectively (Table 2.2 of the Alluvial ACL Application). However, we note that a primary purpose of evaporation ponds is to reduce water volume while retaining solids. Therefore, we can assume that evaporation increased chloride concentrations in pond solutions. The highest concentration ever observed in groundwater directly downgradient of the tailings impoundments is 5,800 mg/L (Table 2.2 of the Alluvial ACL Application). We arbitrarily assign upper and lower limits of model chloride concentrations of approximately 2,000 mg/L above and below that highest observed concentration.
- **Source Duration** – 18 to 24 years. Ponds 7 and 8 were constructed in 1961 and taken out of service by 1983, a period of 22 years. The period that the ponds were a source of constituents to groundwater may have been decreased by the period of time that it took for seepage from the pond to reach groundwater or increased by the time that the vadose zone remained a source of contaminants after ponds were decommissioned.

- Average Groundwater Velocity – 50 to 220 feet per year. The groundwater velocity is a function of the hydraulic conductivity of the aquifer, the porosity of aquifer material and the pressure gradient on the system. Stone et al. (1983) report a range of hydraulic conductivity values between 0.7 and 1.5 feet per day for fluvial sandstones within the Dakota Formation. Based on a range of hydraulic conductivity values between 0.7 and 1.5 feet per day, a porosity range from 0.2 to 0.35 (sand and gravel, mixed [Fetter, 1988]), and a measured gradient of 0.037 feet per foot (Bedrock ACL Application), we calculate a range of groundwater velocities between 50 and 220 feet per year.
- Longitudinal Dispersivity – 30 to 1,000 feet. Values were taken from literature values as summarized by Gelhar et al. (1992) and recommended by NRC reviewers.

The sensitivity analysis consisted of choosing the midrange of each parameter for initial model input and then varying each parameter across its range one parameter at a time. Other parameters were held constant at the midrange during each model run. Figure 1 presents the results of the sensitivity analysis for each parameter along with concentration targets for POC well 36-06KD and POE well 36-04KD. Calibration targets were developed from the range of concentrations observed in those wells during the 1992 to 1994 time period (years 31-33 from the start of the model). Results show that the best fit for all parameters is closer to the middle of each range, rather than at any extreme. Model results are relatively insensitive to variations in some parameters (specifically source duration and dispersivity above 500 feet) while calibration targets can only be matched in a narrow range for others (specifically groundwater velocity and source concentration). Therefore, statistical goodness of fit analyses were not considered necessary. The final optimized model for chloride transport (Figure 2) used the following values:

- Source Concentration                      5,800 mg/L
- Source Duration                              22 years
- Average Groundwater velocity        125 feet per year
- Longitudinal Dispersivity                500 feet

### **Retardation Factors**

Retardation factors are, by nature, less well constrained than many other parameters. The SOLUTE Model describes constituent transport by the processes of advection and dispersion. Reversible sorption processes are simulated by modifying advective and dispersive processes with a retardation factor that reduces the highest concentration seen at any location and slows the velocity of the solute pulse. No attempt is made to model non-reversible processes that are known to occur in many geochemical environments or changes to geochemical conditions that occur along a flowpath. Using reversible sorption to simulate attenuation mechanisms is only adequate in idealized situations but modelers currently have few practical alternatives (Zeng and Bennett, 1995). We approach this problem with an arsenal consisting of direct site observations, standard geochemical reasoning, and judicious use of appropriate literature values.

The best record we have of the behavior of constituents of concern is in POC well 36-06KD. This well is approximately 800 feet downgradient of the source. Other wells are more than 4,500 feet from the source, and concentrations of constituents of concern are not detectable in groundwater at these locations. Figure 3a presents the time series trend of chloride concentrations in 36-06KD. Note that the record begins in 1989, when the well was installed, with a chloride concentration of 1,840 mg/L and falls off steeply to some point in 1993 or 1994 where it appears to level out at around 900 mg/L. This trend can be interpreted to illustrate the decline in concentrations from some peak before 1989 and the migration of that solute pulse past the well. The distinctive concentration rise in the most recent data will be discussed later.

### **Mobility of Uranium and Other Constituents**

Constituent trends are evident in data reported for Monitor Well 36-06KD. The chloride trend in Monitor Well 36-06KD is markedly similar to trends exhibited by concentrations of uranium and nickel in the same well (Figures 3b and 3c). Radium-226 and radium-228 exhibit similar trends (Figures 3d and 3e), though less smooth and with more noise. Concentrations of Thorium-230 start high and then drop to mainly non-detect (Figure 3f), without the concentration rise in recent data seen in other trends. Lead-210 exhibits no apparent trend (Figure 3g). pH rises from a low near 3 to a high near 6 before it begins to drop again in 1997 or 1998 (Figure 3h).

These data from Monitor Well 36-06KD suggest several transport conditions as summarized below:

- The similarity in periodicity of chloride, uranium, nickel, and radium suggest that in these low pH waters, these constituents traveled at a similar velocity.
- Radium trends are not as well defined as chloride, uranium and nickel trends, suggesting that radium transport may not be as continuous or as fast as chloride, uranium, and nickel.
- The transport velocity of thorium and lead is likely slower than the other constituents.

Eh-pH diagrams from Brookins (1988) (Figure 4) provide a framework for understanding data trends in monitor well 36-06KD. Note that all constituents of concern are in solutions as cationic species at the low pH's expected in acid leach tailings solutions. At low pH values, negative sorbent surfaces in the aquifer matrix are saturated with positive charge from  $H^+$  in solution. Under these conditions, cations are not adsorbed and travel with chloride at roughly the same velocity as groundwater flow. As the solution becomes more neutral, cations, with less competition from  $H^+$  ions, are increasingly adsorbed. Therefore, concentrations of constituents of concern decrease as the pH rises. However, note that radium, thorium and lead tend to precipitate as solid phases as the pH rises (Figure 4c, 4d, and 4e). Radium and thorium are soluble only below a pH of about 3 and lead is soluble only below a pH of less than 1. Concentration-limiting solids change the transport characteristics of radium, thorium, and lead in groundwater, irreversibly removing some concentration of these constituents from solution.

In contrast, uranium and nickel have no concentration-limiting solid forming as the pH rises. As a consequence, these constituents can be expected to be more mobile than

radium, thorium, and lead. Uranium is present as uranyl ion ( $\text{UO}_2^{2+}$ ) at low pH. Various uranyl carbonate complexes become the predominant uranium species in groundwater as the pH rises. The uranyl carbonate species are neutral or anionic, completely changing the transport characteristics of uranium in groundwater from those observed for uranyl ion. Nickel ion ( $\text{Ni}^{2+}$ ) is the dominant nickel species in solution below a pH of 9 (Rai and Zachara, 1984). As a result, nickel becomes increasingly adsorbed as the pH rises, which may cause the transport of nickel to be retarded relative to uranium, particularly in carbonate rich water.

Because no constituents of concern are observed in Dakota monitor wells downgradient of 36-06KD, it is difficult to assign a realistic retardation factor to any of them. One way to approach this problem is to examine concentrations of uranium and nickel (the two constituents expected to be most mobile) relative to concentrations of chloride in monitor well 36-06KD. Following the reasoning presented above, we would expect that uranium and nickel would travel at the same velocity as chloride in the lowest pH groundwater, but as pH increases, the movement of uranium and nickel would be retarded relative to chloride. Noting the similar timing of the decreasing concentrations of chloride, uranium, and nickel in data from Figure 3, we normalize the uranium and nickel data to the chloride data in Figure 5 (normalization is accomplished by multiplying the uranium or nickel datasets by whatever factor necessary to make the earliest constituent concentration equal the earliest chloride concentration). This allows preservation of the shape of uranium and nickel curves while making a direct comparison of the retardation of uranium and nickel relative to chloride.

Figure 5 shows that the movement of both uranium and nickel are retarded relative to chloride. Second-degree regression lines are shown for all three data trends, and high correlation coefficients for these regressions indicate that the trends are not the products of random variation. Based on a visual estimate, the region of all trends that is the most flat is the 1994 to 1998 time period. The average of the chloride data for this period is 854 mg/L. Averages of chloride-normalized uranium and nickel data for this same period are 152 and 92 mg/L, respectively. Dividing the average chloride concentration by the average chloride normalized uranium and nickel concentration gives a *minimum* retardation factor for these constituents relative to chloride of 6 and 9, respectively.

These are minimum retardation factors because they reflect transport in the near source, acidic region of the aquifer. More reasonable estimates of retardation factors can be made from recent research and compilations by the EPA and DOE (EPA, 1999 and Yu, et al., 2001). Figure 6 presents results of a study by Serkiz and Johnson (1994) reported in EPA (1999) that plots field-derived adsorption coefficients or  $K_d$ 's for uranium as a function of pH. Note that the  $K_d$ 's increase in a linear trend from a pH of near three to a pH of near 4 where the  $K_d$ 's range from 100 to more than 10,000 ml/g and trends are no longer apparent. The increase in  $K_d$ 's seen in low pH waters is consistent with observations of uranium retardation in monitor well 36-06KD. Note that the  $K_d$  value is related to the retardation factor by the following equation:

$$R = 1 + \frac{n_b}{\zeta} * K_d \quad (1)$$

Where R is the retardation factor,  $\tilde{n}_b$  is the bulk density of the aquifer matrix, and  $\zeta$  is the effective porosity of the aquifer matrix.

Bulk density of sandstone ranges from 1.34 to 2.32 g/cm<sup>3</sup> (Beljin and van der Heijde, 1998). We have estimated the effective porosity for sand and gravel mixed to be between 0.2 and 0.35 (see Calibration of Chloride in the Dakota). Using the smallest possible  $\tilde{n}_b/\zeta$  term, and a minimum value of 100 ml/g as the uranium Kd above pH 5 from Figure 6), in Equation 1, we can calculate the minimum retardation factor for the more neutral areas of the Dakota aquifer to be 384.

Figure 7 from EPA (1998) shows the effect of variation in pH from 28 sandy aquifers in Denmark on the nickel retardation factor. Retardation increases linearly with pH from near 100 at a pH of 5 to more than 10,000 at a pH of 8. Comparison of this trend with the uranium Kd trends depicted in Figure 6 helps to explain the possible retardation of nickel relative to uranium that has been observed at some uranium mill tailings sites.

A study and literature summary (Yu et al., 2001) designed to provide estimates of Kd values for input into the transport model RESRAD produced the data presented in Table 2. The Kd ranges and geometric means for nickel, radium, and thorium are considerably higher than those provided for uranium, indicating that across this collection of literature values, uranium is consistently more mobile than the other three constituents. These data are consistent with observations from the Rio Algom site suggesting that the movement of radium, thorium and lead has been retarded relative to uranium and nickel. The minimum Kd value for nickel reported in Table 2 is 60 ml/g, which would result in a minimum retardation factor for nickel of 231. This value is an order of magnitude higher than the conservative retardation value of 10 used to set proposed ACLs for the bedrock aquifer.

<b>Table 2. Kd values (ml/g) summarized by Yu et al., (2001) showing the range of measured values taken from the literature and classified by aquifer matrix type. The geometric mean of the range is also shown.</b>		
	<b>Geometric Mean</b>	<b>Range</b>
<b>Uranium</b>		
Sand	35	0.03 to 2,200
Loam	15	0.2 to 4,500
Clay	600	46 to 395,100
Organic	410	33 to 7,350
<b>Nickel</b>		
Sand	400	60 to 3,600
Loam	300	NA
Clay	650	305 to 2,467
Organic	100	360 to 4,700
<b>Radium</b>		
Sand	500	57 to 21,000
Loam	36,000	1,262 to 530,000
Clay	9,100	696 to 56,000
Organic	2,400	NA
<b>Thorium</b>		
Sand	3,200	207 to 150,000
Loam	300	NA
Clay	5,800	244 to 160,000
Organic	89,000	1,579 to 13,000,000

A uranium retardation calculation using the geometric mean for sand from Table 2 results in a retardation factor of 135. This retardation factor and the retardation factors calculated in the above paragraphs are an order of magnitude above the retardation factor of 10 used in bedrock ACL Application modeling, confirming that the calculated attenuation factor of 0.16 is a conservative estimate.

### **Uranium Source Concentration**

The NRC correctly points out that the source concentration used in the uranium transport model to calculate the 0.16 attenuation factor ignores early data that indicates that uranium concentrations have been as high as 8 mg/L. That circumstance occurred when the pH was below 4 (Figure 3h). While the pH has again dropped below 4 in the most recent data (for reasons that will be discussed below), the uranium concentration has not been reported above 1 mg/L. We interpret this as follows: early, very acid water (pH 1 to 3) could transport high concentrations of uranium, but higher pH water (pH 3 to 5) can transport lower concentrations (0.01. to 1 mg/L).

The transport behavior of uranium in the first 800 feet from the source to the POC well is very different than the behavior of uranium in the remaining 3,900 feet between the POC and the POE well. In order to develop a realistic estimate of attenuation it is necessary to make an estimate of the uranium concentration that could persist past the near source zone of low pH. A conservative approach to this problem uses the highest uranium concentration observed in more recent data at monitor well 36-06KD (1 mg/L), and adds a safety factor equal to twice the observed concentration, resulting in a model input of 3 mg/L. This input is modeled along the 3,900 foot flow path from POC monitor well 36-06KD to POE monitor well 36-04KD (Figure 8). This model results in an attenuation factor of approximately 0.07, which is less than one half of the attenuation factor used to set bedrock ACLs. Therefore, the attenuation factors used to calculate currently proposed bedrock ACLs are considered conservative, appropriate, and not overly optimistic.

### **Recent Trends At Well 36-06KD**

It is common to see increases of constituents in groundwater during or following surface remediation at tailings sites. This is due to a number of factors, including exposure of previously protected and/or stabilized contamination to leaching, disturbance of flow paths, and differential loading of sediments as heavy equipment move back and forth across the site and new clean fill is placed. During the years 1991 through 1994 more than 160,000 cubic yards of contaminated material was removed from the area of ponds 7 and 8, and placed in the disposal cell, thus removing the bulk of the source of constituents to groundwater. A pulse of lower pH, higher chloride, higher uranium water reached monitor well 36-06KD approximately three years later (Figure 3 [note for example that the chloride trend begins to increase a some point after December 1997]). Chloride and uranium concentrations increased to a maximum and then began to decline. Approximately 108,000 cubic yards of clean soil were placed in the area of ponds 7 and 8 during the period from 1998 to 2002. Beginning in 2000, a corresponding rise in uranium and chloride concentrations was observed in monitor well 36-06KD. Extrapolating the slopes of the increases in chloride and uranium seen in 2000 to 2004 or 2005 when, based on travel time of the pulse following contaminant removal,

concentrations should begin to decline, we can expect maximum concentrations of 1,300 mg/L chloride and 2 mg/L uranium. These predicted concentrations may be conservative estimates because the bulk of the contamination source was removed during remedial activities during the 1991 to 1994 period. Note that these estimated concentrations would have no effect on concentrations predicted by modeling to occur at downgradient wells and the predictions confirm that the choice of 3 mg/L for the uranium concentration used to establish attenuation factors is conservative.

### **COMMENT B.3**

A basis is required for the statement that ACLs based on well 36-06KD will also be protective when applied at other POC wells.

**REQUIRED ACTION:** Provide justification for the assumption that the proposed ACLs will be as protective at POC wells 30-02KD and 30-48KD as they are at POC well 36-06KD. Alternatively, modify the ACLs appropriately.

### **RESPONSE TO COMMENT B.3**

*“Alternate concentration limits are established on a site-specific basis, provided it can be demonstrated that (i) the constituents will not pose a substantial present or potential hazard to human health or the environment, as long as the alternate concentration limits are not exceeded and (ii) the alternate concentration limits are as low as is reasonably achievable, considering practicable corrective actions.” (NRC 2002, NUREG-1620)*

The Bedrock ACL application has established that existing concentrations of constituents in the Bedrock Units are as low as reasonably achievable (ALARA). The worst-case concentrations that occur at POC well 36-06KD are ALARA. POC well 36-06KD is the closest POC well to the source of constituents of concern (ponds 7 and 8) and the well where the highest levels of constituents of concern can be expected to occur. Modeling has shown that proposed ACLs at POC well 36-06KD will be protective of human health and the environment by the time constituents of concern arrive at the POE. In this case, the dual purpose of establishing ACLs for POC well 36-06KD is to ensure that concentrations at the POE do not exceed those that are protective of human health and the environment and, at the same time, ensure that inevitable fluctuation in constituent concentrations do not trigger unwarranted corrective actions. POC wells 30-02KD and 30-48KD are more than 5,500 feet farther from the source than POC well 36-06KD and therefore concentrations of constituents of concern in these wells will be attenuated relative to concentrations in POC 36-06KD. Modeling shows that concentrations of constituents of concern will be protective at POE well 36-04KD, which is 3,900 feet downgradient of POC well 36-06KD. Therefore, it is reasonable to infer that concentrations of constituents of concern will be protective at well locations that are an additional 1,600 feet downgradient of the source.

*“The point of compliance is the location at which the ground water is monitored to determine compliance with the ground-water protection standards. The objective in selecting the point of compliance is to provide*

*the earliest practicable warning that the impoundment is releasing hazardous constituents to the ground water. The point of compliance must be selected to provide prompt indication of ground-water contamination on the hydraulically downgradient edge of the disposal area. The point of compliance is defined as the intersection of a vertical plane with the uppermost aquifer at the hydraulically downgradient limit of the waste management area.” (NRC 2002, NUREG-1620).*

Based on the above guidance, POC well 36-06KD is in the best location to serve as a compliance well. The guidance implies that one POC well should be selected and one set of ACLs proposed for each hydrologic unit. Wells 30-02KD and 30-48KD are not in a location to provide prompt indications of ground-water contamination and, thus, may not be appropriate POC wells. Modeling demonstrates that it is likely to be well over 100 years before concentrations of constituents of concern arrive at these two wells, if they arrive at all.

#### **COMMENT B.4**

Much of the groundwater currently in the alluvial formation is expected to drain into the Tres Hermanos A (TRA) and Tres Hermanos B (TRB) bedrock units, but the application contains no discussion or analysis of fate and transport of contaminated alluvial-system drainage in the bedrock formations.

**REQUIRED ACTION:** Rio Algom should provide fate and transport assessments for constituents of concern entering the uppermost bedrock units as drainage from the overlying alluvial formations.

#### **RESPONSE TO COMMENT B.4**

Groundwater flow modeling for the Alluvium indicates that 58,000 cubic feet per day of seepage moves from the alluvial materials to bedrock units. Figure 2.19 of the Alluvial ACL Application shows the distribution of drain cells used in modeling. The largest pattern of drain cells, in the center of the figure, represents the subcrop of the Tres Hermanos B Sandstone in the vicinity of the alluvium. Drain cells representing the subcrop of the Tres Hermanos C Sandstone are located directly south of the DOE site, and do not drain any water impacted by the Rio Algom site. The Tres Hermanos A Sandstone does not act as a major drain for alluvial materials and only subcrops the area of ponds 7 and 8 and, to an extent, in the far downgradient area near monitor well 5-02 where concentrations of constituents of concern are low (see figures 1.2 and 1.3 from the Alluvial ACL Application). Therefore, only drainage from the alluvial material to the Tres Hermanos B is of concern to the Rio Algom ACL applications.

Note that flow in the Arroyo del Puerto bypass and intercept trench acts as a hydrologic barrier to seepage to the Alluvium from the Rio Algom site. Due to the hydrologic barrier, seepage from the Rio Algom site can only enter the Tres Hermanos B west of the bypass. Note also that infiltration of water from the bypass (treated mine water) likely provides the overwhelming bulk of seepage to the Tres Hermanos B in this area (flux estimates are provided in Section 2.2.3.4 of the Alluvial ACL Application) causing any seepage from Rio Algom tailings impoundments to be diluted.

A simplified geologic map of the Rio Algom site showing the subcrop of the Tres Hermanos B is presented in Figure 9. Also shown are vent holes from the Westwater Canyon Formation to the surface. The transport of constituents from the Rio Algom site to the Tres Hermanos B will be along the following pathway: Constituents may originate at either the tailings impoundment or an unlined evaporation pond, infiltrate the Alluvium, move from the Alluvium to the Tres Hermanos B west of the Arroyo del Puerto bypass, move down dip in the Tres Hermanos B to the north and northeast (Bedrock ACL Application) where they will ultimately be contained by the hydrologic depression created by over 40 years of mine pumping in the valley.

Alluvial monitor well 31-63 (Figure 1.2 of the Alluvial ACL Application) currently has the highest concentrations of site-related constituents of all the alluvial wells, making this well a good and conservative choice to estimate concentrations of constituents seeping into the Tres Hermanos B. Using all uranium concentration data for well 31-63 (1984 through 2002) gives an average uranium concentration of 1.9 mg/L (these data contain some values that are suspected order of magnitude errors, i.e., 16-May-98, 2.57 mg/L should probably be 0.257 mg/L and 15-Apr-02, 4.05 mg/L should probably be 0.405 mg/L). The distance from this well to the nearest vent hole to the northeast is approximately 3,800 feet. A SOLUTE transport model using a uranium concentration of 1.9 mg/L, and similar assumptions to those used for the Dakota Formation (Figure 10), shows that peak uranium concentrations at the vent hole within the withdrawal area are near 0.2 mg/L, giving an attenuation factor of approximately 0.12.

The actual pathway that flow takes from one point to another in the Tres Hermanos B is variable, but it is generally down dip to the northeast and toward vent holes to the north and northeast. This information, combined with the above semi-quantitative analyses of transport and attenuation, makes it possible to conclude that seepage in the Tres Hermanos B will not pose a threat to human health and the environment. This conclusion is confirmed by concentrations of constituents reported in TRB monitor well 31-67 located approximately 600 feet northeast of alluvial well 31-63, and along the expected flow path. The highest uranium concentration measured during the period of record (1988-2002) in monitor well 31-67 is 0.024 mg/L. More quantitative models of fate and transport would be problematic due to poor control in the Tres Hermanos B and the complex interaction of sources (tailings seepage from multiple sites, seepage from unlined ponds, surface leaching from mine waste and ore piles, and seepage from mine dewatering).

#### **COMMENT B.5**

Some aspects of the results of the filtration test are ambiguous.

**REQUIRED ACTION:** For the 36-06KD filtration tests, explain the deviations from the expected case that filtered concentrations would be lower than unfiltered concentrations.

#### **RESPONSE TO COMMENT B.5**

From a field perspective, uncertainties that result in deviations from what is expected can arise from factors such as the following:

1. **Sampling technique.** Rio Algom uses a bailer to collect water from wells. This results in the agitation of the water within the well, which suspends the fines in the well water. This agitation may cause some of the adsorbed/precipitated material on sediment to dissolve, thereby influencing or increasing constituent concentrations.
2. **Collection of water for sample.** Due to bailer size, numerous trips down the well are required to acquire sufficient sample volume. This water, which is disturbed as explained in Item 1 above, is placed into a bucket from which the individual sample bottles are prepared. Depending on total sample volume needed and bucket size (2 gallon bucket) additional bails from the well may be needed once room is available in the bucket. This would only occur when split samples are collected as the bucket holds sufficient volume for routine sample collection needs.
3. **Sample preparation sequence.** When total versus dissolved sample bottles are prepared, the timing of the preservation process may influence concentrations. Typically, the bottles requiring 'total' analysis are prepared first due to the ease in preparation (i.e., pour water into bottle). The 'filtered' samples require filtering through a 0.45 micron filter prior to acid addition. Depending on the suspended solid load in the water, this can be time consuming. Some wells have required over an hour to filter the desired volume of water. This time delay can influence the concentrations through changes in water temperature, which will occur over that time interval as the bucket from where the water is being pumped from typically is placed on the floor of the passenger side of the truck due to the cord length of the sample pump. Temperature changes would be expected at any time of year that sampling is performed and would probably be more pronounced in the winter months as the sample is placed into a warm vehicle to perform the filtering. In the case of the well data in question, the sample was collected from well 36-06KD in December and the water within that well is usually reported to be cloudy. Discussions with the technician who prepared the sample stated that the 'total' bottles were filled first followed by the filtered sample bottles. Therefore, the deviation is attributed to the sample preparation sequence which caused a temperature change in the sample and potentially sampling technique.

Uncertainties from the lab are expected to be the standard quality assurance concerns associated with sample receipt, preparation, analysis, and calculation of results. Laboratory uncertainties can include the following:

1. **Sample mix-up.** Not likely, but possible.
2. **Sample preparation/digestion.**
3. **Technician work practices.**
4. **Dilution factors.**
5. **Analysis methods.**
6. **Analysis times, especially for radiological samples.**
7. **Calculation of results.**

Discussion with the laboratory did not identify any clear indication of a laboratory concern.

**COMMENT B.6**

Provide additional support for the conclusion that the rising concentrations of U-nat in TRB compliance well 31-66 will not result in exceedence of the proposed ACL.

**REQUIRED ACTION:** Provide a technical basis for the attribution of elevated uranium in well 31-66 to a brine pit source, and provide a basis for the conclusion that uranium in this well will not exceed the proposed ACL in the future.

**RESPONSE TO COMMENT B.6**

Following the logic presented in the Bedrock ACL Application for derivation of the TRB ACL for nickel, we propose to modify the TRB ACL for Uranium as follows.

Given an attenuation factor for uranium in well 31-66 of 0.16 (Bedrock ACL) or lower:

$$\begin{aligned} \text{Protective Conc. (mg/L)} &= \text{Health Risk Based Conc. (mg/L)/ Attenuation factor} \\ &= (0.25 \text{ mg/L})/ 0.16 \end{aligned}$$

$$\text{TRB ACL for Uranium} = 1.56 \text{ mg/L Uranium}$$

**COMMENT B.7**

Data on source concentrations relevant to the nickel attenuation model for the TRB are required.

**REQUIRED ACTION:** Provide the data supporting tailings liquid contaminant concentrations, such as are cited for nickel in the bedrock aquifer application and such as are tabulated in the alluvial aquifer application.

**RESPONSE TO COMMENT B.7**

Discussion of tailing fluid quality is provided in Section 2.1 of the bedrock ACL, pp. 2-1 through 2-5 and in Section 2.1.4 of the alluvial ACL. The tables within the bedrock ACL provide water quality data for tailings solutions. The source of the data presented in Table 2-1 was derived from Rio Algom's original 1991 ACL application (Table 4 in that submittal). This information was obtained from past license renewal applications (prior to NRC resumption of jurisdiction in 1986) by Kerr McGee to NMED from a table describing the process waste stream characteristics of the mill. The table in the old renewals contains a footnote that the values are based on 72-hour composites collected January 16-19, 1980. This actual data could not be located.

The data presented in Table 2-2 are from an NRC sampling event conducted at Rio Algom's facility in 1987 as part of development of the site monitoring program. This is where the source nickel concentration of 1.0 mg/L for nickel comes from.

Table 2.2 in the alluvial ACL simply used the values that were in Table 2-1 and 2-2 of the bedrock ACL.

The 1987 data was provided to the Center during their site visit in November 2002. The specific sample is labeled as "870406-036 Quivira Q-2. Copies were also sent to the NRC Project Manager.

## **COMMENT C.1**

Elevated Ra-226 in well 5-08 is not consistent with models of flow in the alluvial aquifer.

**REQUIRED ACTION:** Provide the technical basis for attribution of elevated Ra-226 at well 5-08 to a local source that is not related to the licensee's activities. Provide an explanation for increasing Ra-226 at the well, as well as justification that levels will not exceed the health-based limit of 44 pCi/L in the future.

## **RESPONSE TO COMMENT C.1**

We concur with reviewers that elevated Ra-226 concentration in alluvial monitor well 5-08 is not consistent with transport from Rio Algom's tailings impoundment or mine dewatering sources. Groundwater in that well had a Ra-226 concentration of 12.3 pCi/L reported when the initial sample was collected in 1983. Concentrations of Ra-226 in monitor well 5-08 have consistently been among the highest concentrations reported at the site.

### **Solubility of Radium**

It is well known that radium is soluble at very low pH (Langmuir and Reese, 1985; Brookins, 1988) and becomes more insoluble as pH rises above 2 where we encounter the stability field of solid radium sulfate. Brookins (1988) goes so far as to state that "*Ra should be immobile in the natural environment due to the extreme insolubility of RaSO<sub>4</sub>*". We know from the Alluvial ACL Application that alluvial material is fine-grained and contains abundant clay, calcite and iron oxyhydroxides. The calcite insures that initial low pH at tailings sources will become more neutral as transport progresses. Clay and iron oxyhydroxides are strong adsorbants and will inhibit transport of radium (Langmuir, 1997).

### **Radium Retardation**

Yu et al., (2001) report Kds for radium ranging from 57 to 530,000 (see Table 2 of the current document). Using the minimum Kd of 57 and calculating a minimum retardation factor in the same way as was done in the response to comments B.1 and B.2, results in a retardation factor of 218. Assuming that the calibrated average groundwater velocity used in alluvial groundwater modeling is correct (0.5 ft/day or 182.5 ft/year), distance to the nearest Rio Algom source (pond 10) is approximately 4,000 feet, and a retardation factor of 218, it would take approximately 5,000 years for Rio Algom radium to show up in monitor well 5-08. When it did, you would expect to see a plume like distribution of radium in the alluvial materials, with higher concentrations between the source and well 5-08. Currently, there is no plume like the distribution of radium, and well 5-08 is one of only three wells on site that contain groundwater with radium concentrations above the current 5 pCi/L groundwater protection standard (Figure 2.12 of the Alluvial ACL Application). The other two wells are immediately adjacent to evaporation pond sources.

### **Source of Radium in Well 5-08**

If radium in groundwater from well 5-08 did not come from the Rio Algom tailings solutions, where did it come from? The Alluvial ACL identifies the following three sources of uranium ore related constituents: tailings seepage, mine pumping and discharge, and runoff and erosion from mine spoils and ore piles. Experience from many

UMTRA sites and numerous studies (Langmuir and Reese, 1985; Brookins, 1988) indicate that radium is not easily transported in water, making tailings seepage and mine discharge unlikely sources. We know that well 5-08 is installed adjacent to the Copin Mine haul road. Site personnel tell us that the fill material of the volume needed for a haul road to cross Arroyo del Puerto was often taken from mine spoils piles. This suggests that radium concentrations in groundwater from well 5-08 could be due to uranium-rich material from spoils used in the building of the haul road.

If this scenario were true, it is possible to postulate a mechanism for the presence of radium and the notable lack of uranium in groundwater at this location (uranium concentrations are historically less than 0.015 mg/L). The measured Eh in this water is low (45 millivolts, corrected to Eh from ORP), suggesting that several uranium minerals including uraninite would be stable, maintaining uranium at low concentrations. However, uranium daughter products would be unstable in whatever mineral lattice position was previously occupied by uranium. Unstable radium would have a tendency to diffuse out of the mineral and into groundwater. Once in groundwater, radium would have a tendency to be removed quickly (by all the arguments cited above), suggesting that monitor well 5-08 would have to be in close proximity to the uranium spoils if radium would be detected in water collected from that well.

This scenario is not supported by elevated scintillometer readings at the road surface, but studies associated with Alluvial ACL Application Appendix A (Background Report) show that some spoils material has very high readings (up to 2100  $\mu$ R/hr). Given the geochemical characteristics of radium in groundwater (Langmuir and Reese, 1985; Brookins, 1988; Yu et al., 2001) and the known use of uranium spoils for fill material, the local source scenario is a much more likely explanation for the elevated radium concentrations observed in well 5-08 than radium transport from Rio Algom seepage.

#### **Will Radium Exceed the ACL?**

New data collected at monitor well 5-08 is presented in Table 3. This table shows that increased purging of well 5-08 results in lower concentrations of Ra-226 in the water sample. Site personnel indicate that well 5-08 contains a larger volume of water than many wells at the site. Historical sampling practice has been to remove a certain number of bailers of water prior to sampling at this well. This practice is justified by producing a water sample that errs on the conservative side. That is, this practice likely produces samples with higher concentrations of most constituents than those produced by a more rigorous three-pore volume purge. These new data, collected during a recent well test, shows that a sample collected by previous site methods produced a Ra-226 concentration of 26.3 pCi/L, consistent with recently measured concentrations. In samples collected after several additional purges, Ra-226 concentrations dropped to a fairly uniform 5.3 to 7.1 pCi/L. We believe that higher Ra-226 concentrations reported in the past represent sampling bias and that a near 6 pCi/L value represents a more realistic concentration of Ra-226 in water in this well. In the future, this well will be purged a full three bore volumes before sampling. Therefore, we believe that Ra-226 will not exceed health-based limits at monitor well 5-08.

**Table 3. Results of additional well purging on Ra-226 concentrations in alluvial monitor well 5-08.**

Date	Time	Volume Pumped (gal.)	pH	Cond.	Ra-226 (pCi/L)
02/11/2003	1500	-	7.33	5.74	26.3
02/12/2003	1000	21			
02/12/2003	1600	11	7.24	6.11	6.76
02/13/2003	730	19	7.24	6.1	7.14
02/13/2003	1600	16	7.28	6.31	5.34
02/14/2003	1130	23.5	7.23	6.02	6.98
02/18/2003	930				
02/19/2003	930	25	7.21	6.2	6.48

**COMMENT C.2**

Proposed ACLs for the alluvial aquifer are especially high and are based on data which may be irrelevant to background at the alluvial POE.

**REQUIRED ACTION:** Justify the implicit assumption that the high contaminant levels reflected in the proposed background-derived ACLs could reasonably be expected in the vicinity of the POCs and POE, resulting from the influence of the Title I facility. Alternatively, propose other ACLs.

**COMMENT C.3**

The proposed ACL for Pb-210 must be demonstrated to reflect background or to be protective of health.

**REQUIRED ACTION:** Demonstrate that the proposed ACL for Pb-210 is a background value or is protective of health. Alternatively, propose another ACL.

**COMMENT C.4**

The results of the geochemical model intended to demonstrate the attenuating capacity of the alluvium are not adequately constrained.

**REQUIRED ACTION:** Provide a more thorough technical basis for the geochemical model, or revise the model. If the model is not better constrained or revised, provide alternative demonstrations of the alluvial attenuation capacity or abandon reliance on attenuation.

**RESPONSE TO COMMENTS C.2, C.3, AND C.4**

Referring to Comment C.2; we concede that high contaminant levels reflected in the proposed background-derived ACLs, resulting from the influence of the Title I facility, would not reasonably be expected in the vicinity of the Rio Algom POCs and POE. We believe, however, that they are relevant to background at the alluvial POE. It should be stressed that all background concentrations are derived from non-licensed sources (10 CFR 20.1003, Definitions). We believe that any concentrations of constituents that arrive at the POE are just as likely to come from the DOE Facility as from Rio Algom.

Whatever constituent concentrations arrive at the POE will be reduced by attenuation on alluvial materials. The starting concentrations (POC concentrations) are the highest concentrations observed at either site, or some weighted highest concentration as was used in development of the currently proposed ACLs. The ACLs are intended to ensure that concentrations do not exceed those that are protective of human health and the environment and, at the same time, there has to be a safety factor in place to ensure that inevitable fluctuations in constituent concentrations do not trigger unwarranted corrective actions. We do not believe that a molecule of uranium seeping from the DOE site will necessarily travel to a Rio Algom POC well and from there to the POE. What we do believe is that concentrations of constituents allowed at a POC well should be as high as those observed at a similar source located at a similar distance from the POE, over which Rio Algom has no control. Therefore, we believe that currently proposed ACLs are justified.

We believe that attenuation in alluvial materials is obvious from inspection of Figures 2.7 to 2.15 in the Alluvial ACL Application. *All* the input to alluvial groundwater comes from so called "sources", including seepage from both Rio Algom and the DOE Facilities, mine pumping and discharge, and runoff and erosion from mine spoils and ore piles. In spite of approximately 40 years of input from these "sources", Figures 2.7 through 2.15 demonstrate that levels of constituents of concern only occur at locations directly adjacent to tailings piles, former evaporation ponds, and the Arroyo del Puerto bypass.

This lack of constituent transport from sources is evidence that the attenuation capacity in the alluvial materials is high. The only question remaining is how to attach a quantitative number to attenuation. In simpler systems, this is typically done by geochemical transport modeling. The current state of geochemical transport modeling is such that quantitatively including three or four sources of constituents, multiple flow paths, and multiple geochemical processes is at the outer edge of feasibility. While it may be possible to construct such a model, there would be little confidence in the results.

If it were possible to construct such a model, it would be difficult to justify the time and effort, given that the NRC has already accepted a no further action scenario for the DOE Facility, located approximately one mile east of Rio Algom's site, based on the assertion that groundwater in the Alluvium is not a resource. The following quote and Table are taken from the LTSM Program 2002 UMTRCA Title I Annual Report Ambrosia Lake, New Mexico.

*"The Long-Term Surveillance Plan establishes that ground water monitoring is not required at this site because (1) the ground water is heavily contaminated from underground uranium mining and naturally occurring mineralization, and (2) the uppermost aquifer is of limited use due to low yield. However, at the request of the New Mexico Environment Department, DOE conducts limited monitoring at two locations. Monitor well 0675 is completed in the alluvium, and monitor well 0678 is completed in the uppermost sandstone bed. DOE samples these locations once every third year, for up to 30 years, and evaluates the results after every third sampling event.*

*The first post-closure sampling event was conducted on December 7, 2001. The data from this sampling event are presented in Table 1 -2."*

Table 1 -2. Analytical Results from the December 7, 2001, Sampling Event (From DOE LTSM Program 2002 UMRCA Title I Annual Report Ambrosia Lake, New Mexico)

Well	pH	Electrical Conductivity μOhms/cm	Uranium mg/L	Molybdenum mg/L	Selenium mg/L	Nitrate (as N) mg/L	Sulfate mg/L
0675	6.72	7,000	3.17	3.92	0.433	41.7	4,040
0678	7.26	14,280	0.073	0.023	0.169	479	7,440

μOhms/cm = micro-ohms per centimeter

mg/L = milligrams per liter

Note that there are no NRC monitoring requirements and there are no ACLs or other monitoring standards. We understand that the DOE program is administered under UMRCA Title I while Quivira is administered under Title II, meaning that each program has different regulatory options. However, the conceptual and technical understanding of the Alluvium should be common to both programs. If the NRC agrees that the alluvium at the DOE site is heavily contaminated from underground uranium mining and naturally occurring mineralization, and is of limited use due to low yield, then the same conditions must pertain to the alluvium at the Rio Algom site.

Reviewers note that geochemical modeling supporting the attenuation capacity of the Alluvium is poorly constrained. We agree with this comment but point to our previous explanation of the current state of geochemical transport modeling as not quantitatively useful in a complex environment such as that found at Ambrosia Lake. Further we note that the DOE closed their site without geochemical transport modeling.

One way to provide an indication of transport from the Rio Algom side of the Alluvium is to ignore other sources and do a one dimensional SOLUTE transport model similar to the one applied to the simpler groundwater system in the Dakota. This is done with the understanding that distributions of constituents from sources other than Rio Algom will not be accounted for in the model, and therefore, the model cannot be calibrated.

Selection of retardation factors is not straightforward because the Alluvium has multiple sources of constituents and multiple flow paths. Dakota modeling used direct site observations, standard geochemical reasoning, and judicious use of appropriate literature values to arrive at a retardation factor of 10 for uranium transport. The Dakota formation is a relatively clean (fine-to medium-grained subarkose to mature arkose), well indurated fluvial sandstone (Stone et al., 1983) and a uranium attenuation factor of 10 is appropriate. In contrast, the Alluvium is derived primarily from the marine Mancos Shale and associated Tres Hermanos Sandstones. We know that the Alluvium contains high concentrations of clay minerals, calcite, and iron oxides (as presented in the Alluvial ACL Application), suggesting that attenuation in this unit is likely higher than the attenuation that would occur in the Dakota Formation. Therefore, using an attenuation factor of 10 for uranium in the alluvium (see response to Comments B.1 and B.2 for why uranium is likely to be the most mobile constituent of concern) will result in a conservative estimate of alluvial attenuation.

Uranium modeling for the Alluvium (Figure 11) shows that the proposed ACL based on the following: a background concentration of 11.1 mg/L, a distance of 5,500 feet from alluvial POC well 31-61 to the POE, and assumptions similar to those used for the Dakota, results in a POE concentration of 0.056 mg/L in 100 years. The 100-year time frame is based on groundwater flow modeling that demonstrates almost complete dewatering of the Alluvium within 100 years. The modeled POE concentration of 0.056 mg/L for uranium results in an attenuation factor of 0.005. The attenuation factor of 0.005 is applied to background levels of constituents of concern as shown in Table 4, along with health-based concentrations.

**Table 4. Modeled attenuation factor of 0.005 applied to background concentration of the constituents of concern and compared to health-based concentrations at the POE.**

	<i>Background Concentration</i>	<i>0.005 Attenuation Factor Applied to Background Concentrations</i>	<i>Health Based Concentration at POE</i>
Mo (mg/L)	83	0.415	0.18
Ni (mg/L)	0.14	0.007	0.1
Se (mg/L)	3.1	0.015	0.05
Gross Alpha (pCi/L)	16726	83.6	8.57
Ra-226 + 228 (pCi/L)	196.1	0.98	32.3
Th-230 (pCi/L)	5	0.025	139
U (mg/L)	11.1	0.056	0.24
Pb-210 (pCi/L)	36	0.29	13

Note that currently proposed ACLs based on background levels will be attenuated to below health-based standards at the POE with the exception of Molybdenum and gross alpha. We are willing to consider an alternate way to estimate background for these two constituents. The current concentration of Mo in DOE alluvial monitor well 0675 is 3.92 mg/L. Also, the highest gross alpha concentration observed in alluvial monitor well 32-57 (the furthest east of Rio Algom monitoring wells, and closer to the DOE site than Rio Algom [Figure 2.15 of the Alluvial ACL]) was 720 pCi/L. If these values of molybdenum and gross alpha are considered to represent alluvial background, the 0.005 attenuation factor would bring modeled POE concentrations down to 0.0196 mg/L Mo and 3.6 pCi/L gross alpha. Note that gross alpha has already exceeded the modeled value and the health-based value at alluvial well 5-08 near the proposed POE. This is likely due to the conservative way this value was calculated (see response to Comment A.2), and sources of constituents that are not related to Rio Algom seepage (e.g., Arroyo del Puerto, mine spoils and ore piles).

Based on the above discussion we propose the alluvial ACLs as presented in Table 5. Note that the alluvial ACL for Th-230 has been reduced to the 5 pCi/L background concentration from the value of 10 pCi/L obtained from well 31-63 (Comment C.3).

**Table 5. Proposed Alluvial ACLs.**

	<i>Alluvial ACL</i>
Mo (mg/L)	3.92
Ni (mg/L)	0.14
Se (mg/L)	3.1
Gross Alpha (pCi/L)	720
Ra-226 + 228 (pCi/L)	196.1
Th-230 (pCi/L)	5
U (mg/L)	11.1
Pb-210 (pCi/L)	36

**COMMENT C.5**

The notion of the alluvial “groundwater sweep” is not supported by the map of groundwater elevation contours.

**REQUIRED ACTION:** Provide the technical basis for flow as represented in the “groundwater sweep” model. If appropriate, re-draw the groundwater elevation contours on Figure 2.17.

**RESPONSE TO COMMENT C.5**

See the redrawn groundwater elevation contours presented in Figure 2.17 included as Figure 12 of this document.

**COMMENT C.6**

If mine ventilation shafts are to be backfilled as part of the site reclamation, the effects of this action on the predicted time for dewatering of the alluvial sediments must be addressed.

**REQUIRED ACTION:** Indicate whether ventilation shafts that drain alluvial and bedrock aquifers are to be backfilled as part of site reclamation activities. If the ventilation shafts are to be backfilled, indicate what effects this action would have on the time required for drainage of alluvial groundwater.

**RESPONSE TO COMMENT C.6**

Rio Algom is authorized to close vent holes by either backfilling them or installing a concrete cap at the surface. Rio Algom will close the vent holes between the mill and the mine via the capping method, which will achieve surface reclamation and also leave the vent holes open to collect the minimal water that flows into the holes.

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# FIGURES

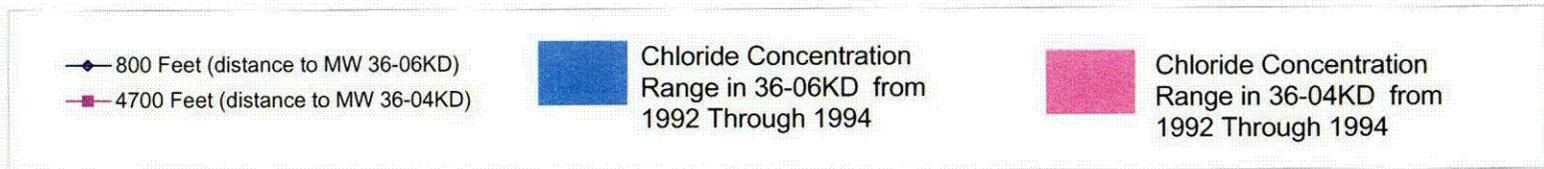
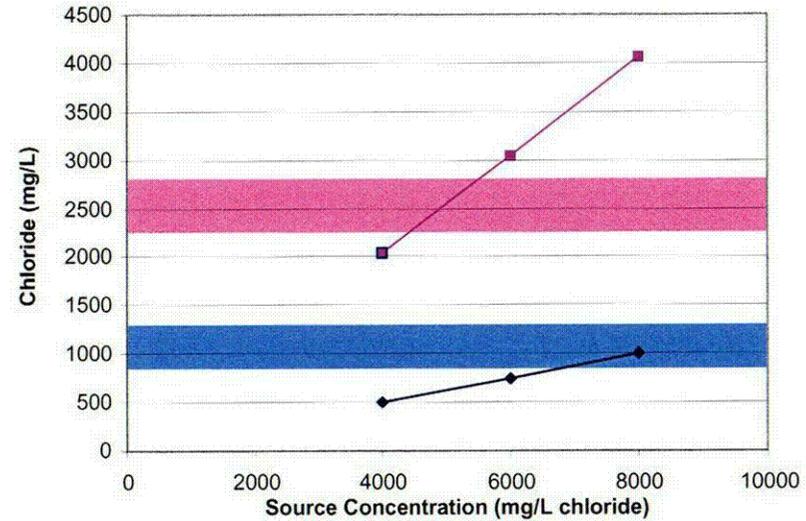
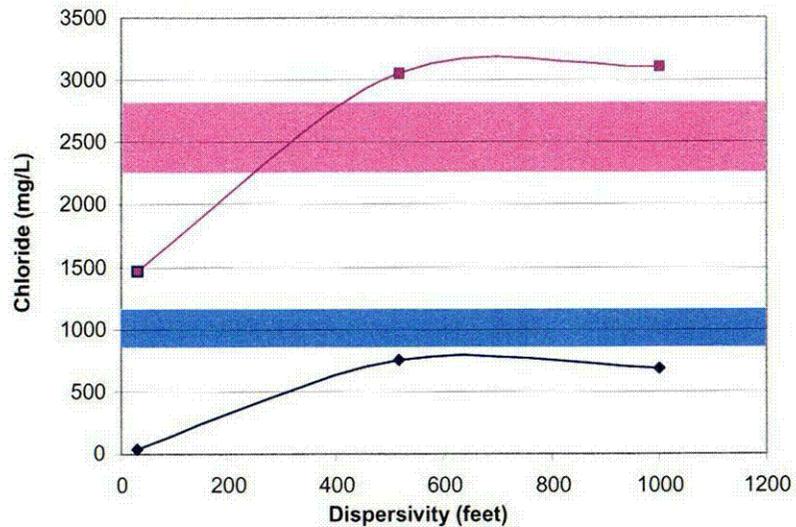
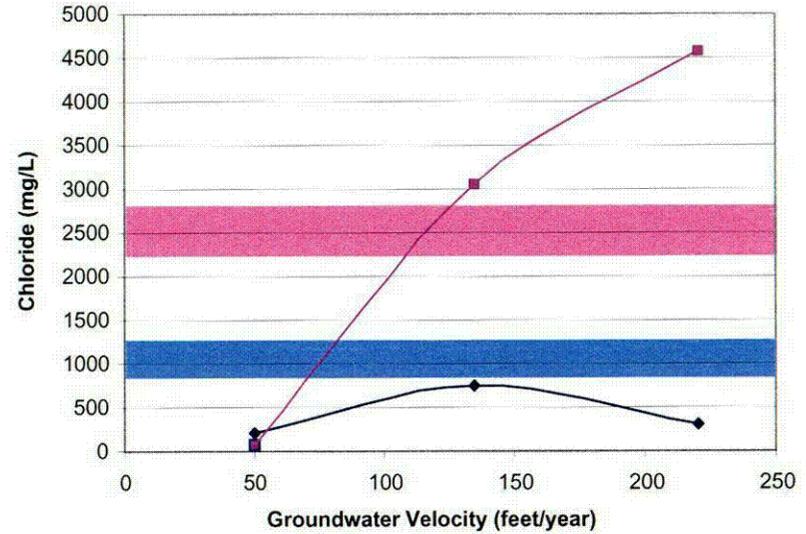
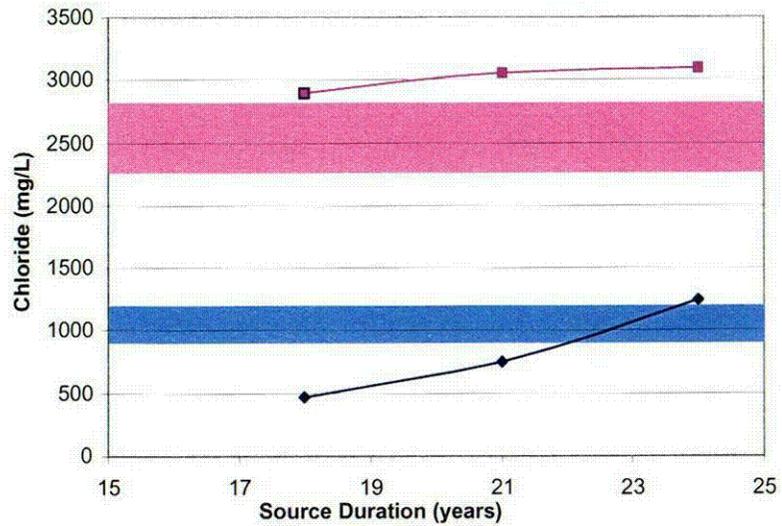
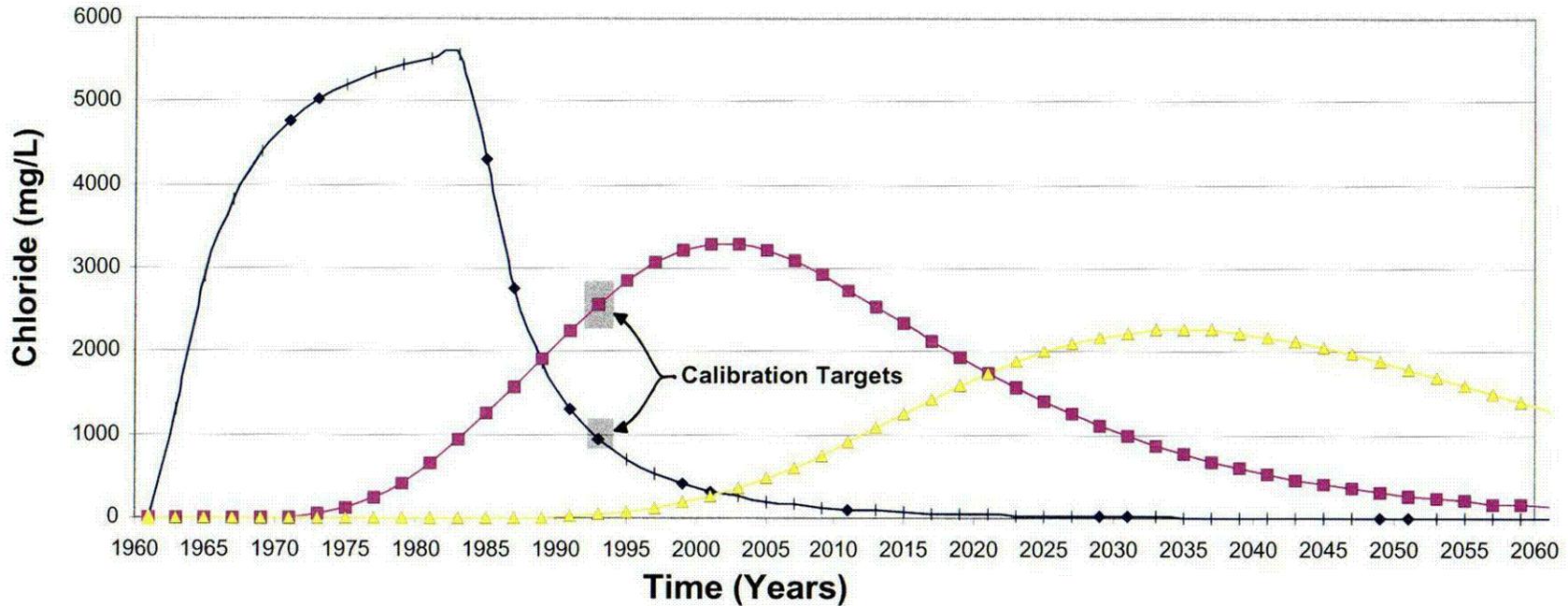


Figure 1. Sensitivity analysis using the midrange of each parameter for initial model input and then varying each parameter across its range one parameter at a time.

S O L U T E version 4.06  
 ANALYTICAL MODELS FOR SOLUTE TRANSPORT  
**Model: One-D**  
**Chloride in the Dakota**



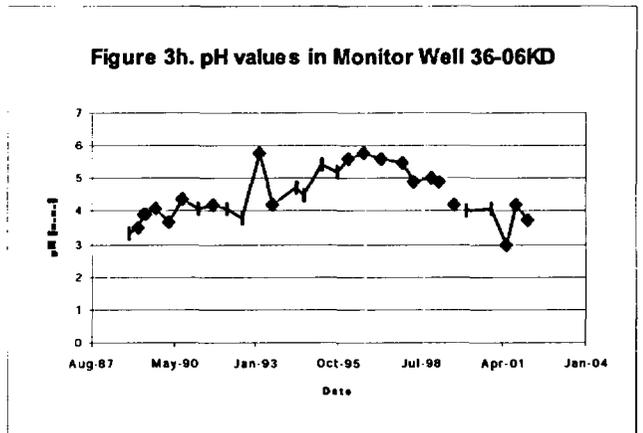
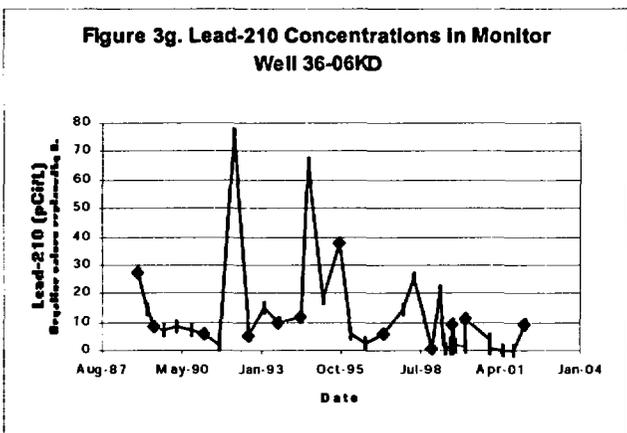
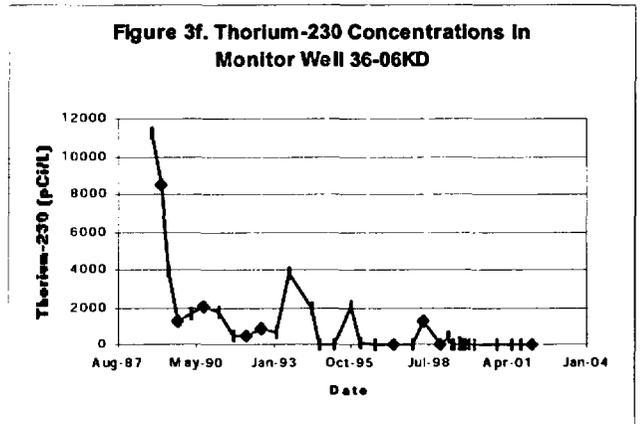
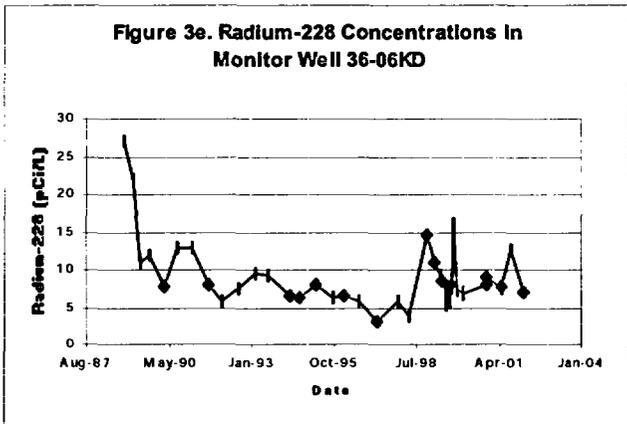
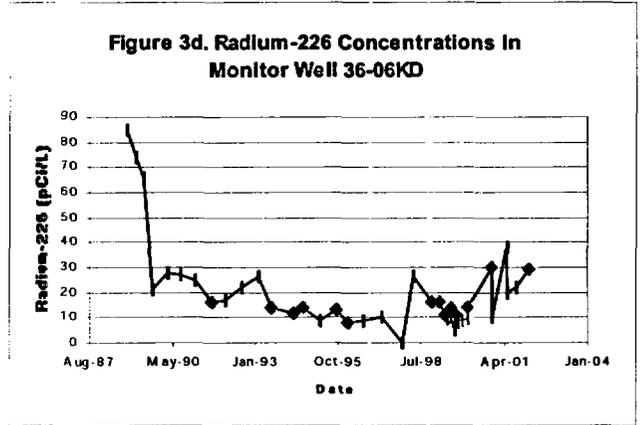
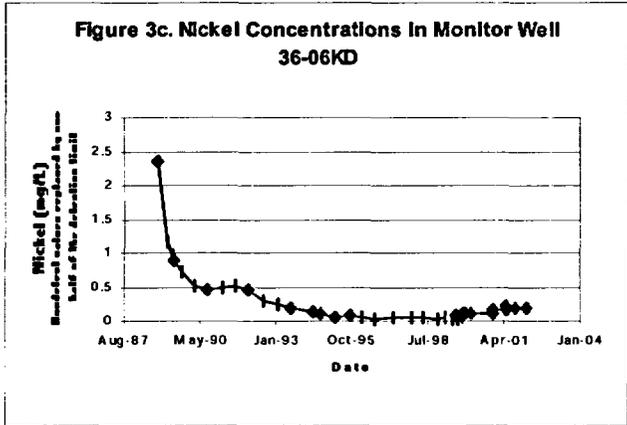
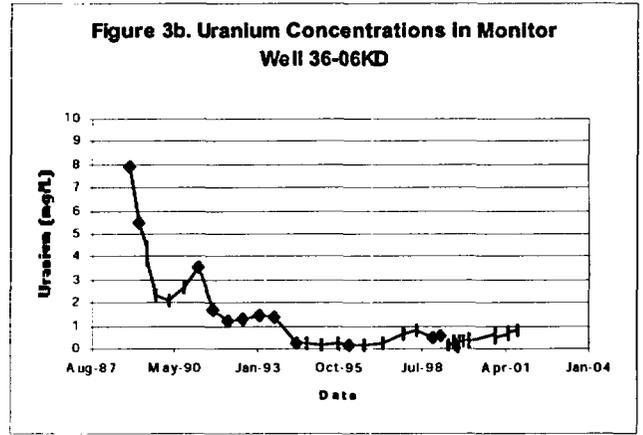
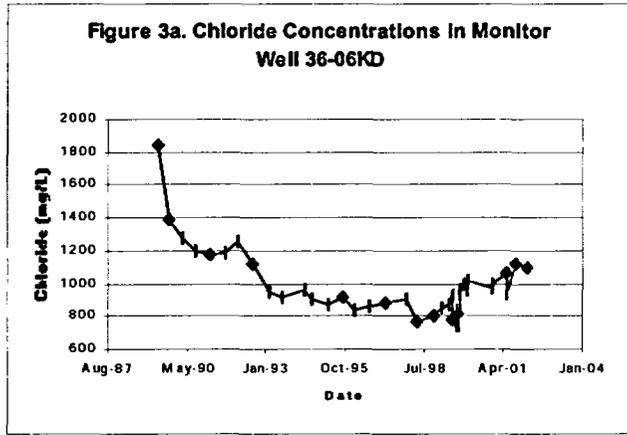
- ◆ Concentration 800 Feet  
(Distance to MW 36-06)
- Concentration 4700 Feet  
(Distance to MW 36-04)
- ▲ Concentration 9100 Feet  
(Distance to Far POE)

**INPUT DATA:**

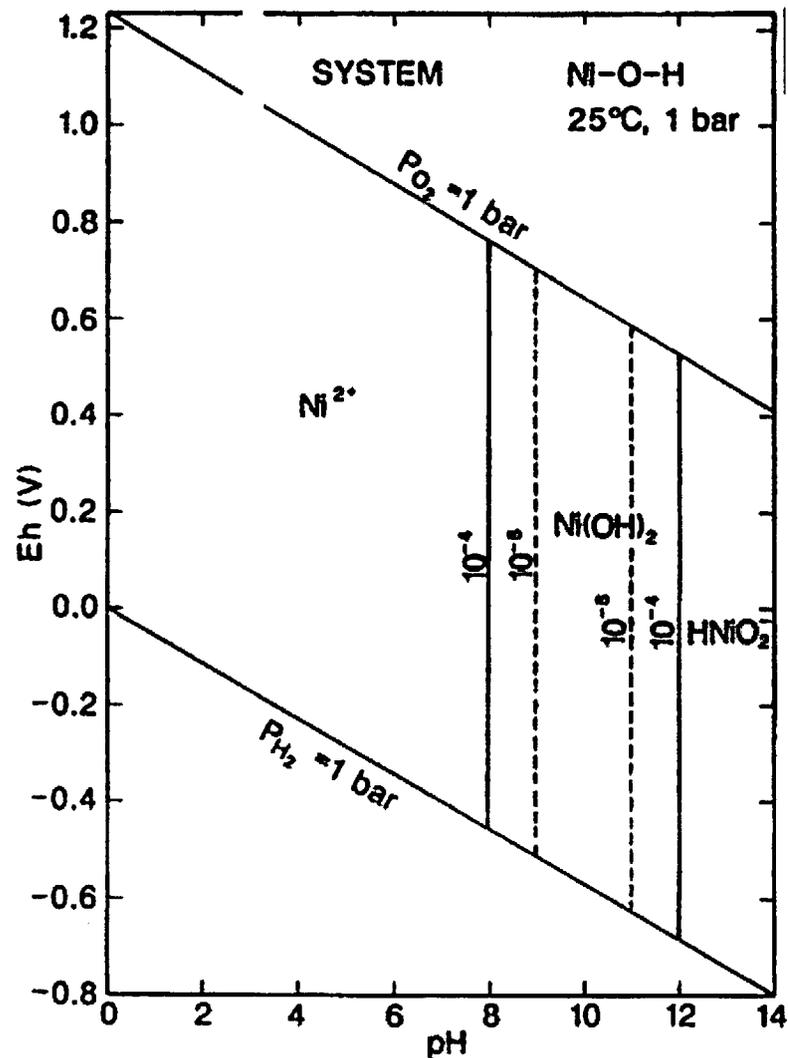
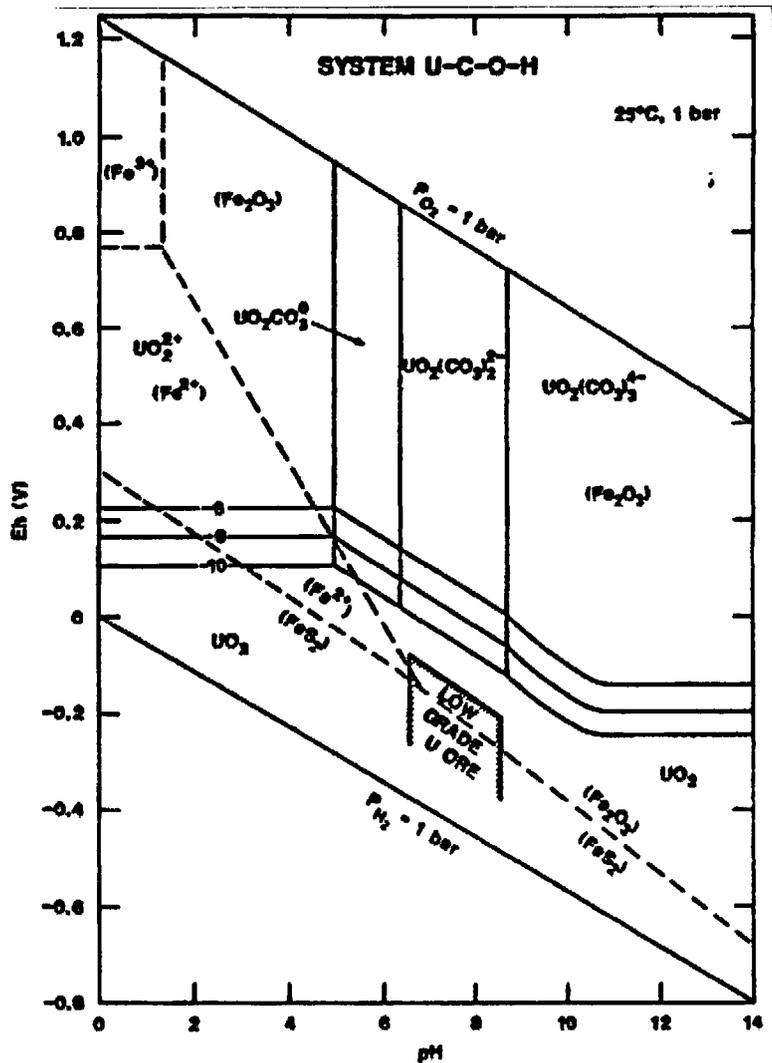
Groundwater (seepage) velocity... = 125 [ft/y]  
 Longitudinal dispersivity..... = 500 [ft]  
 Retardation factor..... = 1  
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 Constant source concentration.... = 5.80000D+03[mg/L]  
 Duration of solute pulse..... = 22 [y]  
 Half - life in aquifer (no decay=0) = 0 [y]  
 Decay coefficient for aquifer.... = 0.0000D+00 [1/y]  
 Length of time step..... = 2 [y]  
 Number of time steps..... = 50  
 Number of observation points = 3

Figure 2. Final optimized model for chloride transport in the Dakota.

C-02



**Figure 3. Time Concentration Plots for Constituents of Concern in Monitor Well 36-06KD.**

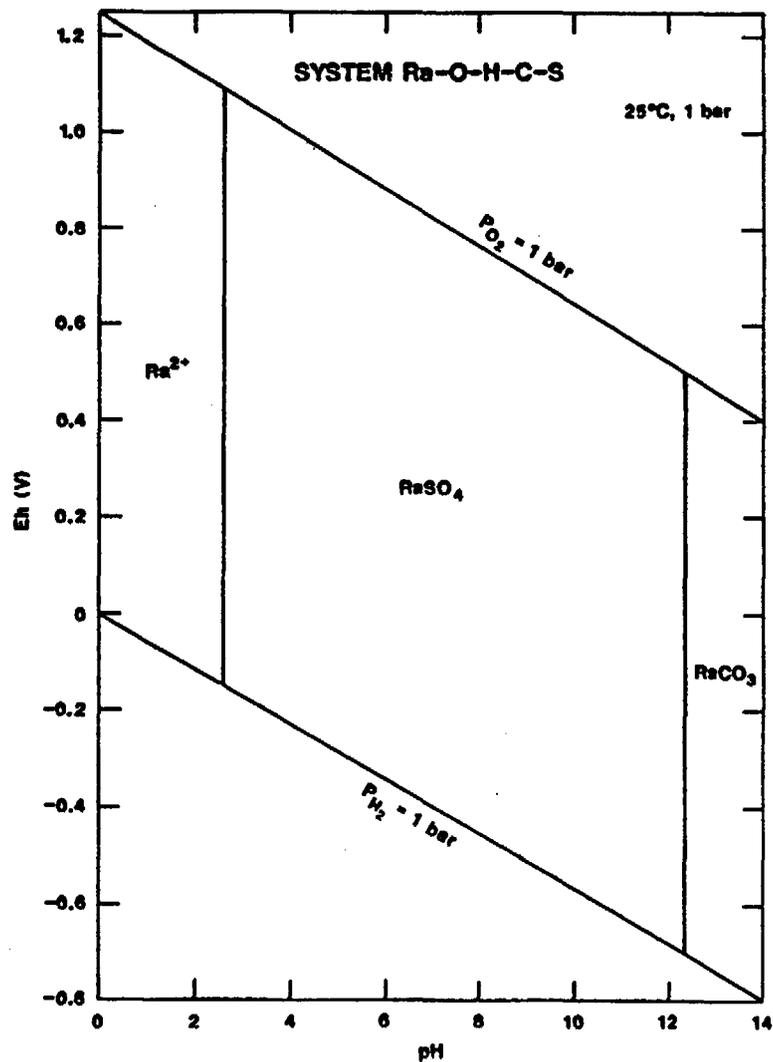


4a. Eh-pH diagram for part of the system U-C-O-H with part of the system Fe-S-O-H superimposed.

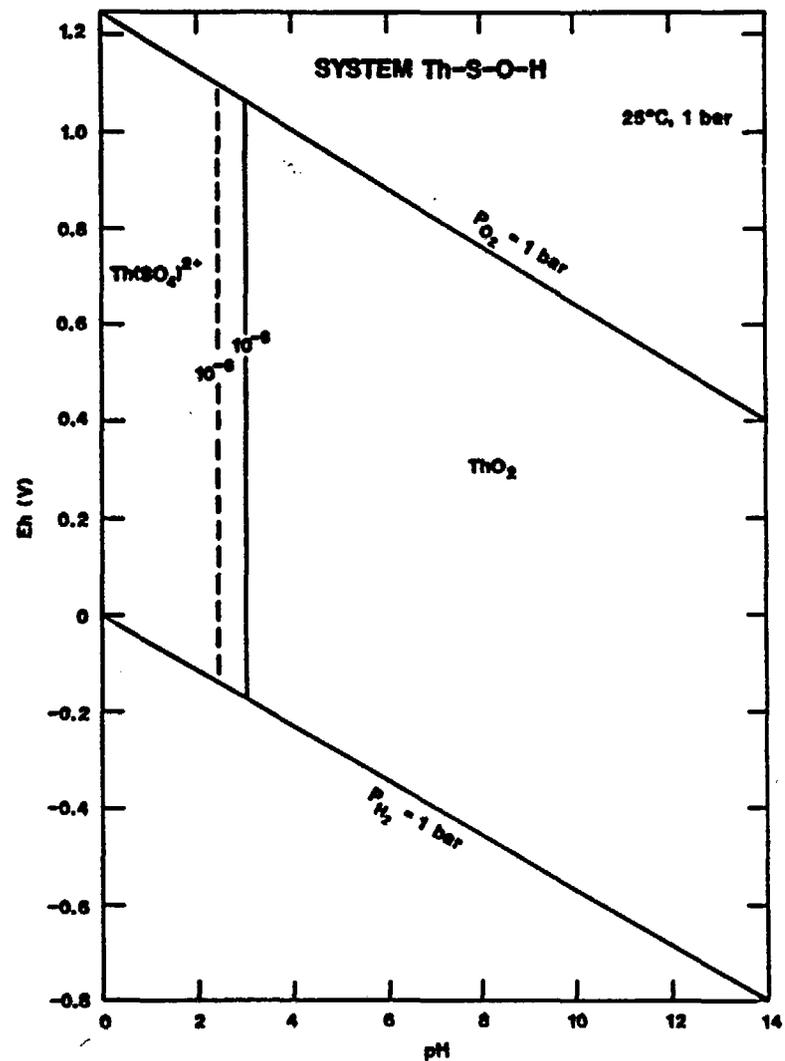
Assumed activities for dissolved species are:  $U = 10^{-6}$ ,  $S = 10^{-10}$ ,  $C = 10^{-3}$ ,  $Fe = 10^{-6}$ ,  $S = 10^{-3}$ . Area marked *U Ore* from Brookins (1982).

4b. Eh-pH diagram for part of the system Ni-O-H. Assumed activity of dissolved Ni =  $10^{-4}$  -  $10^{-6}$ .

Figure 4. Eh-pH Diagrams for the Constituents of Concern in Groundwater from the Dakota Formation, Rio Algom Site, Ambrosia Lake, New Mexico. Diagrams from Brookins (1988).

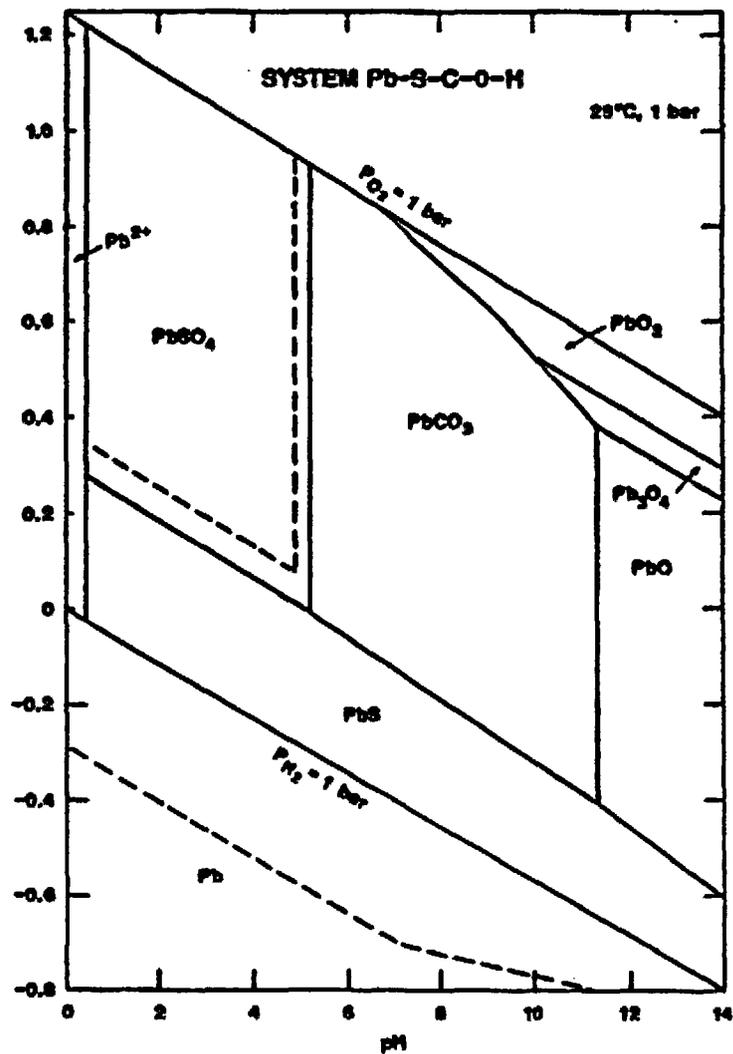


4c. Eh-pH diagram for part of the system Ra-O-H-C-S. Assumed activities for dissolved species are:  $Ra = 10^{-8}$ ,  $S = 10^{-3}$ ,  $C = 10^{-3}$ .



4d. Eh-pH diagram for part of the system Th-S-O-H. Assumed activities for dissolved species are:  $Th = 10^{-6}$ ,  $S = 10^{-3}$ .

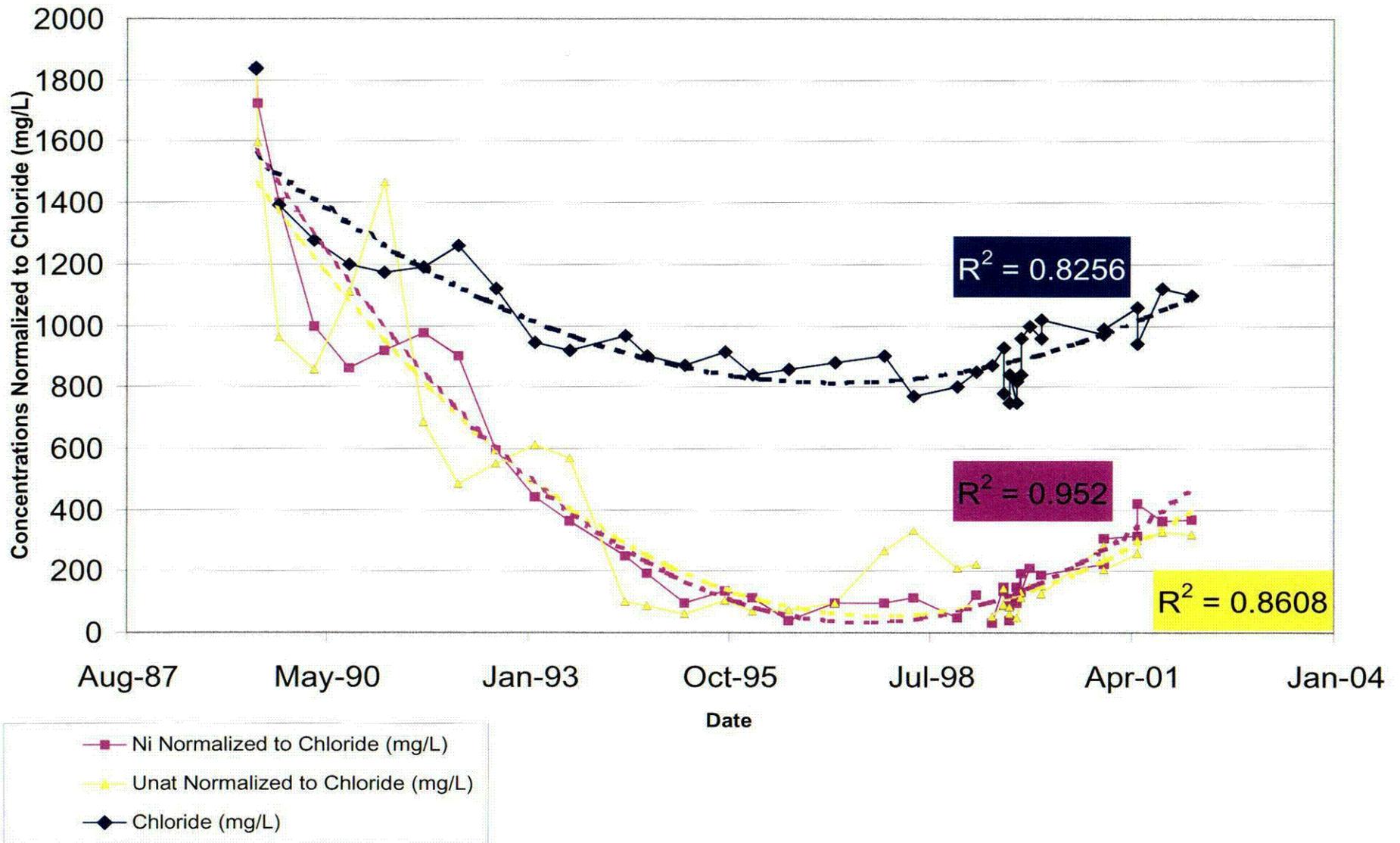
Figure 4. Eh-pH Diagrams for the Constituents of Concern in Groundwater from the Dakota Formation, Rio Algom Site, Ambrosia Lake, New Mexico. Diagrams from Brookins (1988) (Continued).



4e. Eh-pH diagram for part of the system Pb-S-C-O-H.  
The assumed activities of dissolved species are:  $Pb = 10^{-6}$ ,  $S = 10^{-3}$ ,  $C = 10^{-3}$ .

Figure 4. Eh-pH Diagrams for the Constituents of Concern in Groundwater from the Dakota Formation, Rio Algom Site, Ambrosia Lake, New Mexico. Diagrams from Brookins (1988) (Continued).

**Figure 5. Chloride Normalized Concentrations of Uranium and Nickel from Monitor Well 36-06KD**



C-03

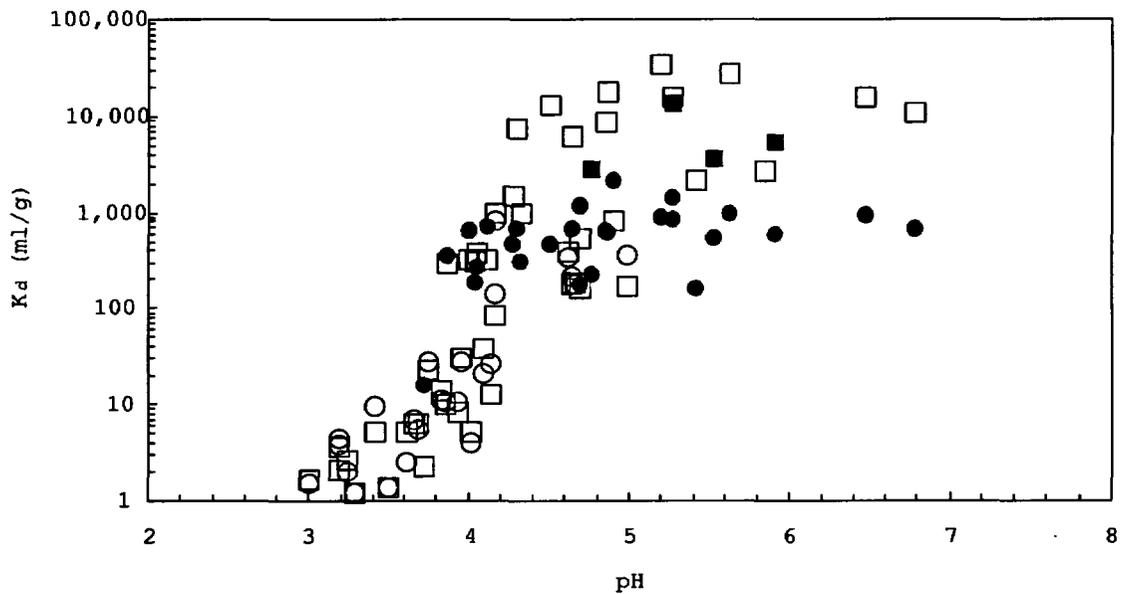


Figure 6. Field-derived  $K_d$  values for  $^{238}\text{U}$  and  $^{235}\text{U}$  from Serkiz and Johnson (1994) plotted as a function of porewater pH for contaminated soil/porewater samples. [Square and circle symbols represent field-derived  $K_d$  values for  $^{238}\text{U}$  and  $^{235}\text{U}$ , respectively. Solid symbols represent minimum  $K_d$  values for  $^{238}\text{U}$  and  $^{235}\text{U}$  that were based on minimum detection limit values for the concentrations for the respective uranium isotopes in porewaters associated with the soil sample.] (From EPA, 1999)

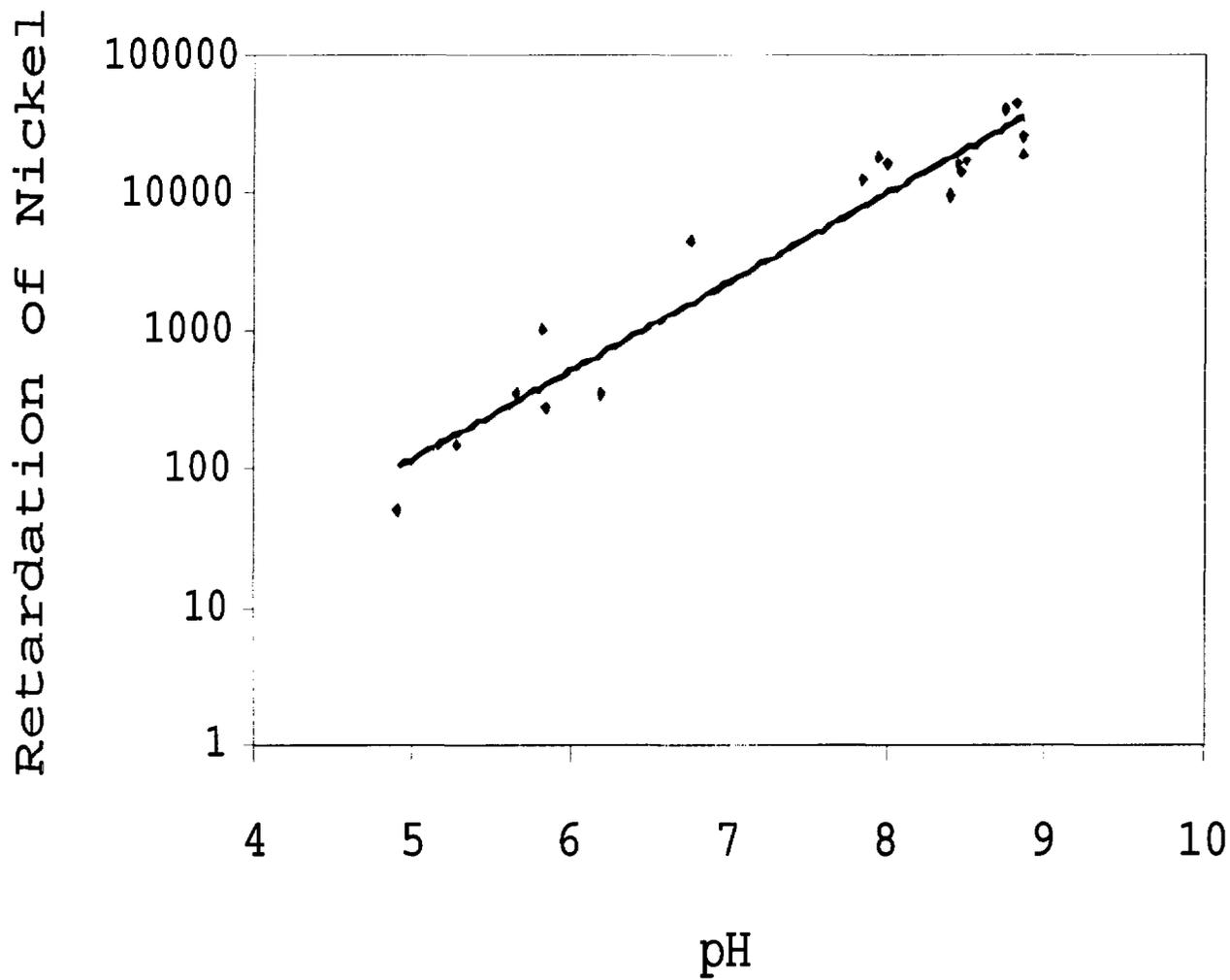
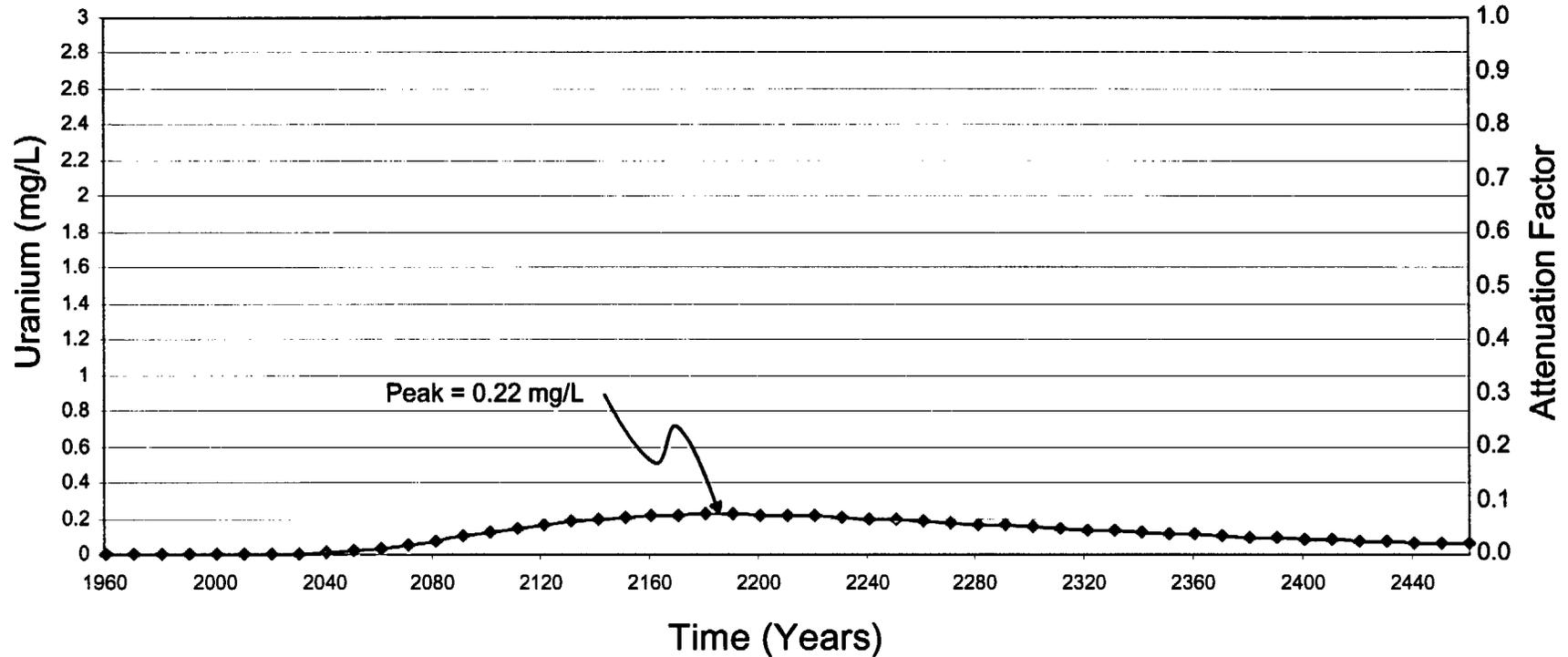


Figure 7. Effect of pH on retardation of Nickel in core material from 28 sandy aquifers in Denmark (from EPA, 1998)

S O L U T E version 4.06  
 ANALYTICAL MODELS FOR SOLUTE TRANSPORT  
 Model: One-D  
 Uranium in the Dakota



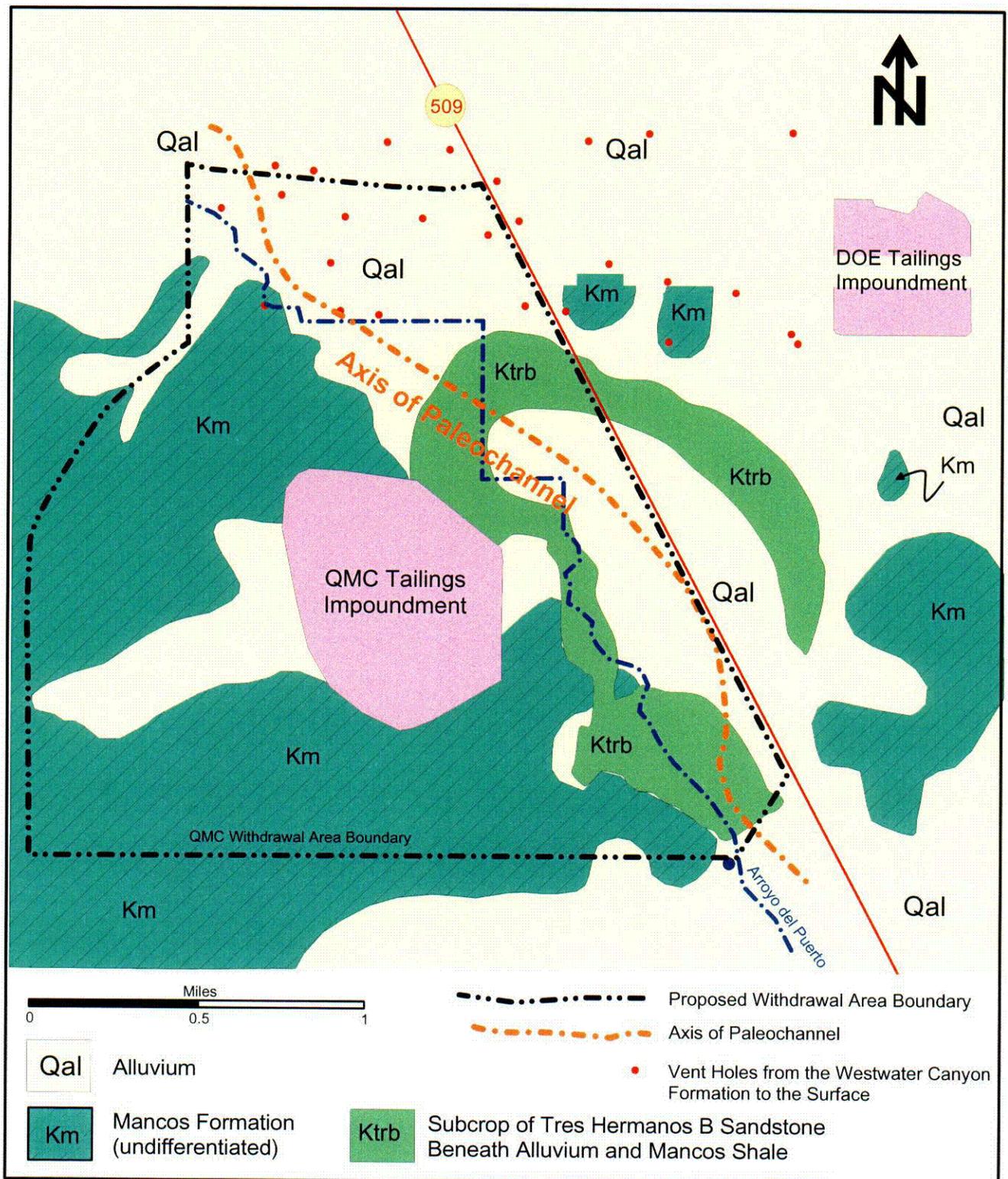
◆ Concentration at 3900 ft (Distance from POC Monitor Well 36-06KD to POE Monitor Well 36-04KD)

Attenuation Factor = Peak Concentration/Initial Concentration  
 = 0.22 mg/L/3 mg/L  
 = 0.07

**INPUT DATA:**

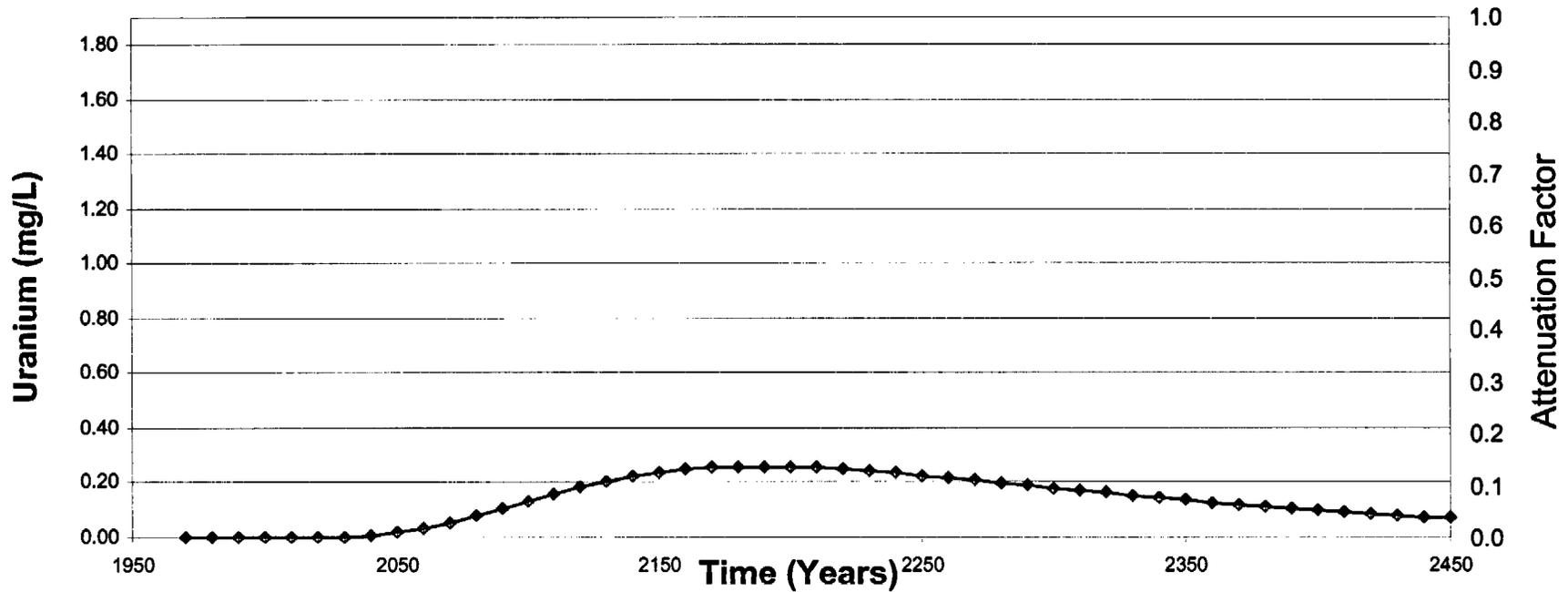
Groundwater (seepage) velocity... = 125 [ft/y]  
 Longitudinal dispersivity..... = 500 [ft]  
 Retardation factor..... = 10  
 Initial aquifer concentration.... = 0.00000D+00[mg/l]  
 Constant source concentration.... = 3 [mg/L]  
 Duration of solute pulse..... = 22 [y]  
 Half - life in aquifer (no decay=0) = 0 [y]  
 Decay coefficient for aquifer.... = 0.0000D+00 [1/y]  
 Length of time step..... = 10 [y]  
 Number of time steps..... = 50  
 Number of observation points = 1

Figure 8. Final optimized model for uranium transport in the Dakota



Simplified Geologic Map of the QMC Site Showing Location of Vent Holes and Subcrop of the Tres Hermanos B Sandstone Beneath the Alluvium.

**S O L U T E** version 4.06  
**ANALYTICAL MODELS FOR SOLUTE TRANSPORT**  
**Model: One-D**  
**Uranium in the TRB**



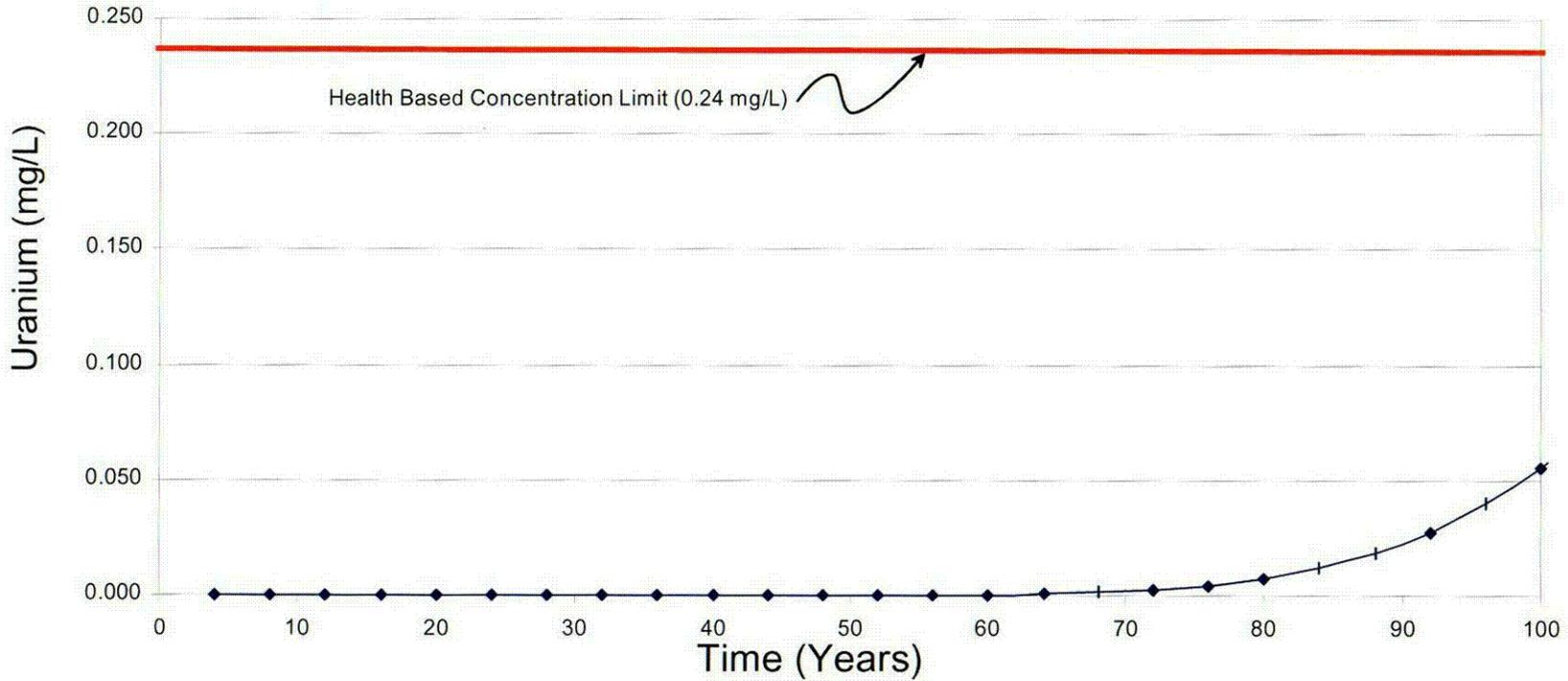
◆ Concentration 3800 Feet  
 (distance from MW 31-63  
 to the nearest vent hole).

**INPUT DATA:**

Groundwater (seepage) velocity... = 125 [ft/y]  
 Longitudinal dispersivity..... = 500 [ft]  
 Retardation factor..... = 10  
 Initial aquifer concentration.... = 0.00000D+00[mg/l]  
 Constant source concentration.... = 1.90000D+00[mg/L]  
 Duration of solute pulse..... = 40 [y]  
 Half - life in aquifer (no decay=0) = 0 [y]  
 Decay coefficient for aquifer.... = 0.00000D+00 [1/y]  
 Length of time step..... = 10 [y]  
 Number of time steps..... = 50  
 Number of observation points = 1

Figure 10. Model for Uranium transport in the Tres Hermanos B.

S O L U T E version 4.06  
 ANALYTICAL MODELS FOR SOLUTE TRANSPORT  
**Model: One-D**  
**Uranium in the Alluvium**



◆ Concentration at 5500 ft (Distance from POC Monitor Well 31-61 to the POE)

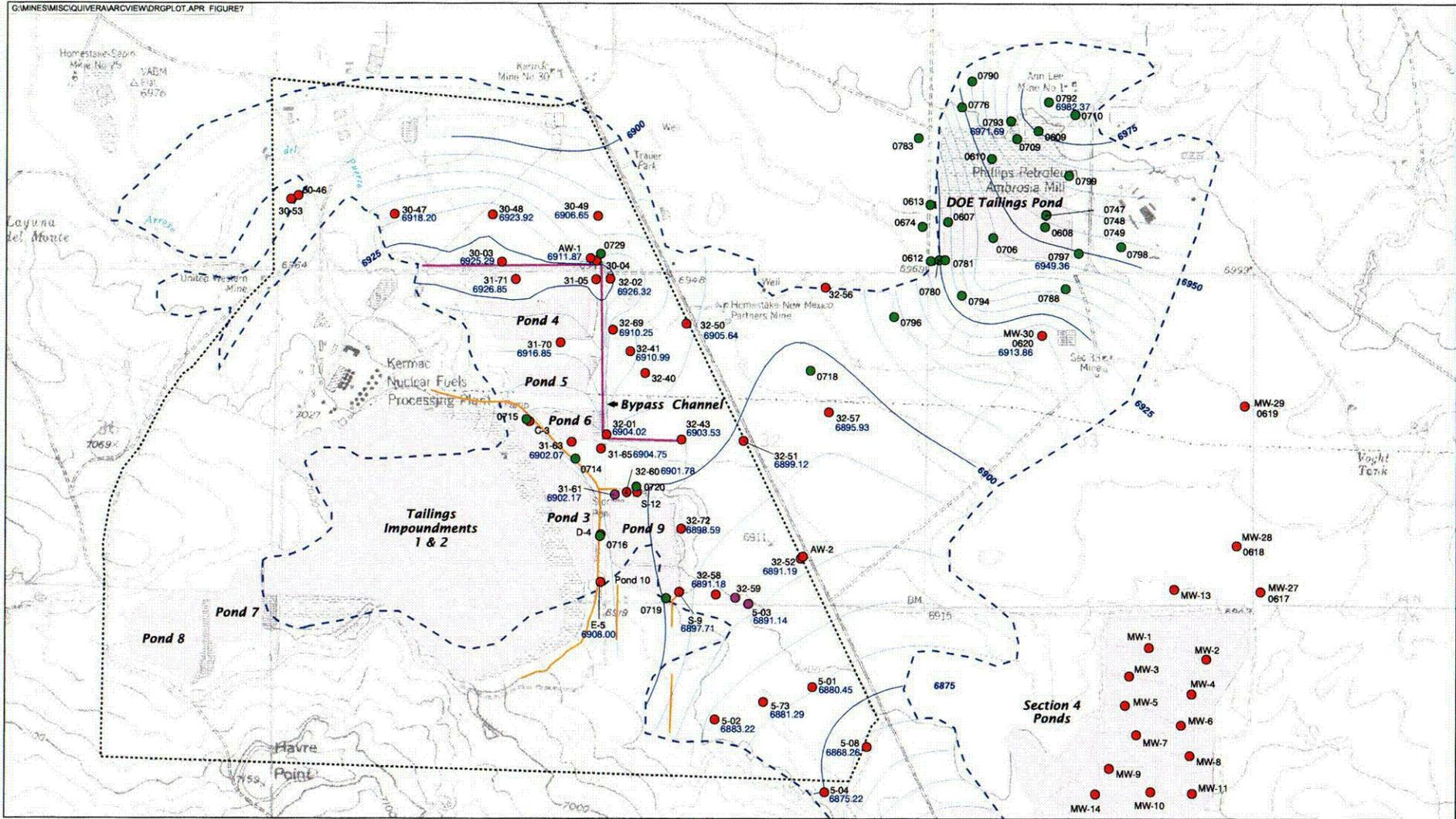
Attenuation Factor = Peak Concentration/Initial Concentration  
 = 0.056 mg/L/11.1 mg/L  
 = 0.005

**INPUT DATA:**

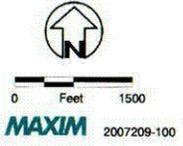
Groundwater (seepage) velocity... = 182.5 [ft/y]  
 Longitudinal dispersivity..... = 500 [ft]  
 Retardation factor..... = 10  
 Initial aquifer concentration.... = 0.00000D+00[mg/l]  
 Constant source concentration.... = 11.1 [mg/L]  
 Duration of solute pulse..... = 60 [y]  
 Half - life in aquifer (no decay=0) = 0 [y]  
 Decay coefficient for aquifer.... = 0.00000D+00 [1/y]  
 Length of time step..... = 2 [y]  
 Number of time steps..... = 50  
 Number of observation points = 1

C-05

Figure 11. Model for uranium transport in the Alluvium



USGS 7.5 Minute Quadrangle - Ambrosia Lake (reprojected to stateplane NM West feet, NAD27)



- ..... Proposed Withdrawal Area
- - - - - Approximate Extent of Saturated Alluvium Boundary
- Interception Trenches
- Bypass Channel
- DOE Alluvial Wells
- Quivera Alluvial Wells
- NRC Point of Compliance Wells

- Index Ground Water Contour
- Intermediate Ground Water Contour
- Contour Interval 5 feet
- Water table elevation readings based on November/December 1997 readings.

Ground Water Table Elevation Map  
Ambrosia Lake Area  
Near Grants, New Mexico  
FIGURE

C-06