Document ID: EDF-5186
Revision ID: 1
Effective Date: 07/10/07

Engineering Design File

Project No. 23415

Groundwater Pathway Risk Assessment for MTR Closure

Idaho Cleanup Project

CH2M•WG Idaho, LLC is the Idaho Cleanup Project contractor for the U.S. Department of Energy

EDF No.: 5186 EDF Rev. No.: 1 Project File No.: 23415

1. Title: Groundwater Pathway Risk Assessment for MTR Closure

2. Index Codes:
   Building/Type N/A SSC ID N/A Site Area 200

3. Commercial Level? ☒ Yes ☐ No

*4. NPH Performance Category: _____ or ☒ N/A SSC Safety Category: _____ or ☒ N/A

*5. (a) Affects Safety Basis: ☐ Yes ☒ No (b) Affects a SNF Facility: ☐ Yes ☒ No

6. Summary:

This Engineering Design File (EDF) documents a screening-level evaluation of contaminated materials in the Materials Test Reactor (MTR). The evaluation supports the engineering evaluation/cost estimate required for the decommissioning of the MTR.

The MTR was constructed at the Idaho National Laboratory (INL) Reactor Technology Complex (formerly known as the Test Reactor Area) between 1950 and 1952. It operated between September 1955 and the end of its service in August 1970, except for special experimental runs. The MTR is being decommissioned. This EDF presents the groundwater pathway streamlined risk assessment for three alternatives ranging from no action (Alternative 1), to grout in place with partial removal (Alternative 2), to reactor removal (Alternative 3).

Based on this streamlined risk assessment, filling the MTR reactor vessel and all belowgrade structures with soil while leaving all current source inventories in place results in predicted groundwater concentrations that meet the required performance criteria. For groundwater, the performance criteria require that contaminant concentrations in the Snake River Plain Aquifer do not exceed a cumulative carcinogenic risk level of 1×10^{-4} or exceed applicable State of Idaho groundwater quality standards in 2095 and beyond. As discussed in the report, this analysis is conservative.

7. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

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9. Does document contain sensitive unclassified information? ☐ Yes ☒ No If Yes, what category:
10. Will document be externally distributed? ☒ Yes ☐ No
*11. NRC related? ☐ Yes ☒ No
12. Registered Professional Engineer's Stamp (if required) ☒ N/A

*** Not required for commercial level calculations**

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FIGURES

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ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
D&D	decommissioning and dismantlement
DD&D	deactivation, decontamination, and decommissioning
DOE	Department of Energy
EDF	Engineering Design File
EPA	Environmental Protection Agency
ESRP	Eastern Snake River Plain
ICDF	Idaho CERCLA Disposal Facility
INL	Idaho National Laboratory
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MCP	management control procedure
MTR	Materials Test Reactor
MWd	megawatt-day
MWth	megawatt-thermal
NCRP	National Council on Radiation Protection
PRG	preliminary remediation goal
RTC	Reactor Technology Complex
SRPA	Snake River Plain Aquifer
TRA	Test Reactor Area

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Groundwater Pathway Risk Assessment for MTR Closure

1. INTRODUCTION

The Idaho National Laboratory (INL) is a U.S. Department of Energy (DOE) facility located 52 km (32 mi) west of Idaho Falls, Idaho. It occupies 2,305 km^2 (890 mi^2) of the northeastern portion of the Eastern Idaho Snake River Plain. The Materials Test Reactor (MTR) building at the INL Site and associated buildings are no longer used and will be decommissioned. The MTR is located at the Reactor Technology Complex (RTC), formerly the Test Reactor Area (TRA), which is located in the south-central portion of the INL Site (see Figure 1). Figure 2 shows the location of the MTR complex within RTC. The screening evaluations presented in this Engineering Design File (EDF) were performed to support the final closure of the MTR complex. The analysis plan for this EDF is provided in Appendix A.

This EDF presents an evaluation of the following three alternatives:

1. Alternative 1 (No Action alternative) – No removal action would be conducted on the MTR vessel and there would be no removal of hazardous substances beyond what is being performed under the Voluntary Consent Order[a] and deactivation activities. This alternative would evaluate the MTR facility subsequent to Voluntary Consent Order and deactivation activities. Current surveillance and maintenance activities would continue. The No Action alternative is included for completeness and comparative purposes. However, the alternative only defers taking further action on the MTR vessel to a future date.

2. Alternative 2 – The MTR vessel would be filled with grout and the aboveground portions of the vessel and the bioshield would be encapsulated in a concrete monolith. The aboveground reactor building would be demolished. Belowgrade structures and systems, including piping, utility systems, and structural steel, would be abandoned in place. In addition, residual radioactive materials in the MTR facility remaining after decommissioning and dismantlement (D&D) activities are complete would remain in place and would be managed under the Sitewide Institutional Control Program. Void spaces would be grouted as necessary and/or backfilled as practicable using inert demolition waste from the abovegrade structures and clean backfill materials.

3. Alternative 3 – This alternative would include removal and disposal of the MTR vessel with vessel internal components intact at an on-Site disposal facility (Idaho CERCLA Disposal Facility [ICDF]). The reactor building would be demolished to ground surface; structures and systems below ground surface consisting of inert materials, such as piping, tanks, structural metal, and utility systems, would be abandoned in place. Residual radioactive materials in the MTR facility remaining after D&D activities are completed would stay in place and would be managed under the Sitewide Institutional Control Program. Void spaces would be backfilled as practicable, including the void left by removal of the MTR vessel. Backfill would consist of grout, as necessary, and/or inert demolition waste from the abovegrade structures and clean backfill materials.

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a. Monson, B. R., Idaho Department of Environmental Quality, to D. N. Rasch, U.S. Department of Engergy Idaho Operations Office, "Consent Order to address hazardous waste compliance concerns at the INEEL," June 13, 2000.

Figure 1. Map of the Idaho National Laboratory Site showing the location of the Reactor Technology Complex.

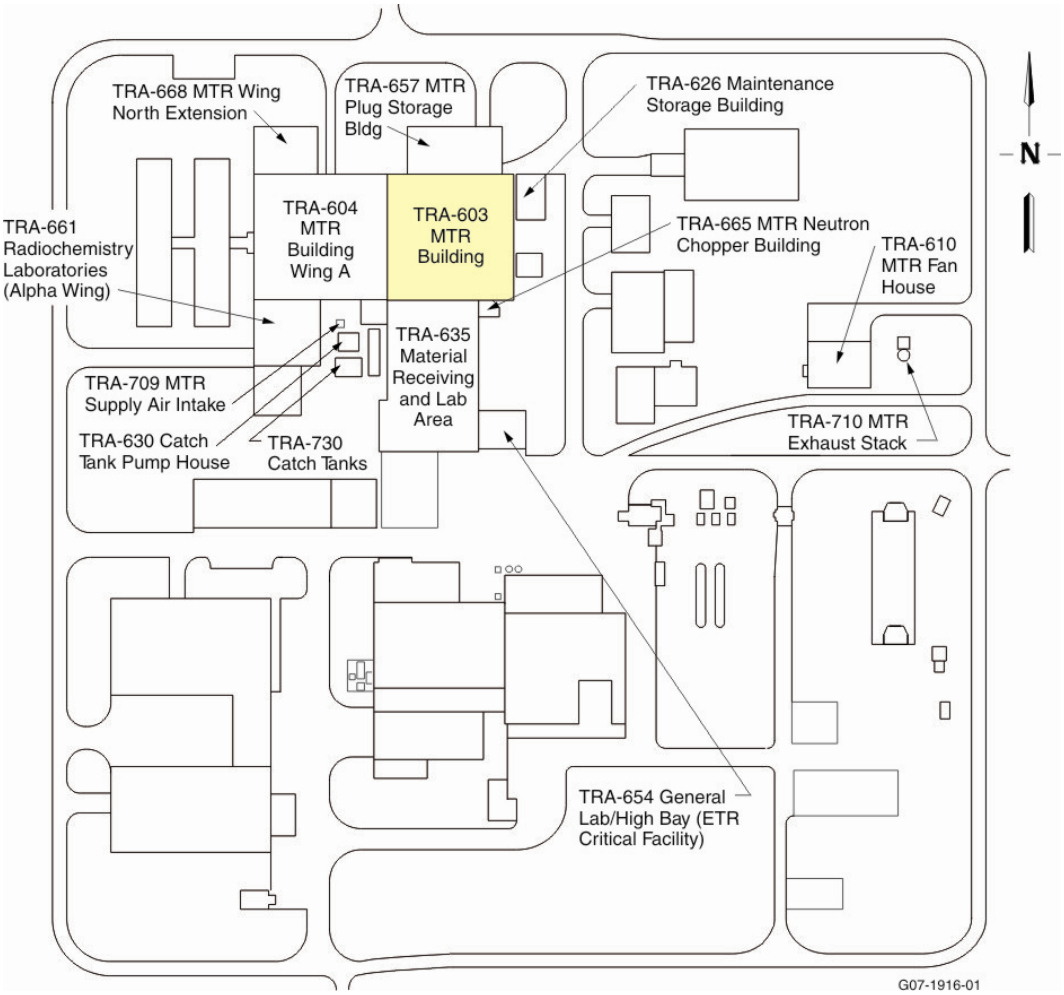


Figure 2. Map showing the location of the Materials Test Reactor complex and other facilities.

1.1 Materials Test Reactor Site Description

The MTR was constructed at the INL TRA between 1950 and 1952. First criticality was in March 1952 using 1,666 g of U-235 in a slab configuration. The original design power was 30 MWth, but it was subsequently found that MTR could be safely operated at 40 MWth. It operated at that power between September 1955 and the end of its service in August 1970, except for special experimental runs. Table 1 contains a summary of the main phases of MTR operation.

Unlike many of the reactors built at the INL, the MTR's core is above ground. It is housed in a large shielding structure in Building TRA-603. Figure 3 shows some aspects of its configuration. Much more detail may be found in EDF-6381 and related references.

The central core of the reactor, inside the tank stack, was water-filled. The core internals were cooled by water circulating through 61-cm (24-in.) process water lines. Those lines ran to the Process Water Building (TRA-605) where the water was degassed in three identical flash evaporator units and subsequently cooled. That water was removed in 1979, and the ducts to the Process Water Building are dry.

Table 1. Summary of the Materials Test Reactor operating history.

Period	Power (MWth)	Energy (MWd)	Description
May 1952 to May 1954	30	26,900	Initial operating mode, 93% U-235 fuel
May 1954 to September 1955	30		U-235 content increased from 130 to 168 to 200 g per fuel element
September 1955 to November 1957	30	550	5,130 g 20% enriched U-235
	40	110	5,130 g 20% enriched U-235
November 1957			20% U-235, Cycle 95
November 1957 to August 1958			Routine operation
August 1958	≤30	262	3,270 g Pu fuel, Cycle 108
August 1958 to March 1960	40	71,323[a]	Routine operation
March 1960 to July 1969	40	108,000	Routine operation
December 1969 to April 1970	30[b]	923	Phoenix Pu core, new Be reflector
August 1970	40	83	Conventional core, 93% U-235
At shutdown (August 1970)		180,329	

MWd = megawatt-day.
MWth = megawatt-thermal.

a Total MWd of operation to that point.
b. The reactor safety work assumed a conservative maximum of 40 MW for the Phoenix core, but thermal-hydraulic safety criteria limited the maximum power to 30 MW.

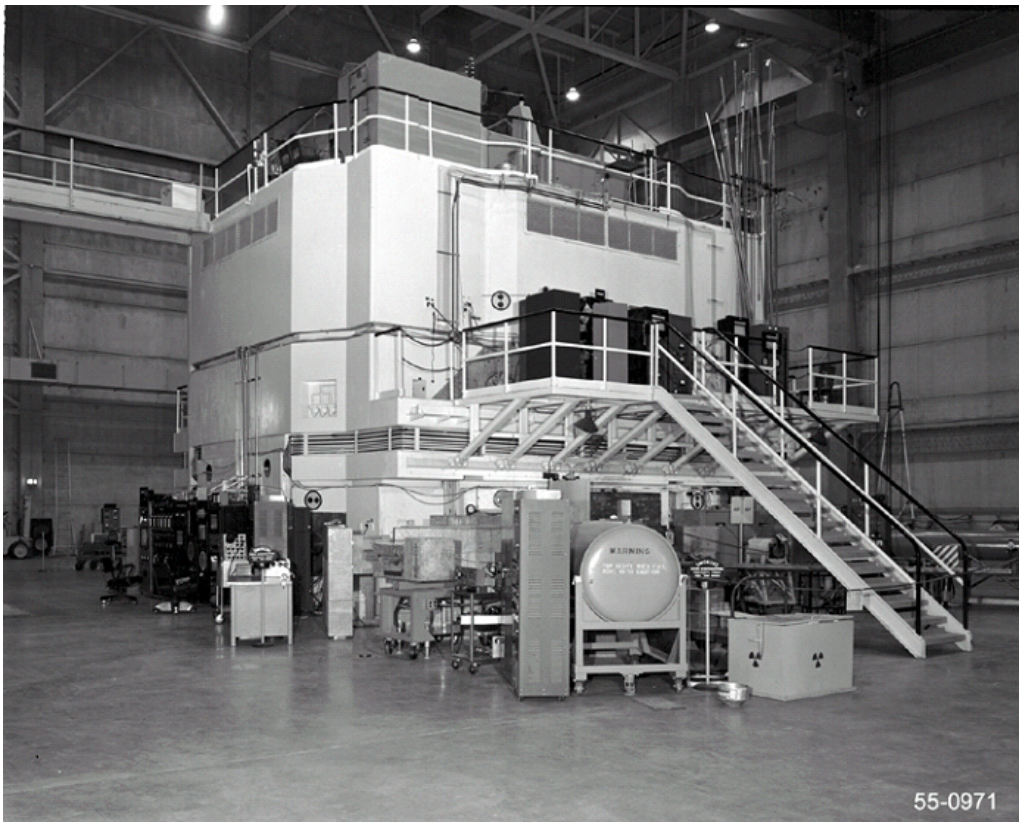


Figure 3. Materials Test Reactor as seen from the southwest during its early operational days.

The portion of the canal immediately under the reactor was isolated from the remainder of the canal soon after MTR operations ceased. It also has been dry since 1979. The eastern part of the canal has been used for storing miscellaneous radioactive items over the period since that time, including test trains from the Power Burst Facility and fuel assemblies from various reactors. However, contamination on the surface of the dry part of the canal may be approximately the same as that inside the reactor core.

The graphite balls in the reflector immediately surrounding the core tanks were cooled by room air drawn in through the vents on the four faces of the biological shield, toward the top. That air was then taken to the Fan House (TRA-610) by large blowers, which have since been removed.

1.2 Contaminated Surfaces

Surfaces within the MTR biological shield that may carry residual contamination include the remaining components in the MTR core, the tanks that make up the core barrel, and the 24-in. -diameter pipes carrying primary coolant to the Process Water Building (TRA-605). Air ducts carrying cooling air that had passed through the graphite reflector also have measured contamination. The surface contamination is discussed in detail in EDF-6381.

The main core tank assembly consisting of Tanks “A” through “E” was filled with water during MTR operations. The internal surface area of those tanks is approximately 219 m^2 (2,362 ft^2). That number includes estimates for nozzles, protrusions, primary coolant pipes (inside the biological shield), process water lines, etc., but it does not include the surface area of the core itself or the reflector.

Two 61-cm (24-in.) -diameter primary coolant pipes carried water between the reactor and the Process Water Building (TRA-605). Those lines have been drained for over 20 years, but it is likely that they have some residual contamination on their surfaces. The parts of those pipes beyond the biological shield are not included in this analysis. Areas of those pipes within the perimeter are included in the surface area values.

Air passing over the graphite balls was ultimately carried through a 1.2-m (4-ft) -diameter exhaust duct. That duct emptied into the exhaust air duct pit, located in TRA-635, and then continued to the Fan House (TRA-607). Smear samples were taken in the exhaust air duct pit after reactor shutdown in 1970 and prior to 1984.

1.3 Physical and Hydrogeologic Setting

The INL Site is located near the northwest margin of the Eastern Snake River Plain (ESRP), which is a prominent, relatively flat, arc-shaped feature of southeastern Idaho. The ESRP has an average elevation of approximately 4,920 ft (1,500 m) above mean sea level. Elevations within the INL Site generally range from 4,760 to 5,200 ft (1,450 to 1,585 m) above mean sea level. A broad topographic ridge extends to the northeast along the central axis of the ESRP. This ridge effectively separates the drainage of the mountain ranges north and west of the INL Site from the Snake River.

This section provides a brief background regarding the hydrologic setting at the RTC. This background information, including the figures, was summarized from a recent study: *Response to the First Five-Year Review Report for the Test Reactor Area, Operable Unit 2-13, at the Idaho National Engineering and Environmental Laboratory* (DOE-NE-ID 2005).

Figure 4 is a general map of the RTC and surrounding vicinity showing monitoring wells and waste disposal ponds. For reference, the area within the double security fence at the RTC is approximately 1,700 × 1,900 ft (518 × 579 m or approximately 70 acres). The RTC is located on an alluvial plain that consists of surficial sediment with thickness ranging from 30 to 75 ft (9.1 to 22.9 m). Perched water bodies of variable size exist in the vadose zone beneath the RTC. The extensive perched water bodies are primarily a result of infiltration from anthropogenic sources and a complex heterogeneous geology. The perched water bodies are present at different depths in the thick vadose zone (approximately 450 ft or 137 m thick).

Native soils in the RTC area are primarily sandy silt loam with sand fractions ranging in size from very fine to very coarse. Soil depths range from very shallow to very deep and are intermixed with basalt flows. Regional data indicate that the soils in this area are primarily loess and are characterized as having moderate infiltration rates. The INL Site's surficial deposits are quite variable and include eolian (loess and sand dunes); alluvial (gravel, sand, and silt); and lacustrine (clay, silt, and sand) deposits. The surface soils vary widely in thickness and in water-holding capacity. Sedimentary interbeds within the subsurface basalt stratigraphy exhibit the same characteristics as the surficial sediments.

1.3.1 Physiographic Setting

The land surface at the RTC is gently sloped to the southwest and is relatively flat with elevations ranging from 4,945 ft (1,507 m) on top of a rubble pile in the cold waste pond to 4,908 ft (1,496 m) at the bottom of the chemical waste pond. The RTC is located on thick deposits of alluvial gravels associated with the relatively flat flood plain of the Big Lost River.

The Big Lost River flood plain overlies the ESRP, which was formed by the eruption of basalts from low-shield volcanoes and vents (Greeley 1982). Overlapping flows and sedimentary deposits produced the complex stratigraphy underlying the RTC.

1.3.2 Stratigraphy/Lithology at the Reactor Technology Complex

The stratigraphy at the RTC consists of a complex stack of basalt flows and sedimentary deposits, as shown in Figure 5. The cross section shown in Figure 5 is for wells to the south of the RTC and does not provide a detailed stratigraphy for the RTC interbeds. Rather, it is an example to help visualize the subsurface geologic system. The interbeds are not modeled individually in the risk assessment; therefore, the RTC stratigraphy was not characterized in detail for this report.

The upper portion of the basalt-sediment stack is capped with a thick section of surficial alluvial/fluvial deposits. The surficial alluvial deposits are unconsolidated sediments. The fluvial deposits (chiefly sands and gravels) rest atop the undulating surface of a massive basalt flow group; hence, the thickness of the alluvium varies throughout the area. Finer-grained sediments seem to have settled into depressions in the basalt surface. In general, thickness of the alluvium ranges from approximately 32 ft (9.75 m) in the northwest section of the RTC to approximately 55 ft (16.8 m) to the south, with a mean thickness of 49 ft (14.9 m) (Anderson 1991).

A thick sequence of basalt flows and sedimentary interbeds underlie the surficial alluvium at the RTC, extending to depths of 2,000 to 3,000 ft (610 to 914 m) below land surface. The basalt stratigraphy at the RTC has been determined by thorough evaluation of cores and cuttings and by correlation of geophysical logs from over 70 wells completed in the eastern Snake River Plain Aquifer (SRPA). A total of 17 basalt flow groups were identified along with at least eight sedimentary interbeds. The basalt flows increase in thickness and decrease in hydraulic conductivity with depth. This decrease can be partially

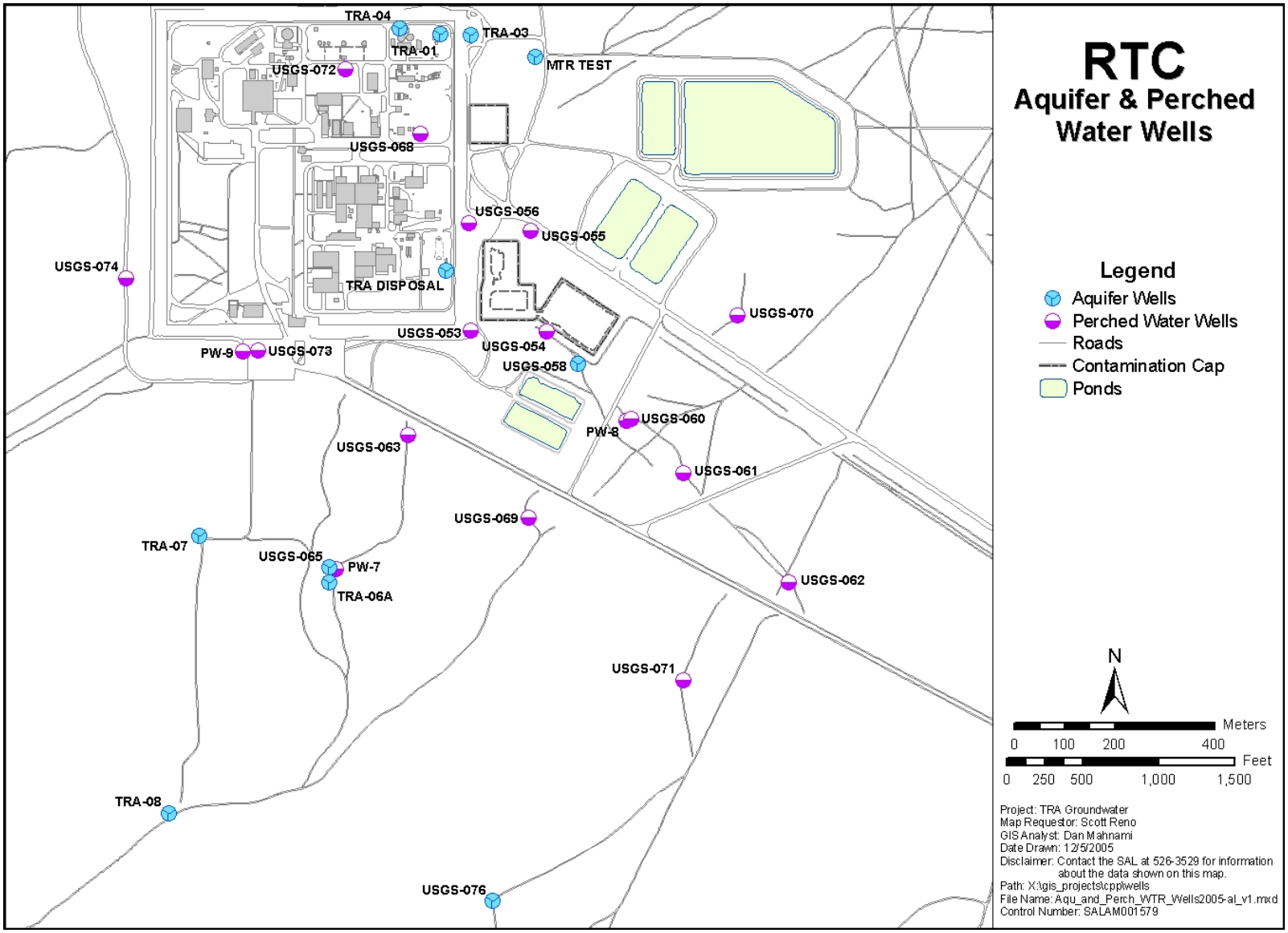
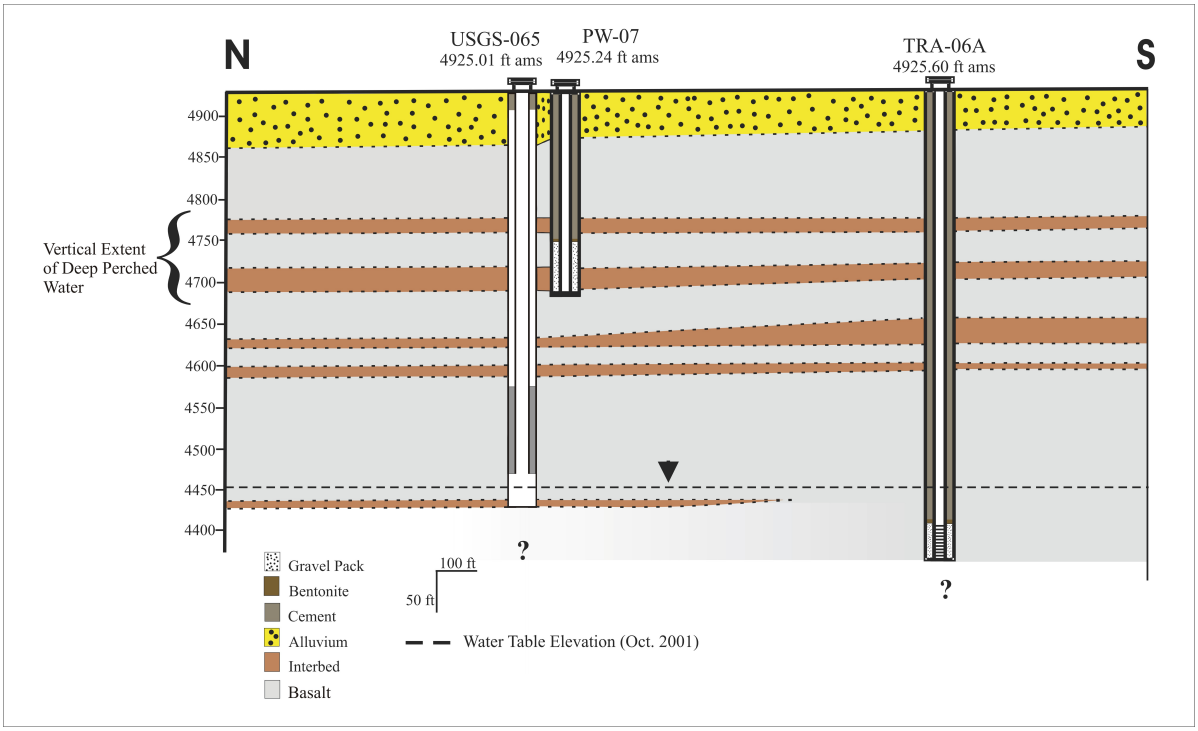


Figure 4. Map of the Reactor Technology Complex showing monitoring wells and waste disposal ponds.



(Source: DOE-NE-ID 2005)

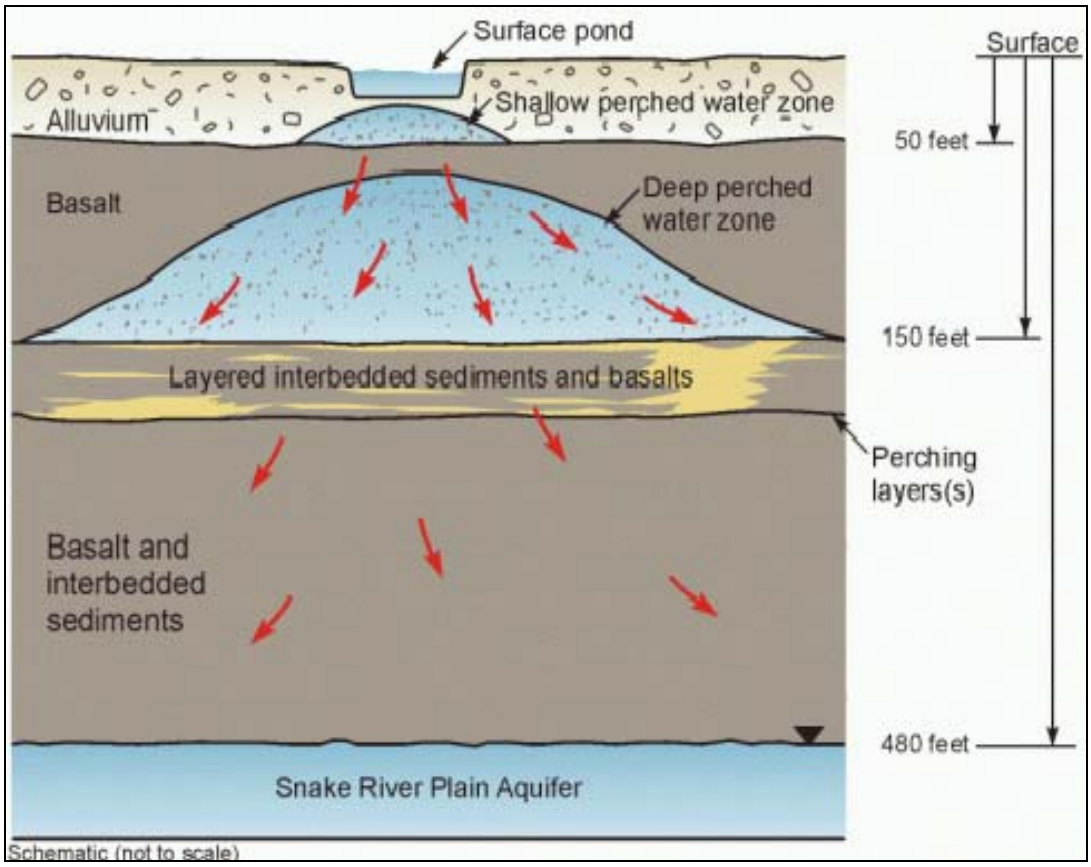
Figure 5. Generalized cross section showing the stratigraphy at USGS-065, PW-07, and TRA-06A.

attributed to decreased interflow rubble zones and to secondary mineralization within fractures and other porous regions of the flows. From a hydrologic perspective, two interbeds are of primary concern. The first is located at an approximate depth of 140 to 200 ft (42.7 to 61 m) below land surface. The thickness of this sedimentary interbed is approximately 60 ft (18.3 m), and it has been encountered in 14 of 17 wells drilled in the area. A second significant sedimentary interbed is encountered in the USGS-65 well at approximately 500 ft (152.4 m) below land surface (INEEL 2002). It is estimated that another 30 ft (9.14 m) of interbed is distributed throughout the vadose zone beneath the MTR at the RTC.

1.3.3 Perched Water at the Reactor Technology Complex

A series of basalt flows interbedded with sedimentary deposits underlie the surficial sediments and make up the subsurface geologic system. The sedimentary interbeds vary in both thickness and lateral extent. The basalt contacts—often rubbly and highly vesicular—are usually very permeable, water-bearing intervals in both the perched water zones and the underlying SRPA. The basalt/sediment interfaces have much lower permeabilities and act as aquitards and perching layers.

Perched water forms in the vadose zone when the rate of infiltrating water exceeds the capacity of a low-permeability layer (such as sediments of massive basalt) to transmit water. The size or “footprint” of the perched water body expands until sufficient area is wetted to transmit the flux of infiltrating water. Alternatively, water can “spill” over the edge of a perching layer that is not laterally extensive. Thus, widespread layers with very low permeability can form larger perched water bodies if there is a large source of water infiltration. The footprint and depth of the perched water body will increase or decrease as the rate of infiltration increases or decreases. A conceptual drawing illustrating the development of perched water beneath the RTC is shown in Figure 6.



(Source: DOE-NE-ID 2005).

Figure 6. Conceptual diagram demonstrating the perched water formation.

Water discharge to past and present RTC ponds has resulted in the formation of relatively large perched water bodies in the vadose zone beneath the RTC. After closure of the facility, there will be no large surface-water discharges and the perched water bodies are expected to largely disappear. Since the MTR is not close to the ponds and the perched water is expected to largely disappear after closure, effects of the ponds on contaminant transport are not included in this analysis.

1.3.4 Snake River Plain Aquifer beneath the Reactor Technology Complex

The SRPA is defined as the series of water-bearing basalt flows and sedimentary layers that underlie the ESRP. The SRPA is approximately 200 mi long, 40 to 60 mi wide, and covers an area of 9,600 mi^2 (approximately 25,000 km^2) (Hull 1989). The aquifer is relatively permeable because of the presence of fractures, fissures, and rubble zones at contacts between individual basalt flows. At the RTC, the SRPA occurs at approximately 480 ft (146.3 m) below land surface.

Generally, groundwater in the SRPA flows to the southwest under the ambient hydraulic gradient (Figure 7). The RTC is shown with its previous name, TRA, in the figure. Figures 7 and 8 are from the *Response to the First Five-Year Review Report for the Test Reactor Area, Operable Unit 2-13, at the Idaho National Engineering and Environmental Laboratory* (DOE-NE-ID 2005). Figure 8 depicts the aquifer water table at the RTC in October 2002. The inherent heterogeneity of the fractured basalt aquifer makes it very difficult to contour the water table, and local flow directions may vary significantly. Figure 8 also shows the inferred direction of groundwater flow beneath the RTC. The direction of flow is

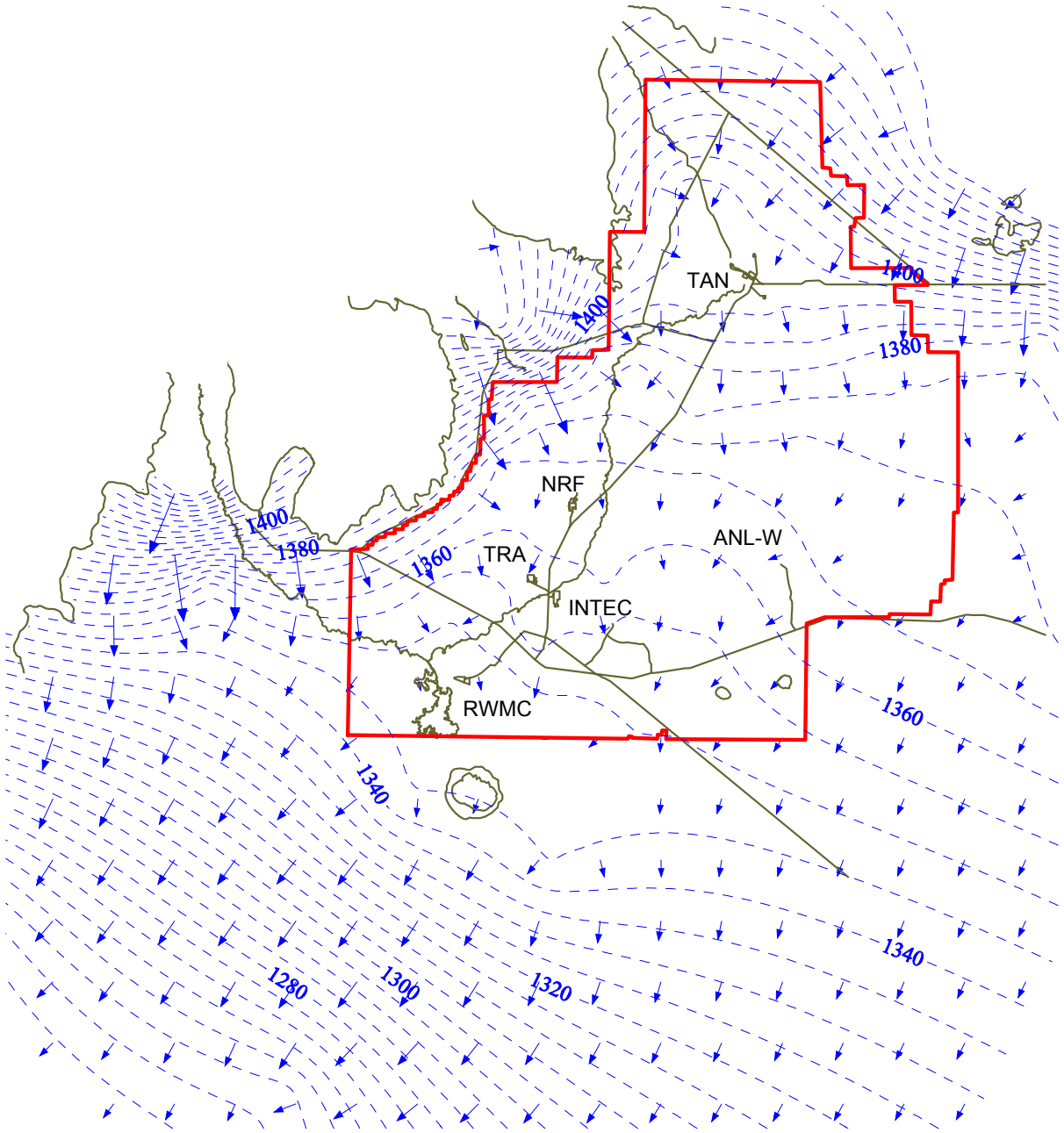


Figure 7. June 2004 water table elevation contour map (meters above mean sea level) for the Snake River Plain Aquifer in the vicinity of the Idaho National Laboratory Site with hydraulic gradient vectors (shown proportional to gradient magnitude). (Figure source: DOE-NE-ID 2005. The Test Reactor Area is the former name for the Reactor Technology Complex and Argonne National Laboratory-West is the former name for the Materials and Fuels Complex.)

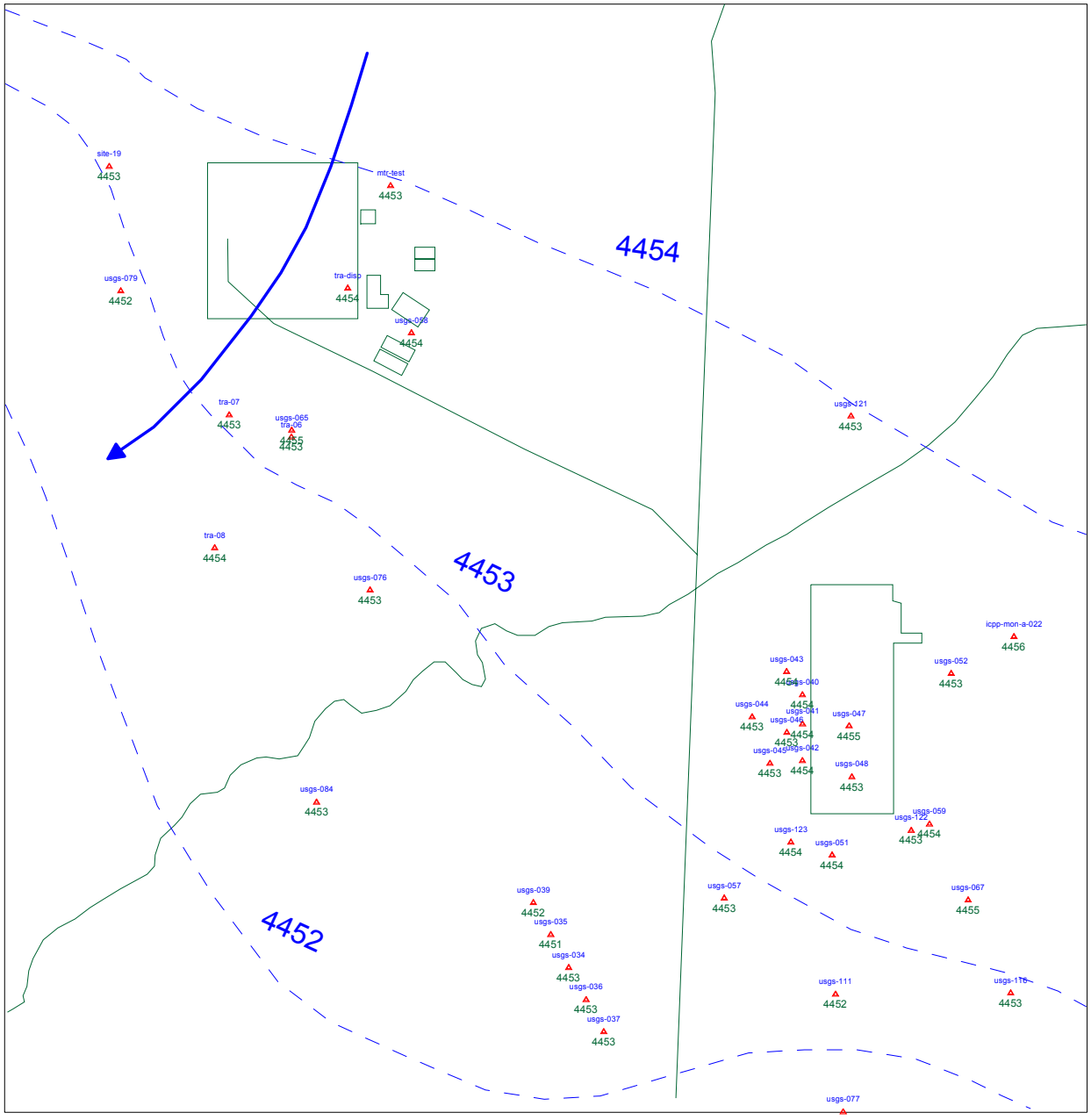


Figure 8. Aquifer water table configuration for October 2002 in the vicinity of the Reactor Technology Complex. (Figure source: DOE-NE-ID 2005)

inferred, because the aquifer's highly heterogeneous nature creates anisotropy that can result in flow paths not perpendicular to the water level contours. Fluctuating water levels caused by recharge and pumping further complicate determination of the aquifer flow directions. The figure provides a general estimate of flow direction after closure of the RTC (end of pumping and simplification of recharge) but does not provide local scale flow directions related to the October 2002 water table measurements. Groundwater flow beneath the RTC is generally to the southwest (Figure 8), but the direction and water table gradient vary in both time and space.

2. CONTAMINANT INVENTORY

The MTR contains both radionuclide and nonradionuclide contaminants. Evaluations of the radionuclide inventory are presented in WM-F1-83-016 and EDF-6381. For the nonradionuclides, inventory calculations are shown in EDF-6244. A short summary of the radionuclide inventory and summary tables for the radionuclide and nonradionuclide inventories are presented in Sections 2.1 and 2.2.

2.1 Radionuclide Inventory of the Materials Test Reactor

Radiological contaminant inventories associated with MTR are documented in

- WM-F1-83-016, *Characterization of the Materials Testing Reactor*
- EDF-6381, "Materials Test Reactor (MTR) Complex Activity vs. Depth."

The physical and radiological conditions of the inactivated MTR were characterized more than 20 years ago and documented in WM-F1-83-016. In 2004, a detailed study (EDF-6381) was performed to characterize the radiological contamination remaining in the MTR and associated buildings. Major contamination groups include activated structures inside the MTR vessel and surface contamination on facility walls and other surfaces. For activated material within the reactor vessel and nearby, calculations were performed, making use of the MCNP-4C code to estimate neutron fluxes at various locations; then, the ORIGEN2 code, with more detailed mass and composition data than have been used in the past, was used to calculate activation and fission products.

The source term of the MTR complex above grade level, from grade level to 3 ft below grade, from grade level to 10 ft below grade, and the source term below grade level (to the bottom of the concrete slab of the lowest level for each building in the MTR complex) are estimated in EDF-6381. Buildings associated with the MTR complex that are scheduled for D&D include the following and can be found in Figure 2:

- TRA-603, MTR Reactor Building, designed to enclose the reactor structure, canal, and to provide space for experimental facilities (both on the main floor and in the basement). The second and third floors of this building contained the control room, electrical equipment room, and office areas.
- TRA-604, laboratory facility located to the west of the reactor building.
- TRA-610, Fan House, located near the MTR stack which houses the blowers used to circulate air through the MTR and other facilities.
- TRA-626, Compressor Building, located on the northeast corner of the reactor building.
- TRA-630, Catch Tank Pump Pit, located to the south of Building TRA-604. The pit contains pumps valves and piping associated with the TRA-730 hot waste catch tanks.

- TRA-635, Reactor Services Building, located to the south of the reactor building. This building was used for warehousing and storage, quality inspections, and x-ray operations.
- TRA-654, ETRC building that was used to house the Engineering Test Reactor Critical Facility.
- TRA-657, Plug Storage Facility, used to store radioactive materials.
- TRA-661, radiochemical laboratory facility.
- TRA-665, Twenty-Meter Neutron Chopper House, located on the east corner of the reactor building.
- TRA-668, physics laboratory facility and clean room.
- TRA-709, air intake shaft for the MTR reactor building.
- TRA-710, MTR exhaust stack and monitor building.
- TRA-730, underground vault containing four hot waste catch tanks.
- TRA-784, liquid nitrogen tank.

Source term details for each facility can be found in EDF-6381. The values used for this analysis were taken from EDF-7405.

Table 2 lists the radionuclide inventory for the three closure alternatives. Note there is very little difference between Alternative 1 and Alternative 2 in terms of total inventory. The inventory is primarily in the reactor; therefore, there is a significant difference between the inventories of Alternatives 1 and 2 when compared to Alternative 3, which assumes the reactor is removed.

Table 2. Radioactive inventory for Materials Test Reactor decommissioning and dismantlement activities for 2005.

Radionuclides	Alternative 1 (No Action) (Ci)	Alternative 2 (abovegrade building removed, only) (Ci)	Alternative 3 (abovegrade building plus reactor removed) (Ci)
Ac-227	4.77E-07	4.77E-07	0.00E+00
Ag-108m	1.61E-01	1.61E-01	0.00E+00
Ag-110m	4.80E-15	4.80E-15	0.00E+00
Am-241	9.21E-02	9.15E-02	1.68E-02
Am-243	6.61E-05	6.61E-05	0.00E+00
Be-10	5.59E-02	5.59E-02	0.00E+00
C-14	3.32E+00	3.31E+00	1.08E-02
Ce-144	5.69E-04	5.69E-04	5.69E-04
Cf-252	4.99E-06	4.99E-06	4.99E-06
Cl-36	3.20E-02	3.20E-02	0.00E+00
Cm-242	9.78E-07	9.78E-07	9.78E-07
Cm-243	4.64E-05	4.64E-05	0.00E+00
Cm-244	1.29E-03	1.29E-03	6.23E-05
Cm-245	1.77E-07	1.77E-07	0.00E+00
Cm-246	3.10E-08	3.10E-08	0.00E+00
Cm-247	4.00E-14	4.00E-14	0.00E+00
Cm-248	4.81E-14	4.81E-14	0.00E+00

Table 2. (continued).

Radionuclides	Alternative 1 (No Action) (Ci)	Alternative 2 (abovegrade building removed, only) (Ci)	Alternative 3 (abovegrade building plus reactor removed) (Ci)
Co-60	6.06E+01	6.05E+01	1.30E-01
Cs-134	2.36E-03	2.36E-03	1.15E-03
Cs-137	7.35E-01	7.01E-01	2.30E-01
Eu-152	5.65E+00	5.65E+00	3.09E-05
Eu-154	1.02E+00	1.02E+00	2.06E-04
Eu-155	9.50E-05	9.50E-05	9.50E-05
Fe-55	6.02E-06	6.02E-06	6.02E-06
H-3	2.22E+02	2.22E+02	0.00E+00
I-129	6.25E-04	3.99E-04	3.95E-04
Mn-54	2.07E-10	2.07E-10	0.00E+00
Nb-94	5.31E-02	5.31E-02	0.00E+00
Nb-95	4.24E-06	4.24E-06	4.24E-06
Ni-59	4.53E+00	4.53E+00	6.02E-07
Ni-63	4.69E+02	4.69E+02	6.63E-03
Np-237	1.03E-06	1.03E-06	0.00E+00
Pa-231	6.43E-07	6.43E-07	0.00E+00
Pb-210	1.90E-10	1.90E-10	0.00E+00
Pu-238	8.40E-02	8.39E-02	6.65E-02
Pu-239	1.84E-01	1.84E-01	1.45E-01
Pu-240	6.78E-02	6.77E-02	5.36E-02
Pu-241	4.12E-01	4.12E-01	0.00E+00
Pu-242	2.08E-05	2.08E-05	0.00E+00
Pu-244	3.77E-13	3.77E-13	0.00E+00
Ra-226	5.12E-10	5.12E-10	0.00E+00
Ru-106	9.57E-11	9.57E-11	0.00E+00
Sb-125	3.75E-04	3.75E-04	5.60E-05
Sr-90	4.39E-01	4.27E-01	2.31E-01
Tc-99	3.61E-03	3.61E-03	0.00E+00
Th-228	4.55E-05	4.55E-05	0.00E+00
Th-229	7.19E-07	7.19E-07	0.00E+00
Th-230	4.74E-08	4.74E-08	0.00E+00
Th-232	3.31E-05	3.31E-05	0.00E+00
U-232	1.28E-05	1.28E-05	5.66E-07
U-233	1.76E-04	1.76E-04	0.00E+00
U-234	1.21E-04	1.21E-04	1.31E-05
U-235	4.70E-06	4.70E-06	1.15E-07
U-236	9.79E-07	9.79E-07	0.00E+00
U-238	1.04E-04	1.04E-04	3.55E-07
Zn-65	3.18E-06	3.18E-06	3.18E-06

2.2 Nonradionuclide Inventory of the Materials Test Reactor

The nonradiological contaminant inventory associated with MTR is documented in EDF-6244, "Materials Test Reactor Complex Chemical Constituent Source Term." For the No Action alternative, the entire nonradiological inventory from EDF-6244 (and summarized in EDF-7405), which includes inventory in buildings other than TRA-603, is used in this risk assessment. For Alternatives 2 and 3, the inventory from EDF-6244 is modified to be consistent with the values used in EDF-7405. Since the mass of the uranium was not shown in EDF-7405, it was calculated based upon the activities of the uranium isotopes shown in Table 2 to obtain total uranium mass. The nonradionuclide inventory is shown in Table 3.

Table 3. Total mass of nonradioactive contaminants associated with Materials Test Reactor.

	No Action Alternative (kg)	Alternative 2 (kg)	Alternative 3 (kg)
	Organics		
Polychlorinated biphenyls (Aroclor 1254 and 1260)	4.10E-03	3.40E-03	3.40E-03
	Inorganics		
Aluminum	1.26E+04	1.26E+04	1.00E+01
Antimony (and compounds)	6.00E-01	6.00E-01	6.00E-01
Barium (and compounds)	1.45E+06	1.45E+06	1.00E+01
Beryllium (and compounds)	2.15E+03	2.15E+03	1.00E+01
Boron	1.40E+02	1.40E+02	1.00E+01
Chromium (total)	1.59E+04	1.59E+04	5.75E+03
Copper (and compounds)	2.93E+04	2.93E+04	1.47E+04
Lead	1.22E+04	1.22E+04	3.00E+01
Manganese (and compounds)	5.61E+03	5.61E+03	2.40E+03
Nickel (soluble salts)	9.79E+03	9.79E+03	3.98E+03
Silver (and compounds)	3.00E+01	1.00E+00	1.00E+00
Tin	6.00E+01	6.00E+01	6.00E+01
Uranium (from isotopes) [a]	3.12E-01	3.12E-01	1.11E-03
Zinc	1.80E+02	1.80E+02	1.80E+02

a. The uranium mass is the sum of the mass from each of the uranium isotopes shown in Table 2.

3. RADIONUCLIDE CONTAMINANT EVALUATION

The inventory for the MTR consisted of 56 individual radionuclides and 15 nonradionuclides. The large number of contaminants presents difficulties in estimating future dose impacts and dilutes resources from those nuclides that are most important. Therefore, contaminant screening was performed to reduce the number of contaminants to a manageable level and focus resources on those contaminants that are most important. Contaminant screening and the conservative risk assessment analysis used are discussed below.

Contaminant transport evaluation and risk assessment were performed through a series of two screening phases, followed by a more detailed risk assessment. Each screening phase begins with conservative assumptions. The conservative assumptions are lessened through each phase of the screening process. The two screening analysis phases are as follows:

- Phase 1 screening is used only for radionuclides. It used screening factors developed by the National Council on Radiation Protection (NCRP) (NCRP 1996) together with the estimated contaminant inventory. This screening approach has been used in a variety of past INL studies, including the engineering evaluation/cost analyses for the Engineering Test Reactor (DOE-ID 2006; EDF-5142) and CPP-603 (DOE-NE-ID 2004; EDF-4488), and the ICDF Performance Assessment (DOE-ID 2003).

- Phase 2 screening used a simple and conservative application of the GWSCREEN (Rood 2003) model to calculate a screening dose, risk, or concentration, based on the contaminant radionuclide or nonradionuclide inventory. The GWSCREEN application considers dispersion and unsaturated transit time, whereas the NCRP does not. The Phase 2 screening application of GWSCREEN is based on the Track 2 screening approach used in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC § 9601 et seq.) process at the INL Site. The Track 2 screening approach is documented in *Track 2 Sites: Guidance for Assessing Low Probability Hazard Sites at the INEL* (DOE-ID 1994). The methodology was originally developed to perform conservative analysis on low-probability CERCLA sites with the goal to systematically eliminate No Action sites from further evaluation. Since that time, the methodology has regularly been used for contaminant screening at the INL.

In Phase 2, using the Track 2 screening approach, radionuclides are screened from further consideration if the predicted maximum risk for the groundwater pathway is less than 10^{-6}. In order to screen nonradionuclides, fractions were calculated that are defined as the fraction of the predicted nonradionuclide concentrations in relation to the maximum contaminant levels (MCLs) for each contaminant. For the conservative screening, a peak constituent-specific fraction of 0.1 (peak concentration equal to one-tenth the MCL) was used to eliminate contaminants of concern (COCs) that will not significantly contribute to the total aquifer contamination.

As will be discussed later in this document, not all of the nonradionuclides have an MCL. Yet some measure of the impact on groundwater quality is needed for each nonradionuclide. For purposes of this analysis, constituents with no MCL are evaluated using other standards. The other standards include secondary MCLs, action levels, remanded MCLs, and preliminary remediation goals (PRGs). The U.S. Environmental Protection Agency (EPA) refers to a secondary MCL as a National Secondary Drinking Water Regulation and is a nonenforceable guideline regulating contaminants that might cause cosmetic effects (such as taste, odor, or color) in drinking water. Action levels are related to a treatment technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, then water systems must take additional steps to control pipe corrosion. A remanded MCL is an MCL that was adopted in the past and then removed as an MCL. The MCL for nickel was remanded on February 9, 1995. This means that while many water suppliers continue to monitor nickel levels in their water, there is currently no EPA legal limit on the amount of nickel in drinking water. The EPA is reconsidering the limit on nickel. A PRG is defined by EPA's Region 9 office as a nonenforceable, generic standard for evaluating and cleaning up contaminated sites. It is a risk-based concentration that is intended to assist risk assessors and others in initial screening-level evaluations of environmental measurements.

Contaminants not screened out are defined as the COCs. For the COCs' risk assessment, some of the more stringent, conservative assumptions used in the Phase 2 screening were relaxed. However, the final analysis is still conservative in the sense that it is based, in large part, on the conservative assumptions of a Track 2 analysis, changing some of the parameters to more accurately represent the MTR source term and flow and transport system. A primary conservative assumption retained through the screening and final risk assessment is that the contaminants are immediately available for leaching from the source. In fact, this is a very conservative assumption for many of the contaminants because much of the contamination is contained within the stainless steel, beryllium, and lead. Therefore, the metals must corrode before the contaminants are released and available for leaching to the subsurface. Assuming that the metals have already corroded is a very conservative assumption.

For the COC risk assessment, the modified parameters are as given below:

- The infiltration rate was changed from 10 cm/yr to 1 cm/yr. An infiltration rate of 1 cm/yr is the estimated infiltration rate for undisturbed soils at the INL Site (DOE-NE-ID 2005; DOE-ID 2003). The assumption is that the MTR will be left with at least a soil cover that will limit the infiltration rate to the rate of undisturbed soils. Contaminants are primarily contained in metals that must corrode before the contaminants are available for transport. Significant fractions of the contaminants will not be available until long after the MTR is closed and the soil cover is established. Therefore, a steady-state infiltration assumption is reasonable for this analysis.

- The dispersion in the unsaturated zone was modified. In the Phase 2 screening simulations there is no dispersion in the unsaturated zone. For the COC risk assessment, dispersion in the unsaturated zone is included.

3.1 Phase 1 Screening of Radionuclide Inventory

The NCRP provides a series of simple screening techniques and factors that can be used to demonstrate compliance with environmental standards or other administratively set reference levels for releases of radionuclides to the atmosphere, surface water, or groundwater. The NCRP screening factor is the product of an environmental transfer factor, exposure factor, and a dose conversion factor having units of total effective dose equivalent per unit of activity in sieverts per Becquerel (Sv/Bq). These factors incorporate radionuclide fate and transport processes and an assumed exposure scenario to calculate the annual total effective dose equivalent to a hypothetical receptor per unit of activity in the source volume. The screening factors applicable to groundwater exposure consider leaching and subsequent dilution of radionuclides in groundwater from a generic waste site. Factors are calculated for six delay times: 0, 2, 10, 30, 100, and 1,000 years. During the delay time, radionuclides are decayed and ingrown. The maximum of the six values is then reported in the screening factor tables for groundwater.

The exposure scenario essentially assumes that the entire waste inventory is susceptible to leaching over a period of 1 year into a water volume equal to the annual average per capita use of groundwater in rural regions of the United States (91,000 L). The receptor is then assumed to drink 800 L of this contaminated water over a period of 1 year and his/her dose is computed for that intake.

The screening factor for groundwater is given in Equation (1) (NCRP 1996) by:

$$SF = \lambda_L \, A_o \frac{U_{DW}}{V} \sum_{i=0}^{N} X_i \, DCF_{ing,i} \qquad (1)$$

where

SF = groundwater screening factor (Sv/Bq)

λ_L = leach rate constant (yr^{-1})

A_o = initial activity (Bq)

U_{DW} = consumption of drinking water (assumed to be 800 L/yr)

V = dilution volume (assumed to be 91,000 L)

X_i = annual average fraction of the original parent activity for decay chain member (i)

DCF_{ing} = ingestion dose conversion factor (Sv/Bq)

N = number of progeny in the decay chain.

Assuming there is 100% containment of the waste during the delay time and the release of radioactivity is averaged over the first year of the release following the delay time, the fraction of the original parent activity leached to the dilution volume over 1 year for the parent (X_0) is given in Equation (2) by:

$$X_0 = \frac{\left(1 - e^{-\left(\lambda + \lambda_0^r\right)T_{avg}}\right) e^{-\lambda_0^r T_{del}}}{T_{avg}\left(\lambda_L + \lambda_0^r\right)} \tag{2}$$

where

λ^r_o = radioactive decay rate constant for parent (yr^{-1})

T_{avg} = averaging time (1 yr)

T_{del} = delay time (yr).

A typographical error in Equation (2) was noted in the NCRP text.

The fraction of progeny activity relative to the parent that is leached to the dilution volume is given in Equation (3) by:

$$X_i = \frac{1}{T_{avg}}\left(\prod_{j=1}^{K} \lambda_j^r f_j\right)\sum_{h=0}^{N} \frac{\left(1 - e^{-\lambda_h^r T_{avg}}\right) e^{-\lambda_h^r T_{del}}}{\lambda_h^r \prod_{\substack{p=0 \\ p \neq h}}^{K}\left(\lambda_p^r + \lambda_h^r\right)} \tag{3}$$

where

f_j = fraction of parent decaying to *jth* progeny

λ^r_h = radioactive decay rate constant for *jth* progeny parent (yr^{-1}).

The leach rate constant is taken from a formulation described in "A Proposal for Estimation of Soil Leaching and Leaching Constants for Use in Assessment Models" (Baes and Sharp 1983) and used in the models RESRAD (Yu et al. 2001), Multimedia Environmental Pollutant Assessment System (MEPAS) (Whelan, McDonald, and Sato 1996), and GWSCREEN (Rood 2003). The leach rate constant is given in Equation (4) by:

$$\lambda_L = \frac{I}{H\,\theta\left(1+\frac{K_d\rho}{\theta}\right)} \tag{4}$$

where

I = assumed infiltration rate (0.18 m yr^{-1})

H = assumed waste thickness (0.5 m)

ρ = bulk density (cm^3/g)

K_d = sorption coefficient (cm^3/g)

θ = moisture content (0.3 m^3/m^3).

Values for the sorption coefficient used in the NCRP screening were taken from the *Residual Radioactive Contamination from Decommissioning* (Kennedy and Strenge 1992). The assumed infiltration rate represents the upper-bound infiltration rate determined for low-level radioactive waste sites located in the southeastern United States.

The assumption is made in Equation (3) that the unsaturated travel time is instantaneous. For the INL Site, this is an extremely conservative assumption, because unsaturated contaminant travel times have been estimated to take from several years to hundreds of thousands of years depending on the sorption properties of the contaminant. Under these assumptions, the NCRP groundwater-screening model provides a conservative estimate of the potential dose.

Nuclides with an NCRP screening dose of less than 1 mrem (1×10^{-5} Sv) were removed from further consideration. These nuclides are identified in Table 4 along with their NCRP screening dose value. The NCRP screening dose is calculated by multiplying the radionuclide inventory by the NCRP screening dose factor. For example, the NCRP screening dose for Ac-227 is shown in Equation (5):

$$\mathrm{SD} = 1.01\times10^{-6}\ \mathrm{Ci} \times 3.7\times10^{10}\ \frac{\mathrm{Bq}}{\mathrm{Ci}} \times 8.1\times10^{-12}\ \frac{\mathrm{Sv}}{\mathrm{Bq}} = 3.03\times10^{-7}\ \mathrm{Sv} \quad . \tag{5}$$

The Alternative 1 inventory was evaluated in the Phase 1 screening because it is the most conservative alternative. Of the 56 nuclides for which inventories are reported in Section 2 and repeated in Table 4, approximately half of the nuclides were screened in Phase 1, leaving 24 nuclides with a screening dose greater than 1 mrem (1×10^{-5} Sv). In addition, because Np-237 is the primary progeny (from a groundwater pathway perspective) of Am-241 and Pu-241, Np-237 is included in the Phase 2 evaluation. A total of 25 radionuclides are retained for the Phase 2 evaluation.

Table 4. Phase 1 screening results for radionuclides using the National Council on Radiation Protection screening factors.[a]

Radionuclide	Radioactive Half-Life (yr)	MTR Inventory (Alternative 1) (Ci)	MTR Inventory (Alternative 1) (Bq)	Groundwater Ingestion NCRP Screening Factor (Sv/Bq)	Screening Dose (Sv)	Is Screening Dose >1 mrem? (>1 × 10^{-5} Sv?)
Ac-227	2.18E+01	4.77E-07	1.76E+04	8.10E-12	1.43E-07	No
Ag-108m	**4.18E+02**	**1.61E-01**	**5.96E+09**	**4.20E-14**	**2.50E-04**	**Yes**
Ag-110m	6.84E-01	4.80E-15	1.78E-04	5.20E-15	9.24E-19	No
Am-241	**4.32E+02**	**9.21E-02**	**3.41E+09**	**5.90E-13**	**2.01E-03**	**Yes**

Table 4. (continued).

Radionuclide	Radioactive Half-Life (yr)	MTR Inventory (Alternative 1) (Ci)	MTR Inventory (Alternative 1) (Bq)	Groundwater Ingestion NCRP Screening Factor (Sv/Bq)	Screening Dose (Sv)	Is Screening Dose >1 mrem? (>1 × 10^{-5} Sv?)
Am-243	7.37E+03	6.61E-05	2.45E+06	6.00E-13	1.47E-06	No
Be-10	**1.51E+06**	**5.59E-02**	**2.07E+09**	**1.40E-14**	**2.90E-05**	**Yes**
C-14	**5.70E+03**	**3.32E+00**	**1.23E+11**	**1.60E-13**	**1.97E-02**	**Yes**
Ce-144	7.81E-01	5.69E-04	2.10E+07	3.60E-15	7.57E-08	No
Cf-252	2.64E+00	4.99E-06	1.85E+05	3.50E-13	6.47E-08	No
Cl-36	**3.01E+05**	**3.20E-02**	**1.18E+09**	**8.30E-13**	**9.83E-04**	**Yes**
Cm-242	4.47E-01	9.78E-07	3.62E+04	1.20E-15	4.34E-11	No
Cm-243	2.91E+01	4.64E-05	1.72E+06	1.50E-13	2.58E-07	No
Cm-244	1.81E+01	1.29E-03	4.78E+07	1.10E-13	5.26E-06	No
Cm-245	8.50E+03	1.77E-07	6.55E+03	5.10E-13	3.34E-09	No
Cm-246	4.76E+03	3.10E-08	1.15E+03	2.90E-13	3.33E-10	No
Cm-247	1.56E+07	4.00E-14	1.48E-03	3.00E-13	4.43E-16	No
Cm-248	3.48E+05	4.81E-14	1.78E-03	1.10E-12	1.96E-15	No
Co-60	**5.27E+00**	**6.06E+01**	**2.24E+12**	**5.80E-14**	**1.30E-01**	**Yes**
Cs-134	2.07E+00	2.36E-03	8.74E+07	4.20E-15	3.67E-07	No
Cs-137	**3.01E+01**	**7.35E-01**	**2.72E+10**	**7.70E-14**	**2.09E-03**	**Yes**
Eu-152	**1.35E+01**	**5.65E+00**	**2.09E+11**	**9.10E-15**	**1.90E-03**	**Yes**
Eu-154	**8.59E+00**	**1.02E+00**	**3.79E+10**	**1.10E-14**	**4.16E-04**	**Yes**
Eu-155	4.96E+00	9.50E-05	3.52E+06	9.50E-16	3.34E-09	No
Fe-55	2.74E+00	6.02E-06	2.23E+05	9.90E-16	2.20E-10	No
H-3	**1.23E+01**	**2.22E+02**	**8.21E+12**	**5.90E-14**	**4.85E-01**	**Yes**
I-129	**1.57E+07**	**6.25E-04**	**2.31E+07**	**1.90E-10**	**4.39E-03**	**Yes**
Mn-54	8.56E-01	2.07E-10	7.66E+00	3.80E-15	2.91E-14	No
Nb-94	**2.03E+04**	**5.31E-02**	**1.96E+09**	**2.70E-14**	**5.30E-05**	**Yes**
Nb-95	9.60E-02	4.24E-06	1.57E+05	7.00E-22	1.10E-16	No
Ni-59	**7.60E+04**	**4.53E+00**	**1.68E+11**	**3.20E-16**	**5.36E-05**	**Yes**
Ni-63	**1.00E+02**	**4.69E+02**	**1.74E+13**	**8.60E-16**	**1.49E-02**	**Yes**
Np-237 [b]	2.14E+06	1.03E-06	3.81E+04	2.40E-10	9.15E-06	No
Pa-231	3.28E+04	6.43E-07	2.38E+04	1.50E-11	3.57E-07	No
Pb-210	2.23E+01	1.90E-10	7.03E+00	5.40E-12	3.80E-11	No
Pu-238	**8.77E+01**	**8.40E-02**	**3.11E+09**	**1.70E-12**	**5.28E-03**	**Yes**
Pu-239	**2.41E+04**	**1.84E-01**	**6.80E+09**	**2.00E-12**	**1.36E-02**	**Yes**
Pu-240	**6.56E+03**	**6.78E-02**	**2.51E+09**	**2.00E-12**	**5.02E-03**	**Yes**
Pu-241	**1.43E+01**	**4.12E-01**	**1.52E+10**	**6.10E-14**	**9.30E-04**	**Yes**
Pu-242	3.73E+05	2.08E-05	7.70E+05	1.90E-12	1.46E-06	No
Pu-244	8.00E+07	3.77E-13	1.39E-02	2.20E-12	3.07E-14	No
Ra-226	1.60E+03	5.12E-10	1.89E+01	4.60E-12	8.71E-11	No
Ru-106	1.02E+00	9.57E-11	3.54E+00	6.50E-14	2.30E-13	No
Sb-125	2.76E+00	3.75E-04	1.39E+07	3.60E-15	4.99E-08	No
Sr-90	**2.88E+01**	**4.39E-01**	**1.62E+10**	**3.50E-12**	**5.69E-02**	**Yes**
Tc-99	**2.11E+05**	**3.61E-03**	**1.34E+08**	**3.20E-12**	**4.27E-04**	**Yes**
Th-228	1.91E+00	4.55E-05	1.68E+06	2.10E-15	3.54E-09	No
Th-229	7.34E+03	7.19E-07	2.66E+04	3.60E-13	9.58E-09	No
Th-230	7.54E+04	4.74E-08	1.75E+03	5.20E-13	9.12E-10	No

Table 4. (continued).

Radionuclide	Radioactive Half-Life (yr)	MTR Inventory (Alternative 1) (Ci)	MTR Inventory (Alternative 1) (Bq)	Groundwater Ingestion NCRP Screening Factor (Sv/Bq)	Screening Dose (Sv)	Is Screening Dose >1 mrem? (>1 × 10^{-5} Sv?)
Th-232	1.41E+10	3.31E-05	1.22E+06	4.80E-13	5.88E-07	No
U-232	**6.89E+01**	**1.28E-05**	**4.72E+05**	**3.30E-11**	**1.56E-05**	**Yes**
U-233	**1.59E+05**	**1.76E-04**	**6.51E+06**	**1.10E-11**	**7.16E-05**	**Yes**
U-234	**2.46E+05**	**1.21E-04**	**4.48E+06**	**4.20E-12**	**1.88E-05**	**Yes**
U-235	7.04E+08	4.70E-06	1.74E+05	1.40E-11	2.44E-06	No
U-236	2.34E+07	9.79E-07	3.62E+04	3.40E-12	1.23E-07	No
U-238	**4.47E+09**	**1.04E-04**	**3.86E+06**	**1.40E-10**	**5.41E-04**	**Yes**
Zn-65	6.69E-01	3.18E-06	1.18E+05	2.90E-15	3.41E-10	No

a. Radionuclides with a screening dose ≥ 1 mrem are in bold and are highlighted. These nuclides were retained for further analysis.
b. Np-237 is the primary progeny (groundwater pathway) of Am-241 and Pu-241; therefore, Np-237 is included in the Phase 2 evaluation.
MTR = Materials Test Reactor.
NCRP = National Council on Radiation Protection.

3.2 Phase 2 Screening

Phase 2 screening used a conservative implementation of the groundwater-screening model GWSCREEN Version 2.5 (Rood 2003) to calculate groundwater concentrations and risk for nuclides that were not screened in Phase 1. For the 15 nonradionuclides in the inventory, the peak concentration was calculated for comparison with the MCL or a related limiting value. The GWSCREEN model was developed to address CERCLA sites at the INL Site. The code, coupled with a set of default parameter values identified in the CERCLA Track 2 risk assessment process (DOE-ID 1994), provides conservative estimates of groundwater concentrations and the related ingestion doses and risks at the INL Site. The contaminants are screened based on the predicted peak dose and risk for radionuclides and the predicted peak concentration for nonradionuclides.

The GWSCREEN conceptual model is illustrated in Figure 9. The following are primary assumptions in the flow and transport analysis:

- All radionuclides present in the MTR are assumed to be mixed homogeneously with soil and placed in a volume represented by the volume of the MTR belowground structure, 39.6 m × 39.6 m. Although the contamination is initially focused in the reactor, the contamination must be released from the metal by corrosion, leached into the backfill in the MTR, and move through the MTR facility and the MTR concrete base. In the process, significant spreading will occur. In addition, after leaving the MTR facility, the contamination will spread as it is transported to the aquifer through the vadose zone. The source length and width used in the GWSCREEN model represent both the source area and the final area over which the contaminants will enter the aquifer. The length and width assumption of the MTR footprint is a simple but reasonable assumption for this complex process.

- One-dimensional transport in an 18.3-m (60-ft) -thick unsaturated zone composed of sedimentary interbeds is assumed. This thickness of the vadose zone sedimentary interbeds is based on well log evaluations used to define the perched water remedial investigation modeling (EGG 1992). The total interbed thickness is conservatively assumed to consist only of the interbed 140 ft below ground surface and neglects the interbed that is 500 ft below ground surface.

- The subsurface environment beneath the INL Site comprises basalt flows separated by sedimentary interbeds. The basalt flows are oftentimes fractured, allowing water to move freely in the vertical direction. The Track 2 methodology (DOE-ID 1994) recognized this feature of the system and assumed that water transport time through the fractured basalt is relatively instantaneous. The overall unsaturated transit time is controlled by the presence of sedimentary interbeds. Therefore, only transport through sedimentary interbeds was considered when computing contaminant transport in the unsaturated zone.

- The receptor well is placed on the downgradient edge of the MTR facility. Note that the receptor distance is measured from the center of the source; therefore, the distance to the receptor well is 39.6 m ÷ 2 = 19.8 m. This receptor is the point where the highest concentrations in the aquifer are estimated.

- The conceptual model assumes no containment, engineered barriers, gradual releases to the source via corrosion, or solubility-limited releases. The waste is assumed to be immediately exposed to infiltrating water, and contaminants are leached from the waste and move into the subsurface.

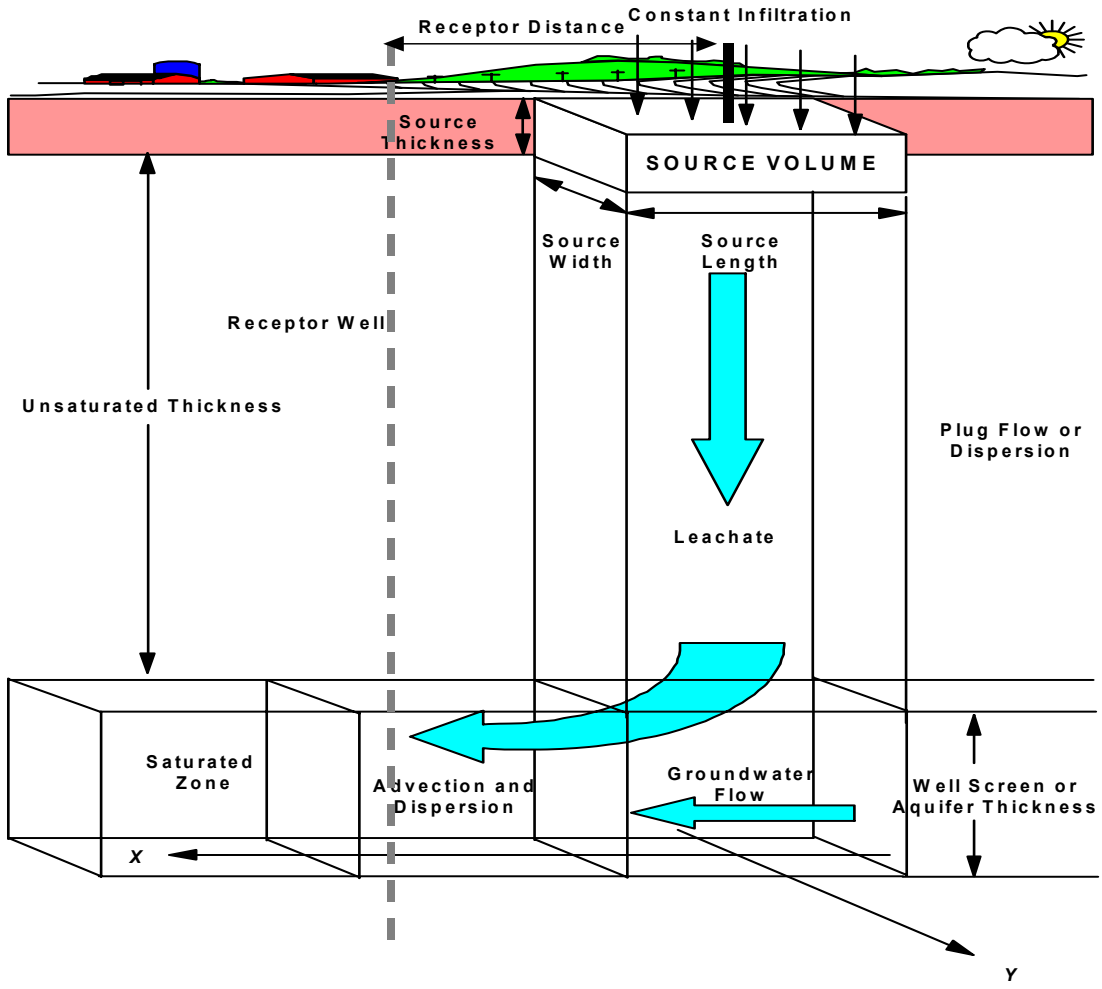


Figure 9. Conceptual model for GWSCREEN groundwater transport model. (For the Materials Test Reactor analysis, the receptor is at the edge of the source.)

- The Track 2 default infiltration rate is 10 cm/yr (3.9 in./yr). This is 10 times larger than the infiltration rate assumed for undisturbed soils at the INL (1 cm/yr).

- No dispersion in the unsaturated zone is assumed. Generally, this is a conservative assumption. However, if the contaminant's travel time through the vadose zone is much less than the radioactive decay half-life, then it is possible that the assumption is not conservative. The screening results were critically reviewed and this exception has basically no effect on this particular analysis.

- The aquifer was assumed to be homogeneous isotropic media of infinite lateral extent and finite thickness.

- Contaminants entering the aquifer from the unsaturated zone mix with water in the aquifer over a depth defined by a typical well screen of 15 m (49.2 ft). The average aquifer thickness is generally assumed to be 76 m (250 ft); therefore, this is a conservative assumption.

The GWSCREEN model also considers transport of radioactive progeny. In the GWSCREEN code, progeny are assumed to travel at the same rate as their parent. Under most circumstances, this assumption leads to conservative risk estimates at the receptor point. However, when considering the transport of a short-lived immobile parent that has a long-lived mobile progeny, results can be distorted and, in many cases, are not conservative. This situation occurs under many infiltration scenarios for the Cm-244⇒Pu-240, Pu-241⇒Am-241⇒Np-237, and Pu-238⇒U-234 decay chains. In general, the short-lived immobile parent nuclide never leaves the waste zone and, instead, decays to its more mobile long-lived progeny. The sorption characteristics of the progeny then determine the overall transit time of the decay chain along with accompanying risk. In addition, this situation can be an issue for Pu-239⇒U-235 and Pu-240⇒U-236. However, whether it is more accurate to simulate the parent or the progeny is a function of the particular simulation assumptions. In this analysis, both Pu-239 and Pu-240 were assessed, assuming transport as plutonium and transport as uranium in order to assure that the most accurate and conservative cases are evaluated.

For conservatism, the entire activity of the short-lived immobile parent is converted to the equivalent progeny activity—Equation (6)—by:

$$A_{Prog} = A_{Parent} \frac{T_{parent}}{T_{Prog}} \tag{6}$$

where

A_{Prog} = equivalent activity of the long-lived mobile progeny (Ci)

A_{Parent} = original activity of the short-lived immobile parent (Ci)

T_{Prog} = half-life of the long-lived mobile progeny (years)

T_{Parent} = half-life of the short-lived immobile parent (years).

For radionuclides, the cancer risk was calculated assuming the receptor ingests water at the peak concentration for a duration of 30 years. The radiological dose coefficients are published in *Cancer Risk Coefficients for Environmental Exposure to Radionuclides* (EPA 1999). The calculation was performed using the GWSCREEN model. The cancer risk was calculated in Equation (7) as:

$$R = C \times I \times ED \times RC \quad (7)$$

where

R = cancer risk

C = predicted peak aquifer concentration (pCi/L)

I = ingestion rate (2 L/d)

ED = exposure duration (30 years)

RC = risk coefficient (risk/pCi).

The radionuclides are screened from further analysis if the predicted peak risk fails the screening criteria. The nonradionuclides are screened based on the relationship between the predicted peak aquifer concentrations and the MCL or related concentration limit. The screening criteria for Phase 2 screening were set as follows:

- For radionuclides, lifetime cancer incidence risk $<10^{-6}$.
- For nonradionulides, the screening criterion was set at one-tenth the MCL or applicable secondary MCL, action level, maximum contaminant level goal (MCLG), remanded MCL, or PRG if no MCL has been defined.

A nuclide is defined as a COC if the predicted peak risk is greater than 10^{-6}. A nonradionuclide is defined as a COC if the predicted peak concentration is greater than one-tenth the MCL or a related limiting concentration.

Input data for the GWSCREEN screening simulation (Table 5) were primarily obtained from the *Track 2 Sites: Guidance for Assessing Low Probability Hazard Sites at the INEL* (DOE-ID 1994). The dimension of the waste disposal site, Darcy velocity in the aquifer, and the sedimentary interbed thickness in the unsaturated zone are site-specific values.

3.2.1 Radionuclide Screening

Nuclide-specific sorption coefficient (K_d) parameter data are reported in the results table (Table 6). The primary source of K_d data was from the *Track 2 Sites: Guidance for Assessing Low Probability Hazard Sites at the INEL* (DOE-ID 1994), which provided guidance for screening across the INL Site. If a value for a given nuclide did not exist in the Track 2 report (DOE-ID 1994), then "Kd Values for INTEC Groundwater Modeling" (Jenkins 2001) was consulted. The K_d values given in "Kd Values for INTEC Groundwater Modeling" (Jenkins 2001) were developed for the ICDF but are assumed to be applicable for this site. The K_d selected values were assumed to be applicable to sedimentary rocks and materials that constitute the surface alluvium and interbeds found in the vicinity of the MTR. Sorption coefficients in fractured basalt, which constitutes most of the aquifer, tend to be lower than in sedimentary materials, because surface area of available sorption sites is lacking. The ratio of the aquifer basalt-to-soil K_d value was estimated in the *Comprehensive RI/FS for the Idaho Chemical Processing Plant OU 3-13 at the INEEL—Part A, RI/BRA Report (Final)* (DOE-ID 1997) to be 0.04 and has been commonly used at the INL in later studies. Therefore, it will be used for this MTR evaluation. The ratio was multiplied by all sediment K_d values to obtain the aquifer K_d values used in the GWSCREEN simulation.

Table 5. Contaminant-independent parameter values for Phase 2 screening of the Materials Test Reactor inventories.

Parameter	Value	Reference
Source		
Length parallel to groundwater flow	39.6 m	Assumed contaminant footprint at the MTR and at the water table (assumes no spreading in the vadose zone) (EDF-7405)
Width perpendicular to groundwater flow	39.6 m	Assumed contaminant footprint at the MTR and at the water table (assumes no spreading in the vadose zone) (EDF-7405)
Thickness of source [a]	5.2 m	Based on the facility description
Background percolation rate	0.1 m/yr	Track 2 report (DOE-ID 1994)
Water-filled porosity—source	0.3	Track 2 report (DOE-ID 1994)
Bulk density—source	1.5 g/cm^3	Track 2 report (DOE-ID 1994)
Unsaturated Zone		
Cumulative vadose zone interbed thickness	18.3	TRA perched water remedial investigation (EGG 1992)
Water-filled porosity—unsaturated zone	0.3	Track 2 report (DOE-ID 1994)
Bulk density—unsaturated zone	1.5 g/cm^3	Track 2 report (DOE-ID 1994); assumed to be sediment-like source
Longitudinal dispersivity	0 mL/g	Generally conservative
Aquifer		
Aquifer thickness	15 m	Track 2 report (DOE-ID 1994)
Well screen thickness [b]	15 m	Track 2 report (DOE-ID 1994)
Aquifer porosity	0.1	Track 2 report (DOE-ID 1994)
Darcy velocity in aquifer	57 m/yr	Track 2 report (DOE-ID 1994)
Average linear velocity	570 m/yr	Darcy velocity divided by porosity
Longitudinal dispersivity	9 m	Track 2 report (DOE-ID 1994)
Transverse dispersivity	4 m	Track 2 report (DOE-ID 1994)
Vertical dispersivity	0.1 m	Conservatively assumed to be small
Bulk density—saturated zone	1.9 g/cm^3	Track 2 report (DOE-ID 1994); assumed to be basalt
Receptor Distance from the Center of the Source		
Parallel to groundwater flow direction	19.8 m	Point of maximum concentration, based on guidance in the Track 2 report (DOE-ID 1994)
Perpendicular to groundwater flow direction	0 m	Track 2 report (DOE-ID 1994)

Table 5. (continued).

Parameter	Value	Reference
Receptor Scenario		
Water ingestion rates for residential receptor	2 L/d	Track 2 report (DOE-ID 1994)
Averaging time	365 d/yr × 70 yr	Track 2 report (DOE-ID 1994)
Exposure frequency (carcinogenic risk)	350 d/yr	Track 2 report (DOE-ID 1994)
Exposure duration (carcinogenic risk)	30 yr	Track 2 report (DOE-ID 1994)

a. Source term thickness is assumed to be the height of the reactor portion of the facility. In reality, the facility is significantly deeper and contamination is distributed over that depth.
b. A vertically averaged solution is used in accordance with the Track 2 guidance (DOE-ID 1994). Thickness of the vertical section is taken to be the well screen thickness.

Table 6. Radionuclide Phase 2 groundwater pathway screening results.[a] Note: The last column is a sensitivity analysis result showing the predicted risk when sorption in the aquifer is assumed to be zero.

Nuclide [b]	Progeny	Half-Life (yr)	K_d [C] (mL/g)	Parent Peak Time (yr)	Screening Level Predicted Peak Concentration (pCi/L)	Morbidity Risk Coefficient (risk/pCi)	Peak Risk	Total Risk (parent plus progeny)	*Sensitivity Analysis (No Aquifer Sorption) Total Risk*
Ag-108m	—	4.18E+02	90	24,778	7.6E-19	8.14E-12	1.2E-25	1.2E-25	*1.3E-25*
Am-241(Np)	—	2.14E+06	8	2,254	6.8E-04	6.18E-11	8.5E-10	8.6E-10	*8.8E-10*
	U-233	1.59E+05	6	—	8.4E-06	7.18E-11	1.2E-11	—	—
	Th-229	7.34E+03	100	—	6.1E-08	2.24E-10	2.8E-13	—	—
Be-10	—	1.51E+06	250	68,756	6.5E-02	7.03E-12	9.6E-09	9.6E-09	*9.6E-09*
C-14	**—**	**5.70E+03**	**0.1**	**83**	**3.2E+03**	**1.55E-12**	**6.0E-05**	**6.0E-05**	***6.0E-05***
Cl-36	**—**	**3.01E+05**	**0**	**55**	**4.7E+01**	**3.30E-12**	**1.5E-06**	**1.5E-06**	***1.5E-06***
Co-60	—	5.27E+00	10	NA	0.0E+00	1.57E-11	0.0E+00	0.0E+00	*0.0E+00*
Cs-137	—	3.01E+01	500	NA	0.0E+00	3.04E-11	0.0E+00	0.0E+00	*0.0E+00*
Eu-152	—	1.35E+01	340	NA	0.0E+00	6.07E-12	0.0E+00	0.0E+00	*0.0E+00*
Eu-154	—	8.59E+00	340	NA	0.0E+00	1.03E-11	0.0E+00	0.0E+00	*0.0E+00*
H-3	**—**	**1.23E+01**	**0**	**55**	**1.5E+04**	**5.07E-14**	**4.3E-06**	**4.3E-06**	***4.3E-06***
I-129	**—**	**1.57E+07**	**0**	**55**	**9.2E-01**	**1.48E-10**	**1.3E-06**	**1.3E-06**	***1.3E-06***
Nb-94	—	2.03E+04	100	27,535	6.2E-02	7.77E-12	1.0E-08	1.0E-08	*1.0E-08*
Ni-59	—	7.60E+04	100	27,535	1.1E+01	2.74E-13	6.0E-08	6.0E-08	*6.1E-08*
Ni-63	—	1.00E+02	100	NA	0.0E+00	6.70E-13	0.0E+00	0.0E+00	*0.0E+00*
Np-237	—	2.14E+06	8	2,254	3.8E-05	6.18E-11	4.7E-11	4.8E-11	*4.8E-11*
	U-233	1.59E+05	6	—	4.7E-07	7.18E-11	6.9E-13	—	—
	Th-229	7.34E+03	100	—	3.4E-09	2.24E-10	1.5E-14	—	—
Pu-238(U234)	—	2.46E+05	6	1,704	1.4E-03	7.07E-11	2.1E-09	2.1E-09	*2.3E-09*
	Th-230	7.54E+04	100	—	1.6E-06	9.10E-11	3.0E-12	—	—
	Ra-226	1.60E+03	100	—	4.8E-07	3.85E-10	3.8E-12	—	—
	Pb-210	2.23E+01	100	—	4.6E-07	8.81E-10	8.3E-12	—	—

Table 6. (continued).

Nuclide [b]	Progeny	Half-Life (yr)	K_d [C] (mL/g)	Parent Peak Time (yr)	Screening Level Predicted Peak Concentration (pCi/L)	Morbidity Risk Coefficient (risk/pCi)	Peak Risk	Total Risk (parent plus progeny)	*Sensitivity Analysis (No Aquifer Sorption) Total Risk*
Pu-239	**—**	**2.41E+04**	**22**	**6,101**	**2.1E+00**	**1.35E-10**	**5.7E-06**	**5.7E-06**	***5.9E-06***
	U-235	**7.04E+08**	**6**	—	**4.4E-05**	**6.96E-11**	**6.1E-11**	—	—
	Pa-231	**3.28E+04**	**550**	—	**3.7E-08**	**1.73E-10**	**1.3E-13**	—	—
	Ac-227	**2.18E+01**	**450**	—	**4.4E-08**	**2.01E-10**	**1.8E-13**	—	—
Pu-239 (U-235)	—	7.04E+08	6.00E+00	1,704	3.0E-04	6.96E-11	4.3E-10	4.3E-10	*5.1E-10*
	Pa-231	3.28E+04	5.50E+02	—	1.4E-07	1.73E-10	5.0E-13	—	—
	Ac-227	2.18E+01	4.50E+02	—	1.7E-07	2.01E-10	7.0E-13	—	—
Pu-240	**—**	**6.56E+03**	**22**	**6,101**	**4.8E-01**	**1.35E-10**	**1.3E-06**	**1.3E-06**	***1.4E-06***
	U-236	**2.34E+07**	**6**	—	**3.9E-04**	**6.70E-11**	**5.3E-10**	—	—
	Th-232	**1.41E+10**	**100**	—	**4.6E-12**	**1.01E-10**	**9.5E-18**	—	—
	Ra-228	**1.60E+03**	**100**	—	**2.4E-12**	**1.04E-09**	**5.2E-17**	—	—
	Th-228	**1.91E+00**	**100**	—	**2.4E-12**	**1.07E-10**	**5.3E-18**	—	—
Pu-240 (U-236)	—	2.34E+07	6	1,704	9.2E-04	6.70E-11	1.2E-09	1.2E-09	*1.3E-09*
	Th-232	1.41E+10	100	—	5.5E-12	1.01E-10	1.1E-17	—	—
	Ra-228	1.60E+03	100	—	1.6E-12	1.04E-09	3.5E-17	—	—
	Th-228	1.91E+00	100	—	1.6E-12	1.07E-10	3.6E-18	—	—
Pu-241(Np)	—	2.14E+06	8	2,254	1.0E-04	6.18E-11	1.3E-10	1.3E-10	*1.3E-10*
	U-233	1.59E+05	6	—	1.2E-06	7.18E-11	1.8E-12	—	—
	Th-229	7.34E+03	100	—	9.0E-09	2.24E-10	4.1E-14	—	—
Sr-90	—	2.88E+01	12	3,351	1.0E-34	5.59E-11	8.6E-41	8.6E-41	*8.8E-41*
Tc-99	—	2.11E+05	0.2	55	5.3E+00	2.75E-12	1.4E-07	1.4E-07	*1.4E-07*
U-232	—	6.89E+01	6	1,704	2.2E-11	2.92E-10	1.2E-16	1.2E-16	*1.6E-16*
	Th-228	1.91E+00	100	—	1.6E-12	1.07E-10	3.1E-18	—	—
U-233	—	1.59E+05	6	1,704	8.4E-03	7.18E-11	1.2E-08	1.3E-08	*1.8E-08*
	Th-229	7.34E+03	100	—	9.1E-05	2.24E-10	4.1E-10	—	—

Table 6. (continued).

Nuclide [b]	Progeny	Half-Life (yr)	K_d [c] (mL/g)	Parent Peak Time (yr)	Screening Level Predicted Peak Concentration (pCi/L)	Morbidity Risk Coefficient (risk/pCi)	Peak Risk	Total Risk (parent plus progeny)	*Sensitivity Analysis (No Aquifer Sorption) Total Risk*
U-234	—	2.46E+05	6	1,704	5.8E-03	7.07E-11	8.3E-09	8.4E-09	*9.2E-09*
	Th-230	7.54E+04	100	—	6.5E-06	9.10E-11	1.2E-11	—	—
	Ra-226	1.60E+03	100	—	1.9E-06	3.85E-10	1.5E-11	—	—
	Pb-210	2.23E+01	100	—	1.9E-06	8.81E-10	3.4E-11	—	—
U-238	—	4.47E+09	6	1,704	5.0E-03	6.40E-11	6.5E-09	6.5E-09	*6.6E-09*
	U-234	2.46E+05	6	—	2.4E-05	7.07E-11	3.5E-11	—	—
	Th-230	7.54E+04	100	—	1.4E-08	9.10E-11	2.5E-14	—	—
	Ra-226	1.60E+03	100	—	2.8E-09	3.85E-10	2.2E-14	—	—
	Pb-210	2.23E+01	100	—	2.7E-09	8.81E-10	4.8E-14	—	—

a. **Bold** indicates these nuclides were retained for further evaluation.
b. Nuclides followed by a progeny in parentheses are assumed to decay instantaneously to the progeny and the progeny is simulated for this evaluation.
c. K_d values are primarily from the Track 2 report (DOE-ID 1994). However, the following are from Jenkins (2001): Np, C, Cl, Eu, Nb, Sr, Pa, Ac, and Tc.

At the request of the State of Idaho, as a sensitivity analysis, the screening also has been simulated assuming that there is no sorption in the aquifer. Whether or not this is a conservative assumption depends on a number of factors, including the ingrowth of progeny during transport through the vadose zone and the timing of the risk contribution from other radionuclides.

Using the criterion that the predicted peak risk is greater than 10^{-6}, C-14, Cl-36, H-3, I-129, Pu-239, and Pu-240 were identified as COCs, and the remaining nuclides were eliminated from further consideration (Table 6). Note that Pu-239 was simulated as both Pu-239 and as U-235. In addition, Pu-240 was simulated both as Pu-240 and U-236. In each case, simulating plutonium produced much higher predicted risks than simulating uranium. However, this is not necessarily true, and depends on the parameters of a particular simulation. If the infiltration rate is decreased and the K_d is increased, it could be that the plutonium will essentially stay in the vadose zone producing uranium and the uranium will be transported to the aquifer and provide all of the risk.

This assessment used the Track 2 screening assumptions and K_d values for soils. Any closure action (such as grouting) would tend to decrease the screened contaminants' mobility and further decrease the predicted risk. In addition, any soil cover that decreases the infiltration rate from 10 cm/yr (Track 2 screening value) to 1 cm/yr (undisturbed INL Site sediment estimate) would decrease the predicted peak concentration by an order of magnitude. Note that the high pH environment created by a grout does not necessarily decrease mobility for all contaminants (as discussed in the next section), but it does decrease mobility for the screened constituents.

The last column in Table 6 shows the radionuclide screening results assuming no sorption in the aquifer (sensitivity analysis). The conservative assumption of no retardation in the aquifer increases the predicted total dose; however, the increase is relatively small and there is no impact on the identification of parameters of concern. In general, changing the aquifer K_d will change the time of the peak concentration but have little affect on the magnitude of the peak concentration.

3.2.2 Nonradionuclide Screening

The chemical-specific parameter data for the nonradionuclides are reported in the results table (Table 7). As with the radionuclide Phase 2 evaluation, the infiltration rate is set at 10 cm/yr, which is a factor of 10 times the undisturbed soil infiltration assumed for INL Site soils.

Using one-tenth the MCL (or related water concentration) as a screening criteria, approximately half of the nonradionuclides were screened from further consideration (Table 7). The nonradionuclides remaining after the screening are aluminum, barium, beryllium, chromium, copper, lead, manganese, and nickel. Of these, only barium, beryllium, and chromium have MCLs assigned. The others have nonenforceable guidelines as listed in Table 7.

Note again that this assessment essentially used the Track 2 screening assumptions and K_d values for soils. Any closure action such as grouting would tend to decrease the screened contaminants' mobility and further decrease the predicted risk. An example of an exception to this statement would be chromium. As the pH increases, the predominant valence state of chromium changes from trivalent (relatively immobile) to hexavalent (relatively mobile) chromium. For this analysis, a relatively mobile form of chromium is assumed for the source, vadose zone, and aquifer, so the fact that chromium does not necessarily become less mobile when grouted does not affect the solution or conclusions. In addition, any soil cover that decreases the infiltration rate from 10 cm/yr (Track 2 screening value) to 1 cm/yr (undisturbed INL Site sediment estimate) would decrease the predicted peak concentration by an order of magnitude.

Table 7. Nonradionuclide Phase 2 groundwater pathway screening results using Track 2 assumptions.[a]

Contaminant[b]	K_d[c] (mL/g)	MCL or Related Concentration Limit (mg/L)	Concentration Limit Description	Screening Results: Screening Level Predicted Peak Concentration (mg/L)	Screening Results: Years to Peak Concentration	Screening Results: Ratio of Peak Concentration to MCL	*Sensitivity Analysis Results Aquifer K_d set to 0 mL/g: Screening Level Predicted Peak Concentration (mg/L)*	*Sensitivity Analysis Results Aquifer K_d set to 0 mL/g: Years to Peak Concentration*	*Sensitivity Analysis Results Aquifer K_d set to 0 mL/g: Ratio of Peak Concentration to MCL*
Polychlorinated biphenyls (Aroclor 1254 and 1260)	100	0.0005	MCL	1.22E-08	27,536	2.45E-05	*1.23E-08*	*27,508*	*2.46E-05*
Aluminum	**250**	**0.05 - 0.2**	**Secondary MCL**	**1.51E-02**	**68,756**	**0.30**	***1.51E-02***	***68,683***	***0.30***
Antimony (and compounds)	50	0.006	MCL	3.57E-06	13,795	5.96E-04	*3.59E-06*	*13,783*	*5.98E-04*
Barium (and compounds)	**50**	**2**	**MCL**	**8.63E+00**	**13,795**	**4.32**	***8.67E+00***	***13,783***	***4.34***
Beryllium (and compounds)	**250**	**0.004**	**MCL**	**2.57E-03**	**68,756**	**0.64**	***2.58E-03***	***68,683***	***0.65***
Boron	5	7.3	PRG	8.04E-03	1,429	1.10E-03	*8.07E-03*	*1,428*	*1.11E-03*
Chromium (total)	**1.2**	**0.1**	**MCL**	**3.39E+00**	**385**	**33.87**	***3.40E+00***	***385***	***33.96***
Copper (and compounds)	**20**	**1.3**	**Action level**	**4.34E-01**	**5,551**	**0.33**	***4.35E-01***	***5,546***	***0.33***
Lead	**100**	**0.015**	**Action level**	**3.64E-02**	**27,536**	**2.43**	***3.66E-02***	***27,508***	***2.44***
Manganese (and compounds)	**50**	**0.05**	**Secondary MCL**	**3.34E-02**	**13,795**	**0.67**	***3.34E-02***	***13,795***	***0.67***
Nickel (soluble salts)	**100**	**0.1**	**Remanded MCL**	**2.92E-02**	**27,536**	**0.29**	***2.93E-02***	***27,508***	***0.29***
Silver (and compounds)	90	0.1	Secondary MCL	9.94E-05	24,788	9.94E-04	*9.99E-05*	*24,763*	*9.99E-04*
Tin	130	22	PRG	1.38E-04	35,780	6.26E-06	*1.38E-04*	*35,743*	*6.29E-06*
Uranium (chemical form)	6	0.03	MCL	1.50E-05	1,704	5.01E-04	*1.51E-05*	*1,702*	*5.03E-04*
Zinc	16	5	Secondary MCL	3.32E-03	4,452	6.64E-04	*3.33E-03*	*4,448*	*6.67E-04*

a. Track 2 assumptions are from DOE-ID (1994).
b. Highlighting indicates nonradionuclide COCs. COCs are defined as having predicted peak concentrations greater than one-tenth the MCL or related concentration limit.
c. K_d values are from Jenkins (2001).

Action level = Lead and copper are regulated by a treatment technique that requires systems to control the corrosiveness of their water. If more than 10% of the tap water samples exceed the action level, water systems must take additional steps.
EPA = Environmental Protection Agency.
MCL = maximum contaminant level as set by the EPA National Drinking Water Standards (40 CFR 141).
PRG = preliminary remediation goal as defined by EPA's Region 9 office. It is a nonenforceable, generic standard for evaluating and cleaning up contaminated sites.
Remanded MCL = The MCL and MCLG for nickel were remanded on February 9, 1995. This means that there is currently no EPA legal limit on the amount of nickel in drinking water. The remanded MCL was 0.1 mg/L; therefore, that value was used for this screening.
MCLG = MCL goal as set by the EPA—nonenforceable guideline. This is protective of adverse human health effects and allows an adequate margin of safety.
Secondary MCL = as set by the EPA—nonenforceable guidelines. Regulate contaminants that may cause cosmetic or esthetic effects.

As previously discussed, at the request of the State of Idaho, as a sensitivity analysis, the screening also has been simulated assuming there is no sorption in the aquifer. These results are presented in the last column of Table 7. Neglecting sorption in the aquifer does not significantly change the predicted peak aquifer concentrations or the conclusions of this screening.

3.3 Materials Test Reactor Contaminant of Concern Risk Assessment

After Phase 2 screening, the six radionuclides and eight nonradionuclides that require further analysis are defined as the COCs and include C-14, Cl-36, H-3, I-129, Pu-239, Pu-240, aluminum, barium, beryllium, chromium, copper, lead, manganese, and nickel. A more detailed and more site-specific risk analysis was conducted for the COCs. The risk assessment for the COCs is presented in this section. For this risk assessment, many of the conservative assumptions made in the screening are retained. However, some specific assumptions are relaxed, because they are overly conservative for the MTR analysis. Changing these parameters allows the simulations to more accurately represent the MTR source term and flow and transport system but remain a conservative simulation. In this section, the changes to the model parameters are discussed and the results are presented. Parameters not discussed will remain the same as the Phase 2 screening parameters. The parameter changes are related to the infiltration rates, unsaturated zone dispersivity, and the sorption of plutonium as explained in the following subsections. The primary conservative assumption retained is that all metals have already corroded and the contaminants in the metals are available for transport rather than being contained in stainless steel, lead, and beryllium.

3.3.1 Infiltration Rate

The Track 2 screening methodology used in the Phase 2 screening is based on an infiltration rate of 10 cm/yr. This rate is assumed to be conservative, because the estimated infiltration rate at the INL Site for undisturbed soil is approximately 1 cm/yr. The undisturbed soil infiltration rate of 1 cm/yr has been used in many INL studies, for example, EDF-5142, “Groundwater Pathway Risk Assessment for Engineering Test Reactor Complex Closure”; EDF-4488, “Streamlined Risk Assessment for the CPP-603 EE/CA”; and the *Performance Assessment for the INEEL CERCLA Disposal Facility Landfill* (DOE-ID 2003). This assessment assumes that, after closure, the facilities will have at least a soil layer that limits the infiltration through the MTR facilities to undisturbed background levels. All of the COCs were evaluated based on the 1-cm/yr infiltration rate for this risk assessment.

3.3.2 Dispersion in the Vadose Zone

The Track 2 screening methodology used in the Phase 2 screening assumed no unsaturated zone dispersivity. In the risk assessment for the COCs, dispersion in the vadose zone was included.

In general, zero dispersion in the vadose zone is a conservative assumption; however, for radionuclides with relatively short half-lives, the assumption may not be conservative. In general, contaminants in the unsaturated zone would spread both in the direction of flow (longitudinal) and perpendicular to the direction of flow (lateral). The computer code used for the risk assessment simulations (GWSCREEN) assumes one-dimensional flow and transport in the unsaturated zone; therefore, only longitudinal dispersivity can be included in the model and the model remains conservative relative to lateral dispersivity.

Dispersivity in the unsaturated zone is a well-known phenomenon, and some effort has been made to quantify the unsaturated longitudinal dispersivity at the INL Site. For purposes of this analysis, since no site-specific values are available, a value of 2.92 m (9.5 ft) is chosen for the unsaturated dispersivity. This value is consistent with the value used for the *Performance Assessment for the INEEL CERCLA Disposal Facility Landfill* (DOE-ID 2003).

3.3.3 Plutonium K_d

The plutonium K_d value used for the screening (Track 2 value of 22 mL/g) is very conservative and not realistic for this risk assessment. Therefore, the K_d was increased from 22 mL/g to 140 mL/g, which is consistent with the K_d used in the *Performance Assessment for the INEEL CERCLA Disposal Facility Landfill* (DOE-ID 2003). This plutonium K_d is still considered to be a conservative value but less conservative than the Track 2 value used in the screening analysis.

3.4 Materials Test Reactor Risk Assessment Results

The contaminants that did not pass the Phase 2 screening were evaluated with more realistic simulation parameters, as explained in the last section. This set of results is for Alternative 1, where the entire inventory is assumed to remain in MTR. Section 3.5 summarizes the difference in the results for the different alternatives.

The radionuclide results are summarized in Table 8. Results are shown both with and without sorption in the aquifer. As can be seen in the table, there is very little change in the predicted peak aquifer concentrations based on the sorption in the aquifer, and the assumption has no impact on the conclusions of the analysis.

Pu-239 and Pu-240 have been simulated both as the parent (plutonium) and conservatively as the primary progeny (uranium). As can be seen in Table 8, for Pu-239 it is more conservative to simulate transport of the parent and for Pu-240 it is more conservative to simulate transport of the progeny. Neither Pu-239 nor Pu-240 is a significant contributor to the cumulative risk.

The predicted peak radionuclide risk in the aquifer is 2×10^{-6} for C-14. This is 50 times smaller than the cumulative groundwater performance criteria of 1×10^{-4}. The risk from the second largest contributor is 7×10^{-8} from Cl-36, which is approximately 1,500 times smaller than the cumulative groundwater performance criteria. Given the number of radionuclides of concern and the difference in peak times in the aquifer, none of the radionuclides are considered significant contributors to the total cumulative risk.

The nonradionuclide results are summarized in Table 9. Results are shown for both with and without sorption in the aquifer. As with the radionuclides, there is very little change in the predicted peak aquifer concentrations based on the sorption in the aquifer, and the assumption has no impact on the conclusions of the analysis.

The predicted peak fraction of the MCL in the aquifer is 0.67 for chromium. That is, the predicted peak aquifer concentration of chromium is 67% of the chromium MCL. The next largest contributors are barium, with a peak aquifer concentration that is 8.6% of the MCL, and lead, which is 4.8% of the MCL. However, there is no cumulative fraction of the MCL between chromium and the others, because (a) chromium concentrations peak in less than 4,000 years, (b) the barium concentrations peak in 140,000 years, and (c) the lead concentrations peak in 280,000 years. Therefore, there is no cumulative interaction between the primary nonradionuclide COCs.

Table 8. Materials Test Reactor radionuclide groundwater risk assessment assuming the contaminants are immediately available for release.

		Risk Assessment Based on Alternative 1 Inventory				*Sensitivity Analysis – No Sorption in the Aquifer*			
Nuclide	Progeny	Time to the Peak Concentration (yr)	Peak Concentration (pCi/L)	Maximum Risk	Total Risk	*Time to the Peak Concentration (yr)*	*Peak Concentration (pCi/L)*	*Maximum Risk*	*Total Risk*
C-14	—	816	5.93E+01	1.93E-06	1.9E-06	*816*	*5.93E+01*	*1.93E-06*	*1.9E-06*
Cl-36	—	558	9.47E-01	6.56E-08	6.6E-08	*558*	*9.47E-01*	*6.56E-08*	*6.6E-08*
H-3	—	125	5.55E-02	5.71E-11	5.7E-11	*125*	*5.55E-02*	*5.71E-11*	*5.7E-11*
I-129	—	558	1.85E-02	5.75E-08	5.8E-08	*558*	*1.85E-02*	*5.75E-08*	*5.8E-08*
Pu-239	—	142,620	1.80E-05	5.09E-11	5.2E-11	*142,610*	*1.80E-05*	*5.09E-11*	*5.1E-11*
	U-235		7.06E-07	1.03E-12			*3.66E-08*	*5.34E-14*	
	Pa-231		8.20E-09	2.98E-14			*3.20E-08*	*1.16E-13*	
	Ac-227		1.00E-08	4.23E-14			*3.20E-08*	*1.35E-13*	
Pu-239 (as U-235)	—	17,311	6.02E-06	8.80E-12	9.0E-12	*17,311*	*6.02E-06*	*8.80E-12*	*2.3E-11*
	Pa-231		2.45E-08	8.89E-14			*1.85E-06*	*6.70E-12*	
	Ac-227		2.99E-08	1.26E-13			*1.84E-06*	*7.77E-12*	
Pu-240	—	76,558	3.07E-09	8.71E-15	8.5E-14	*76,552*	*3.07E-09*	*8.71E-15*	*1.3E-14*
	U-236		5.41E-08	7.61E-14			*2.80E-09*	*3.94E-15*	
	Th-232		1.29E-14	2.74E-20			*9.25E-15*	*1.96E-20*	
	Ra-228		1.25E-14	2.72E-19			*8.93E-15*	*1.95E-19*	
	Th-228		1.25E-14	2.80E-20			*8.93E-15*	*2.01E-20*	
Pu-240 (as U-236)	—	17,309	1.82E-05	2.55E-11	2.6E-11	*17,309*	*1.82E-05*	*2.55E-11*	*2.6E-11*
	Th-232		1.12E-12	2.37E-18			*1.55E-11*	*3.28E-17*	
	Ra-228		9.67E-13	2.11E-17			*1.34E-11*	*2.92E-16*	
	Th-228		9.67E-13	2.17E-18			*1.34E-11*	*3.01E-17*	

Table 9. Materials Test Reactor nonradionuclide groundwater risk assessment assuming the contaminants are immediately available for release.

Contaminant	K_d (mL/g)	MCL or Related Concentration Limit (mg/L)[a]	Time to the Peak Concentration	Alternative 1 Inventory Results		*Sensitivity Analysis*		
				Predicted Peak Concentration (mg/L)	Fraction – Peak Concentration to the MCL (mg/L)	*Time to the Peak Concentration*	*Predicted Peak Concentration (mg/L)*	*Fraction – Peak Concentration to the MCL (mg/L)*
Aluminum	250	0.05	698,600	2.98E-04	0.006	*698,570*	*2.98E-04*	*0.006*
Barium (and compounds)	50	2	140,170	1.71E-01	0.086	*140,160*	*1.71E-01*	*0.086*
Beryllium (and compounds)	250	0.004	698,600	5.09E-05	0.013	*698,570*	*5.09E-05*	*0.013*
Chromium (total)	1.2	0.1	3,909	6.73E-02	0.673	*3,909*	*6.73E-02*	*0.67*
Copper (and compounds)	20	1.3	56,402	8.59E-03	0.007	*56,401*	*8.59E-03*	*0.007*
Lead	100	0.015	279,770	7.21E-04	0.048	*279,770*	*7.21E-04*	*0.048*
Manganese (and compounds)	50	0.05	140,170	6.62E-04	0.013	*140,160*	*6.62E-04*	*0.013*
Nickel (soluble salts)	100	0.1	279,770	5.79E-04	0.006	*279,770*	*5.79E-04*	*0.006*

EPA = Environmental Protection Agency.
Notes:

a. Aluminum and manganese are secondary MCLs. Secondary MCL = as set by the EPA—nonenforceable guidelines. Regulate contaminants that may cause cosmetic or esthetic effects.
Barium, beryllium, and chromium are MCLs. MCL = maximum contaminant level as set by the EPA.
Copper and lead are action levels. Action level = lead and copper are regulated by a treatment technique that requires systems to control the corrosiveness of their water.
Nickel is remanded MCL. Remanded MCL = The MCL and MCLG for nickel were remanded on February 9, 1995. This means that there is currently no EPA legal limit on the amount of nickel in drinking water. The remanded MCL was 0.1 mg/L; therefore, that value was used for this screening. MCLG = MCL goal as set by the EPA—nonenforceable guideline. This is protective of adverse human health effects and allows an adequate margin of safety.

3.5 Results for Alternatives 2 and 3

A simple conservative model has been used for the streamlined risk assessment, and the results indicate that leaving the inventory in place does not result in predicted aquifer concentrations greater than the cumulative groundwater performance criteria. The assumptions of the modeling are conservative, in particular the assumption that the contaminants are immediately available for transport, when, in reality, much of the inventory is contained in metal and cannot be transported until the metal corrodes and releases the contaminants into the subsurface. Since these conservative assumptions were sufficient to demonstrate compliance, there is no reason to include less conservative assumptions in the evaluation of Alternatives 2 and 3.

Alternative 2 assumes that the reactor will be grouted in place and assumes a very small decrease in the overall inventory. Alternative 3 assumes the reactor is removed from the MTR and there is a very large decrease in the overall inventory to remain in the MTR, in particular for radionuclides.

As previously discussed, grouting of the source term will generally increase sorption, making the releases to the vadose zone slower than the assumptions of this streamlined risk assessment. The exception to this rule is chromium, as discussed in Section 3.2.2. However, since chromium is essentially tied up in stainless steel and cannot be released until the metal corrodes, and considering that the modeling already assumed a mobile form of chromium (relatively low K_d), the current chromium simulation approach is still very conservative.

Since more complex modeling of grout sorption and corrosion will not change the conservative conclusions of this report, the results for Alternatives 2 and 3 are based exactly on the assumptions of Alternative 1 with the exception of the inventory. Since the only variable is inventory and the GWSCREEN solutions as run are a linear function of the inventory, the Alternative 2 and Alternative 3 results were scaled from the Alternative 1 results.

Table 10 contains the Alternatives 1, 2, and 3 radionuclide results and Table 11 contains the Alternatives 1, 2, and 3 nonradionuclide results. As can be seen from comparing Tables 10 and 11 to the inventory Tables 2 and 3, the predicted peak risks for the radionuclides and fraction of the MCL for the nonradionuclides are proportional to the change in the inventory for the alternatives. There is very little difference between the results of Alternatives 1 and 2 because the grouting of the reactor has not been considered and the inventories are very similar. In both cases, the predicted peak aquifer concentrations meet the performance criteria. Alternative 3 assumes the removal of much of the contamination, in particular, the radionuclides. The predicted peak radionuclide risk falls from 2×10^{-6} for Alternative 1 to 4×10^{-8} for Alternative 3 (Table 10). Similarly, the maximum ratio of predicted peak concentration to MCL for the nonradionuclides drops from 0.67 for Alternative 1 to 0.24 for Alternative 3 (Table 11).

Table 10. Alternatives 1, 2, and 3 radionuclide results.

	Predicted Peak Risk		
	Alternative 1	Alternative 2	Alternative 3
C-14	1.9E-06	1.9E-06	6.3E-09
Cl-36	6.6E-08	6.6E-08	0.0E+00
H-3	5.7E-11	5.7E-11	0.0E+00
I-129	5.8E-08	3.7E-08	3.6E-08
Pu-239	5.2E-11	5.2E-11	4.1E-11
Pu-240 (as U-236)	2.6E-11	2.5E-11	2.0E-11

Table 11. Alternatives 1, 2, and 3 nonradionuclide results.

	Ratio of Predicted Peak Concentration to MCL		
	Alternative 1	Alternative 2	Alternative 3
Aluminum	6.0E-03	6.0E-03	4.7E-06
Barium and compounds	8.6E-02	8.6E-02	5.9E-07
Beryllium and compounds	1.3E-02	1.3E-02	5.9E-05
Chromium	6.7E-01	6.7E-01	2.4E-01
Copper and compounds	6.6E-03	6.6E-03	3.3E-03
Lead	4.8E-02	4.8E-02	1.2E-04
Manganese and compounds	1.3E-02	1.3E-02	5.7E-03
Nickel (soluble salts)	5.8E-03	5.8E-03	2.4E-03

MCL = maximum contaminant level.

3.6 Soil Contamination under the Materials Test Reactor Facility

Based on records reviewed, potential release sites below the MTR building indicate no known significant contaminant releases besides those that are currently being tracked by the INL CERCLA program. Potential release sites include locations where past releases of waste constituents—primarily radionuclides—are possible, because the concrete structure is built directly on basalt bedrock and contained a sump, which was used to receive, accumulate, and/or store radioactive waste. These include the MTR Canal located within the MTR building. Potential liquid releases to the basement areas that could have found their way to the environment through cracks or fissures in the concrete construction would be impossible to quantify, even if sampling or screening evidence of contamination below the concrete slab could be obtained.

Based on the available information and risk assessment analysis, these areas are not available to surface pathway receptors due to their depth, and there is no evidence that sufficient releases could have occurred under the building to result in an incremental increase to the groundwater (concentration or risk). Under the *Groundwater Monitoring Plan for the Reactor Technology Complex Operable Unit 2-13* (DOE-ID 2007), perched water and aquifer wells are routinely sampled for the COCs chromium, H-3, Co-60, and Sr-90. Previously, perched water and aquifer wells were sampled for the radiological contaminants Am-241, Cs-137, Co-60, Sr-90, and H-3 and the inorganic contaminants arsenic, beryllium, cadmium, chromium, fluoride, lead, manganese, and mercury. Water quality results show little impact (most levels are near the detection limits) for Am-241, Cs-137, arsenic, beryllium, cadmium, fluoride, lead, manganese, and mercury. In addition to sampling for contaminants, water levels are collected from monitoring wells located near the RTC as part of routine monitoring activities. The United States Geological Survey also monitors selected wells at the RTC, and data from the monitoring are used to supplement information collected under CERCLA-driven monitoring.

Based on the available information and this risk assessment, there is no reason to believe that sufficient releases have occurred under the facility to result in a significant risk or fraction of the MCL.

4. SUMMARY

The contaminant screening and risk assessment calculations presented in this report are based on the assumption that the contaminant inventory at the MTR is left in place and the facilities are stabilized with INL Site native soils (Alternative 1). Based on this streamlined risk assessment, the predicted groundwater concentrations meet the required performance criteria. For groundwater, the performance criteria require that contaminant concentrations in the SRPA do not exceed a cumulative carcinogenic risk level of 1×10^{-4} or exceed applicable State of Idaho groundwater quality standard in 2095 and beyond. The maximum predicted cumulative risk is 2×10^{-6} or 50 times smaller than the performance criteria (C-14). The maximum fraction of nonradionuclide concentration to the MCL is 0.67 or 67% of the chromium MCL. The radionuclide risk is dominated by C-14 and the nonradionuclide concentration fraction of the MCL is dominated by chromium. There are essentially no cumulative impacts from the other contaminants because of the significant time differences between when the peak aquifer concentrations occur. Alternatives 2 and 3 were also evaluated. Since the inventory for each is less than Alternative 1 (in particular for Alternative 3), the predicted peak aquifer concentrations, risks, and fraction of the concentration to the MCL all meet the performance criteria.

A number of conservative assumptions were used to calculate peak aquifer concentrations and risks. The following is a list of the primary assumptions and their impact on the predicted contaminant concentrations in the aquifer:

1. The primary conservative assumption is that all metals have already corroded and the contaminants in the metals are available for transport rather than being contained in stainless steel, lead, and beryllium. Thus, the results are conservative.

2. The assumption that native soils are used to fill both the reactor and MTR basement was used to simulate the release of contaminants within the MTR. In general, contaminants are less mobile in a high-pH environment (such as grout) than they are in soils. Therefore, simulating the contaminant release from native soils results in a faster release from the MTR to the subsurface than if the transport was simulated using grout K_ds. This results in higher predicted concentrations in the aquifer than would be expected with a grouted source. As explained in Section 3.2.2, chromium could be an exception to the rule that contaminants are less mobile in a grouted source because as the pH increases, the predominant valence state of chromium changes from trivalent (relatively immobile) to hexavalent (relatively mobile) chromium. Therefore, in order to be conservative, a relatively mobile form of chromium is assumed for the entire analysis.

3. For the Alternative 2 MTR risk assessment, the hydraulic effects of grouting the MTR vessel were ignored. If the facility is grouted, the grouting will isolate the vast majority of the contaminants (reactor vessel) from water for a very long time. A common assumption at the INL is that the grout will remain intact for 500 years and then fail, allowing water to infiltrate, contact contaminants, and leach them to the vadose zone. Any time delay provided by the grout would delay the predicted peak aquifer concentrations and reduce the concentrations through radioactive decay.

4. Water and contaminants are assumed to move straight down through the vadose zone sediments. The contaminant velocity through the sediments depends on the contaminant-specific sediment K_d. There is no retardation effect from the basalt in the vadose zone, and there is no horizontal spreading simulated in the vadose zone. The result of these assumptions is to predict a contaminant travel time from MTR to the aquifer that is shorter than would be expected with horizontal spreading and sorption in the basalt.

5. Track 2 default values are, in general, more conservative than the parameter values used for detailed RTC modeling. Thus, the results are conservative.

6. For screening, the receptor was assumed to be at the edge of the MTR facility. This is the location of the peak concentration in the aquifer. Any change of the receptor location will result in decreased predictions of peak concentration.

Based on this streamlined risk assessment, using the above conservative assumptions, the contamination at the MTR facility is not expected to result in groundwater concentrations that exceed the performance criteria.

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Appendix A

Analysis Plan

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Appendix A

Analysis Plan

The objective of the analysis is to calculate the groundwater pathway risk from the contaminants to potentially be left in place at the Materials Test Reactor (MTR) and related facilities. The calculated risks are used in an engineering evaluation/cost analysis to support the decision-making process for the deactivation, decontamination, and decommissioning (DD&D) of the MTR and related areas.

The MTR groundwater pathway risk assessment is conducted in accordance with management control procedure (MCP) -2374, "Analyses and Calculations." The calculations are associated with a facility that is permanently shut down and has been identified for DD&D. Therefore, the quality level of the structures, systems, and components, as defined in MCP-540, "Assigning Quality Levels," does not apply to this analysis.

The GWSCREEN computer code, Version 2.5a (Enterprise Architecture Identification Number 121200) was used to conduct the calculations for this EDF. The GWSCREEN code has been validated and controlled in accordance with MCP-3039, "Analysis Software Control." The calculations performed were Classification Level B. As defined in the revision of MCP-550, "Software Management," that was current at the time, the "B" classification level generally included low safety consequence or mission critical software. Classification Level "B" software applications generally met one or more of the following criteria:

- Application failure would have an unacceptable impact by causing significant Idaho Cleanup Project mission failure and significant production investment costs and/or recovery costs.
- Application is important to continued operations of the business and is used to support decisions regarding operating activities.
- Application is used to comply with regulatory laws, environmental permits or regulations, and/or other commitments to compliance.
- Application is required for emergency communications with local, state, and federal government agencies.
- Application provides primary support to a process that must be back on-line within a period of time not to exceed 5 days, and for which delays exceeding 5 days would jeopardize some aspect of Idaho Cleanup Project mission success.
- DOE-ID approval is required to institute alternative support mechanisms or operate without the process.

The deliverable for this project is an EDF documenting the calculations and computer files with the input and output for the simulations. The EDF will include a description of the electronic files that would allow someone to reproduce the results.

Technical checking will include verification that input data are appropriate and input and output documented in the EDF match the input and output files for GWSCREEN. The conclusions will be reviewed to ensure they are consistent with the analysis that was presented. The technical checker also will verify that GWSCREEN was appropriate for this use and that the formulas and calculations in any spreadsheet are correct.

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Appendix B

GWSCREEN Input Files

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Appendix B

GWSCREEN Input Files

As explained in the main text, GWSCREEN was used to calculate aquifer concentrations and associated risk for the MTR streamlined groundwater pathway risk assessment. Below are the input files for the simulation runs for Alternative 1. In Alternative 1 all the inventory at the MTR is left in the facility at closure.

Phase 2 Screening – Radionuclide Risk Calculation Input File - MTRRNPIIRisk_r3.par

```
MTR Radionuclide Screening Phase II - Risk - 3/23/2007
$ Phase 2 of screening based on Track 2 screening approach (track 2 defaults used, DOE-ID 1994).
$ Assumed no dispersion in vadose zone and contaminants immediately available for leaching from
source.
$ RNs screened based on predicted peak dose (<0.4 mrem) and carcinogenic risk (using ED=30 yr,
IR=2 L/d)(<10^-6).
2 1 0 1 1                                  (Card 2)  imode,itype,idisp,kflag,idil
1 1 1 1 1                                  (Card 3)  imodel,isolve,isolveu,imoist,imoistu
6 12 0.001                                 (Card 4)  jstart jmax eps
70. 2.555E+04 2.0  350.  30.  1.0E-06      (Card 5)  bw,at,wi,ef,ed,dlim
0.   0.                                    (Card 6)  x0,y0
39.6 39.6 0.10                             (Card 7)  l,w,perc
5.2  1.5                                   (Card 8b) thicks, rhos, (source term values)
0.30                                       (Card 8c) thetas (source term mc)
18.3  1.5  0.                              (Card 9)  depth,rhou,axu
0.30                                       (Card 9a) thetau
9.0 4.0  0.10  76.  15.                    (Card 10) ax,ay,az,b,z(well screen thickness)
57.0  0.10  1.9                            (Card 11) u,phi,rhoa
1                                          (Card 12a)nrecept
19.8  0.0                                  (Card 12b)xrec yrec
27                                         (Card 14) ncontam
$  ------------------------ Ag-108m ------------------------ 1
 0  90  90  108  1.61E-01  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ag-108m'  4.18E+02  3.6  8.14E+00           (card14b) cname thalf kda dcf
$  ------------------------ Am-241(Np) ------------------------ 2
 2  8  8  237  1.86E-05  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Am-241(Np)'  2.14E+06  0.32  6.18E+01     (card14b) cname thalf kda dcf
'U-233'  1.59E+05  0.24  7.18E+01          (card14b) cname thalf kda dcf
'Th-229'  7.34E+03  4  2.24E+02            (card14b) cname thalf kda dcf
$  ------------------------ Be-10 ------------------------ 3
 0  250  250  10  5.59E-02  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Be-10'  1.51E+06  10  7.03E+00              (card14b) cname thalf kda dcf
$  ------------------------ C-14 ------------------------ 4
 0  0.1  0.1  14  3.32E+00  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'C-14'  5.70E+03  0.004  1.55E+00            (card14b) cname thalf kda dcf
$  ------------------------ Cl-36 ------------------------ 5
 0  0  0  36  3.20E-02  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cl-36'  3.01E+05  0  3.30E+00             (card14b) cname thalf kda dcf
$  ------------------------ Co-60 ------------------------ 6
 0  10  10  60  6.06E+01  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Co-60'  5.27E+00  0.4  1.57E+01            (card14b) cname thalf kda dcf
$  ------------------------ Cs-137 ------------------------ 7
 0  500  500  137  7.35E-01  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cs-137'  3.01E+01  20  3.04E+01               (card14b) cname thalf kda dcf
$  ------------------------ Eu-152 ------------------------ 8
 0  340  340  152  5.65E+00  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Eu-152'  1.35E+01 13.6  6.07E+00              (card14b) cname thalf kda dcf
$  ------------------------ Eu-154 ------------------------ 9
 0  340  340  154  1.02E+00  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Eu-154'  8.59E+00 13.6  1.03E+01              (card14b) cname thalf kda dcf
$  ------------------------ H-3 ------------------------ 10
0  0  0  3  2.22E+02  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'H-3'  1.23E+01  0  5.07E-02             (card14b) cname thalf kda dcf
$  ------------------------ I-129 ------------------------ 11
 0  0  0  129  6.25E-04  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'I-129'  1.57E+07  0  1.48E+02             (card14b) cname thalf kda dcf
$  ------------------------ Nb-94 ------------------------ 12
 0  100  100  94  5.31E-02  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Nb-94'  2.03E+04  4  7.77E+00                (card14b) cname thalf kda dcf
$  ------------------------ Ni-59 ------------------------ 13
 0  100  100  59  4.53E+00  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ni-59'  7.60E+04  4  2.74E-01                (card14b) cname thalf kda dcf
$  ------------------------ Ni-63 ------------------------ 14
 0  100  100  63  4.69E+02  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ni-63'  1.00E+02  4  6.70E-01                (card14b) cname thalf kda dcf
```

```
$  ------------------------ Np-237 ------------------------ 15
 2  8  8  237  1.03E-06  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Np-237'  2.14E+06  0.32  6.18E+01         (card14b) cname thalf kda dcf
'U-233'  1.59E+05  0.24  7.18E+01          (card14b) cname thalf kda dcf
'Th-229'  7.34E+03  4  2.24E+02            (card14b) cname thalf kda dcf
$  ------------------------ Pu-238(U234) ------------------------ 16
 3  6  6  234  3.00E-05  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-238(U234)'  2.46E+05  0.24  7.07E+01   (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  4  9.10E+01            (card14b) cname thalf kda dcf
'Ra-226'  1.60E+03  4  3.85E+02            (card14b) cname thalf kda dcf
'Pb-210'  2.23E+01  4  8.81E+02            (card14b) cname thalf kda dcf
$  ------------------------ Pu-239 ------------------------ 17
 3  22  22  239  1.84E-01  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-239'  2.41E+04  0.88  1.35E+02           (card14b) cname thalf kda dcf
'U-235'  7.04E+08  0.24  6.96E+01            (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  22  1.73E+02            (card14b) cname thalf kda dcf
'Ac-227'  2.18E+01  18  2.01E+02            (card14b) cname thalf kda dcf

$  ------------------------ Pu-239 as U-235---------------- 17
$ Note: I simulated as U-235 also, but the simulation as Pu-239 is more accurate and
$       more conservative. Activity is Pu-239 act. times ratio of half lives.
 2  6.  6.  235  6.30E-06  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-239(as U-235)'  7.04E+08  0.24  6.96E+01 (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  22  1.73E+02            (card14b) cname thalf kda dcf
'Ac-227'  2.18E+01  18  2.01E+02            (card14b) cname thalf kda dcf
$  ------------------------ Pu-240 ------------------------ 18
 4  22  22  240  6.78E-02  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-240'  6.56E+03  0.88  1.35E+02           (card14b) cname thalf kda dcf
'U-236'  2.34E+07  0.24  6.70E+01            (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  4  1.01E+02             (card14b) cname thalf kda dcf
'Ra-228'  1.60E+03  4  1.04E+03             (card14b) cname thalf kda dcf
'Th-228'  1.91E+00  4  1.07E+02             (card14b) cname thalf kda dcf

$  ------------------------ Pu-240 as U-236---------------- 18
$ Note: I simulated it as Pu-240 but simulating as U-236 is both more accurate and
$       more conservative. Activity is Pu-240 act. times ratio of half lives.
 3   6. 6.  236  1.90E-05  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-240(as U-236)'  2.34E+07  0.24  6.70E+01 (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  4  1.01E+02             (card14b) cname thalf kda dcf
'Ra-228'  1.60E+03  4  1.04E+03             (card14b) cname thalf kda dcf
'Th-228'  1.91E+00  4  1.07E+02             (card14b) cname thalf kda dcf

$  ------------------------ Pu-241(Np) ------------------------ 19
 2  8  8  237  2.75E-06  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-241(Np)'  2.14E+06  0.32  6.18E+01     (card14b) cname thalf kda dcf
'U-233'  1.59E+05  0.24  7.18E+01          (card14b) cname thalf kda dcf
'Th-229'  7.34E+03  4  2.24E+02            (card14b) cname thalf kda dcf
$  ------------------------ Sr-90 ------------------------ 20
 0  12  12  90  4.39E-01  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Sr-90'  2.88E+01  0.48  5.59E+01           (card14b) cname thalf kda dcf
$  ------------------------ Tc-99 ------------------------ 21
 0  0.0  0.0  99  3.61E-03  0. 1.00E+06  0. (card14a) nprog kds kdu zmw qi rmi sl other
'Tc-99'  2.11E+05  0.0    2.75E+00          (card14b) cname thalf kda dcf
$  ------------------------ U-232 ------------------------ 22
 1  6  6  232  1.28E-05  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-232'  6.89E+01  0.24  2.92E+02           (card14b) cname thalf kda dcf
'Th-228'  1.91E+00  4  1.07E+02            (card14b) cname thalf kda dcf
$  ------------------------ U-233 ------------------------ 23
 1  6  6  233  1.76E-04  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-233'  1.59E+05  0.24  7.18E+01          (card14b) cname thalf kda dcf
'Th-229'  7.34E+03  4  2.24E+02            (card14b) cname thalf kda dcf
$  ------------------------ U-234 ------------------------ 24
 3  6  6  234  1.21E-04  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-234'  2.46E+05  0.24  7.07E+01          (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  4  9.10E+01            (card14b) cname thalf kda dcf
'Ra-226'  1.60E+03  4  3.85E+02            (card14b) cname thalf kda dcf
'Pb-210'  2.23E+01  4  8.81E+02            (card14b) cname thalf kda dcf
```

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$  ------------------------ U-238 ------------------------ 25
 4  6  6  238  1.04E-04  0. 1.00E+06  0.    (card14a) nprog kds kdu zmw qi rmi sl other
'U-238'  4.47E+09  0.24  6.40E+01           (card14b) cname thalf kda dcf
'U-234'  2.46E+05  0.24  7.07E+01           (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  4  9.10E+01            (card14b) cname thalf kda dcf
'Ra-226'  1.60E+03  4  3.85E+02            (card14b) cname thalf kda dcf
'Pb-210'  2.23E+01  4  8.81E+02            (card14b) cname thalf kda dcf
```

Phase 2 Screening – Radionuclide Risk Calculation – Sensitivity Analysis Input File - MTRRNPIIRisk_akd0-r3.par

```
MTR Radionuclide Screening Phase II - Risk - 03/23/2007
$ Here I change the aquifer Kd to 0.
$ Phase 2 of screening based on Track 2 screening approach (track 2 defaults used, DOE-ID 1994).
$ Assumed no dispersion in vadose zone and contam immediately avail for leaching from source.
$ RNs screened based on predicted peak dose (<0.4 mrem) and carcinogenic risk (using ED=30 yr,
IR=2 L/d)(<10^-6).
2 1 0 1 1                                  (Card 2)  imode,itype,idisp,kflag,idil
1 1 1 1 1                                  (Card 3)  imodel,isolve,isolveu,imoist,imoistu
6 12 0.001                                 (Card 4)  jstart jmax eps
70. 2.555E+04 2.0  350.  30.  1.0E-06      (Card 5)  bw,at,wi,ef,ed,dlim
0.   0.                                    (Card 6)  x0,y0
39.6 39.6 0.10                             (Card 7)  l,w,perc
5.2  1.5                                   (Card 8b) thicks, rhos, (source term values)
0.30                                       (Card 8c) thetas (source term mc)
18.3  1.5  0.                              (Card 9)  depth,rhou,axu
0.30                                       (Card 9a) thetau
9.0 4.0  0.10  76.  15.                    (Card 10) ax,ay,az,b,z(well screen thickness)
57.0  0.10  1.9                            (Card 11) u,phi,rhoa
1                                          (Card 12a)nrecept
19.8  0.0                                  (Card 12b)xrec yrec
27                                         (Card 14) ncontam
$  ------------------------ Ag-108m ------------------------ 1
 0  90  90  108  1.61E-01  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ag-108m'  4.18E+02  0.0  8.14E+00           (card14b) cname thalf kda dcf
$  ------------------------ Am-241(Np) ------------------------ 2
 2  8  8  237  1.86E-05  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Am-241(Np)'  2.14E+06  0.    6.18E+01     (card14b) cname thalf kda dcf
'U-233'  1.59E+05  0.         7.18E+01          (card14b) cname thalf kda dcf
'Th-229'  7.34E+03  0.        2.24E+02            (card14b) cname thalf kda dcf
$  ------------------------ Be-10 ------------------------ 3
 0  250  250  10  5.59E-02  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Be-10'  1.51E+06  0.  7.03E+00               (card14b) cname thalf kda dcf
$  ------------------------ C-14 ------------------------ 4
 0  0.1  0.1  14  3.32E+00  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'C-14'  5.70E+03  0.0    1.55E+00             (card14b) cname thalf kda dcf
$  ------------------------ Cl-36 ------------------------ 5
 0  0  0  36  3.20E-02  0. 1.00E+06  0.    (card14a) nprog kds kdu zmw qi rmi sl other
'Cl-36'  3.01E+05  0.  3.30E+00            (card14b) cname thalf kda dcf
$  ------------------------ Co-60 ------------------------ 6
 0  10  10  60  6.06E+01  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Co-60'  5.27E+00  0.0  1.57E+01            (card14b) cname thalf kda dcf
$  ------------------------ Cs-137 ------------------------ 7
 0  500  500  137  7.35E-01  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cs-137'  3.01E+01  0.  3.04E+01               (card14b) cname thalf kda dcf
$  ------------------------ Eu-152 ------------------------ 8
 0  340  340  152  5.65E+00  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Eu-152'  1.35E+01  0.0  6.07E+00              (card14b) cname thalf kda dcf
$  ------------------------ Eu-154 ------------------------ 9
 0  340  340  154  1.02E+00  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Eu-154'  8.59E+00  0.0  1.03E+01              (card14b) cname thalf kda dcf
$  ------------------------ H-3 ------------------------ 10
 0  0  0  3  2.22E+02  0. 1.00E+06  0.        (card14a) nprog kds kdu zmw qi rmi sl other
'H-3'  1.23E+01  0.      5.07E-02             (card14b) cname thalf kda dcf
$  ------------------------ I-129 ------------------------ 11
 0  0  0  129  6.25E-04  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'I-129'  1.57E+07  0.    1.48E+02             (card14b) cname thalf kda dcf
$  ------------------------ Nb-94 ------------------------ 12
 0  100  100  94  5.31E-02  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Nb-94'  2.03E+04 0.     7.77E+00                (card14b) cname thalf kda dcf
$  ------------------------ Ni-59 ------------------------ 13
 0  100  100  59  4.53E+00  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ni-59'  7.60E+04  0.    2.74E-01               (card14b) cname thalf kda dcf
$  ------------------------ Ni-63 ------------------------ 14
 0  100  100  63  4.69E+02  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ni-63'  1.00E+02 0.     6.70E-01               (card14b) cname thalf kda dcf
```

```
$  ------------------------ Np-237 ------------------------ 15
 2  8  8  237  1.03E-06  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Np-237'  2.14E+06  0.    6.18E+01         (card14b) cname thalf kda dcf
'U-233'  1.59E+05   0.    7.18E+01          (card14b) cname thalf kda dcf
'Th-229'  7.34E+03  0.    2.24E+02            (card14b) cname thalf kda dcf
$  ------------------------ Pu-238(U234) ------------------------ 16
 3  6  6  234  3.00E-05  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-238(U234)'  2.46E+05  0.    7.07E+01   (card14b) cname thalf kda dcf
'Th-230'  7.54E+04        0.  9.10E+01            (card14b) cname thalf kda dcf
'Ra-226'  1.60E+03        0.  3.85E+02            (card14b) cname thalf kda dcf
'Pb-210'  2.23E+01        0.  8.81E+02            (card14b) cname thalf kda dcf
$  ------------------------ Pu-239 ------------------------ 17
 3  22  22  239  1.84E-01  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-239'  2.41E+04  0.    1.35E+02          (card14b) cname thalf kda dcf
'U-235'  7.04E+08   0.    6.96E+01           (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  0.  1.73E+02            (card14b) cname thalf kda dcf
'Ac-227'  2.18E+01  0.  2.01E+02            (card14b) cname thalf kda dcf
$  ------------------------ Pu-239 as U-235---------------- 17
$ Note: I simulated as U-235 also, but the simulation as Pu-239 is more accurate and
$       more conservative. Activity is Pu-239 act. times ratio of half lives.
 2  6.  6.  235  6.30E-06  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-239(as U-235)'  7.04E+08  0.    6.96E+01 (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  0.  1.73E+02            (card14b) cname thalf kda dcf
'Ac-227'  2.18E+01  0.  2.01E+02            (card14b) cname thalf kda dcf
$  ------------------------ Pu-240 ------------------------ 18
 4  22  22  240  6.78E-02  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-240'  6.56E+03  0.    1.35E+02          (card14b) cname thalf kda dcf
'U-236'  2.34E+07   0.    6.70E+01           (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  0. 1.01E+02             (card14b) cname thalf kda dcf
'Ra-228'  1.60E+03  0. 1.04E+03             (card14b) cname thalf kda dcf
'Th-228'  1.91E+00  0. 1.07E+02             (card14b) cname thalf kda dcf

$  ------------------------ Pu-240 as U-236---------------- 18
$ Note: I simulated it as Pu-240 but simulating as U-236 is both more accurate and
$       more conservative. Activity is Pu-240 act. times ratio of half lives.
 3   6. 6.  236  1.90E-05  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-240(as U-236)'  2.34E+07  0.    6.70E+01 (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  0. 1.01E+02             (card14b) cname thalf kda dcf
'Ra-228'  1.60E+03  0. 1.04E+03             (card14b) cname thalf kda dcf
'Th-228'  1.91E+00  0. 1.07E+02             (card14b) cname thalf kda dcf
$  ------------------------ Pu-241(Np) ------------------------ 19
 2  8  8  237  2.75E-06  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-241(Np)'  2.14E+06  0.    6.18E+01     (card14b) cname thalf kda dcf
'U-233'  1.59E+05       0.    7.18E+01          (card14b) cname thalf kda dcf
'Th-229'  7.34E+03       0. 2.24E+02            (card14b) cname thalf kda dcf
$  ------------------------ Sr-90 ------------------------ 20
 0  12  12  90  4.39E-01  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Sr-90'  2.88E+01  0.    5.59E+01          (card14b) cname thalf kda dcf
$  ------------------------ Tc-99 ------------------------ 21
 0  0.0  0.0  99  3.61E-03  0. 1.00E+06  0. (card14a) nprog kds kdu zmw qi rmi sl other
'Tc-99'  2.11E+05  0.0    2.75E+00          (card14b) cname thalf kda dcf
$  ------------------------ U-232 ------------------------ 22
 1  6  6  232  1.28E-05  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-232'  6.89E+01  0.    2.92E+02          (card14b) cname thalf kda dcf
'Th-228'  1.91E+00  0. 1.07E+02            (card14b) cname thalf kda dcf
$  ------------------------ U-233 ------------------------ 23
 1  6  6  233  1.76E-04  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-233'  1.59E+05  0.    7.18E+01          (card14b) cname thalf kda dcf
'Th-229'  7.34E+03 0.  2.24E+02            (card14b) cname thalf kda dcf
$  ------------------------ U-234 ------------------------ 24
 3  6  6  234  1.21E-04  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-234'  2.46E+05  0.    7.07E+01          (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  0. 9.10E+01            (card14b) cname thalf kda dcf
'Ra-226'  1.60E+03  0. 3.85E+02            (card14b) cname thalf kda dcf
'Pb-210'  2.23E+01  0. 8.81E+02            (card14b) cname thalf kda dcf
$  ------------------------ U-238 ------------------------ 25
 4  6  6  238  1.04E-04  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-238'  4.47E+09  0.    6.40E+01          (card14b) cname thalf kda dcf
'U-234'  2.46E+05  0.    7.07E+01          (card14b) cname thalf kda dcf
'Th-230'  7.54E+04 0.  9.10E+01            (card14b) cname thalf kda dcf
```

```
'Ra-226'  1.60E+03 0.  3.85E+02          (card14b) cname thalf kda dcf
'Pb-210'  2.23E+01 0.  8.81E+02          (card14b) cname thalf kda dcf
```

Phase 2 Screening – Nonradionuclide Concentration Calculation Input File - MTRNonRNPII_r3.par

```
MTR nonradionuclide Screening Phase II - MCL- 3/23/2007
$ Phase 2 of screening based on Track 2 screening approach (track 2 defaults used, DOE-ID 1994).
$ Assumed no dispersion in vadose zone and contam. immediately avail for leaching from source.
$ Non-RNs screened based on predicted peak concentration (vs MCL or alternative).
4 1 0 1 1                                (Card 2)  imode,itype,idisp,kflag,idil
1 1 1 1 1                                (Card 3)  imodel,isolve,isolveu,imoist,imoistu
6 12 0.001                               (Card 4)  jstart jmax eps
$ when comparing to MCLs the ed and dlim must both be 1.
70. 2.555E+04 2.0  350.   1.  1.         (Card 5)  bw,at,wi,ef,ed,dlim (c / MCL of interest)
0.   0.                                  (Card 6)  x0,y0
39.6 39.6 0.10                           (Card 7)  l,w,perc
5.2  1.5                                 (Card 8b) thicks, rhos, (source term values)
0.30                                     (Card 8c) thetas (source term mc)
18.3  1.5  0.                            (Card 9)  depth,rhou,axu
0.30                                     (Card 9a) thetau
9.0 4.0  0.10  76.  15.                  (Card 10) ax,ay,az,b,z(well screen thickness)
57.0  0.10  1.9                          (Card 11) u,phi,rhoa
1                                        (Card 12a)nrecept
19.8  0.0                                (Card 12b)xrec yrec
15                                      (Card 14) ncontam
$  ------------ PCB Polychlorinated biphenyls --MCL------------------- 1
 0 100. 100. 999.  4.1E+03  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'PCB'  1.00E+12  4. 5.00E-01               (card14b) cname thalf kda dcf (mg/m^3)
$  --- Aluminum ---secondary MCL range 50 - 200 mg/m^3 use minimum -------- 2
 0  250  250  26.98  1.26E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Aluminum'  1.00E+12  10  5.00E+01               (card14b) cname thalf kda dcf
$  ------------------------ Antimony ---MCL------------------ 3
 0  50  50  121.76  6.00E+05  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Antimony'  1.00E+12  2  6.00E+00               (card14b) cname thalf kda dcf
$  ------------------------ Barium(andcompounds) --MCL------------------- 4
 0  50  50  137.33  1.45E+12  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Barium(andcompounds)'  1.00E+12  2  2.00E+03     (card14b) cname thalf kda dcf
$  ------------------------ Beryllium(andcompounds) --MCL------------------- 5
 0  250  250  9.01  2.15E+09  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Beryllium(andcompounds)'  1.00E+12  10  4.00E+00  (card14b) cname thalf kda dcf
$  ------------------------ Boron ---PRG ----------------- 6
 0  5  5  10.81  1.40E+08  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Boron'  1.00E+12  0.2  7.30E+03             (card14b) cname thalf kda dcf
$  ------------------------ Chromium ---MCL (Total)-------- 7
 0  1.2  1.2  52.00  1.59E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Chromium'  1.00E+12  0.048  1.00E+02             (card14b) cname thalf kda dcf
$  ------------------------ Copper(andcompounds) ---action level--------- 8
 0  20  20  63.55  2.93E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Copper(andcompounds)'  1.00E+12  0.8  1.30E+03 (card14b) cname thalf kda dcf
$  ------------------------ Lead ---action level---------------------- 9
 0  100  100  207.20  1.22E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Lead'  1.00E+12  4  1.50E+01                    (card14b) cname thalf kda dcf
$  ---------------- Manganese(andcompounds) ----secondary MCL------------- 10
 0  50  50  54.94  5.61E+09  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Manganese(andcompounds)'  1.00E+12  2  5.00E+01  (card14b) cname thalf kda dcf
$  ------------------------ Nickel ---Remanded MCL--------- 11
 0  100  100  58.69  9.79E+09  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Nickel'  1.00E+12  4  1.00E+02                   (card14b) cname thalf kda dcf
$  ------------------------ Silver(andcompounds) ---Secondary MCL-------- 12
 0  90  90  107.87  3.00E+07  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Silver(andcompounds)'  1.00E+12  3.6  1.00E+02 (card14b) cname thalf kda dcf
$  ------------------------ Tin ---PRG------------------ 13
 0  130  130  118.69  6.00E+07  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Tin'  1.00E+12  5.2  2.20E+04                    (card14b) cname thalf kda dcf
$  ------------------------ Uranium ---MCL------------------ 14
 0  6  6  238.03  3.12E+05  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Uranium'  1.00E+12  0.24  3.00E+01           (card14b) cname thalf kda dcf
$  ------------------------ Zinc ---Secondary MCL-------- 15
 0  16  16  65.39  1.80E+08  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
      'Zinc'  1.00E+12  0.64  5.00E+03              (card14b) cname thalf kda dcf
```

Phase 2 Screening – Nonradionuclide Concentration Calculation – Sensitivity Analysis Input File - MTRNonRNPII_akd0-r3.par

```
MTR nonradionuclide Screening Phase II - MCL- 3/23/2007
$ Phase 2 of screening based on Track 2 screening approach (track 2 defaults used, DOE-ID 1994).
$ Assumed no dispersion in vadose zone and contam. immediately avail for leaching from source.
$ Non-RNs screened based on predicted peak concentration (vs MCL or alternative).
4 1 0 1 1                                (Card 2)  imode,itype,idisp,kflag,idil
1 1 1 1 1                                (Card 3)  imodel,isolve,isolveu,imoist,imoistu
6 12 0.001                               (Card 4)  jstart jmax eps
$ when comparing to MCLs the ed and dlim must both be 1.
70. 2.555E+04 2.0  350.   1.  1.         (Card 5)  bw,at,wi,ef,ed,dlim (c / MCL of interest)
0.   0.                                  (Card 6)  x0,y0
39.6 39.6 0.10                           (Card 7)  l,w,perc
5.2  1.5                                 (Card 8b) thicks, rhos, (source term values)
0.30                                     (Card 8c) thetas (source term mc)
18.3  1.5  0.                            (Card 9)  depth,rhou,axu
0.30                                     (Card 9a) thetau
9.0 4.0  0.10  76.  15.                  (Card 10) ax,ay,az,b,z(well screen thickness)
57.0  0.10  1.9                          (Card 11) u,phi,rhoa
1                                        (Card 12a)nrecept
19.8  0.0                                (Card 12b)xrec yrec
15                                      (Card 14) ncontam
$  ------------ PCB Polychlorinated biphenyls --MCL------------------- 1
 0 100. 100. 999.  4.1E+03  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'PCB'  1.00E+12  0. 5.00E-01               (card14b) cname thalf kda dcf (mg/m^3)
$  --- Aluminum ---secondary MCL range 50 - 200 mg/m^3 use minimum -------- 2
 0  250  250  26.98  1.26E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Aluminum'  1.00E+12  0.  5.00E+01               (card14b) cname thalf kda dcf
$  ------------------------ Antimony ---MCL------------------ 3
0  50  50  121.76  6.00E+05  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Antimony'  1.00E+12  0. 6.00E+00               (card14b) cname thalf kda dcf
$  ------------------------ Barium(andcompounds) --MCL------------------- 4
 0  50  50  137.33  1.45E+12  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Barium(andcompounds)'  1.00E+12  0. 2.00E+03     (card14b) cname thalf kda dcf
$  ------------------------ Beryllium(andcompounds) --MCL------------------- 5
 0  250  250  9.01  2.15E+09  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Beryllium(andcompounds)'  1.00E+12  0.  4.00E+00  (card14b) cname thalf kda dcf
$  ------------------------ Boron ---PRG ----------------- 6
 0  5  5  10.81  1.40E+08  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Boron'  1.00E+12  0.   7.80E+03             (card14b) cname thalf kda dcf
$  ------------------------ Chromium ---MCL (Total)-------- 7
 0  1.2  1.2  52.00  1.59E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Chromium'  1.00E+12  0.0    1.00E+02             (card14b) cname thalf kda dcf
$  ------------------------ Copper(andcompounds) ---action level--------- 8
 0  20  20  63.55  2.93E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Copper(andcompounds)'  1.00E+12  0.   1.30E+03 (card14b) cname thalf kda dcf
$  ------------------------ Lead ---action level---------------------- 9
 0  100  100  207.20  1.22E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Lead'  1.00E+12  0. 1.50E+01                    (card14b) cname thalf kda dcf
$  ---------------- Manganese(andcompounds) ----secondary MCL------------- 10
 0  50  50  54.94  5.61E+09  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Manganese(andcompounds)'  1.00E+12  2  5.00E+01  (card14b) cname thalf kda dcf
$  ------------------------ Nickel ---Remanded MCL--------- 11
 0  100  100  58.69  9.79E+09  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Nickel'  1.00E+12  0. 1.00E+02                   (card14b) cname thalf kda dcf
$  ------------------------ Silver(andcompounds) ---Secondary MCL-------- 12
 0  90  90  107.87  3.00E+07  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Silver(andcompounds)'  1.00E+12  0.   1.00E+02 (card14b) cname thalf kda dcf
$  ------------------------ Tin ---PRG------------------ 13
 0  130  130  118.69  6.00E+07  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Tin'  1.00E+12  0.   2.20E+04                     (card14b) cname thalf kda dcf
$  ------------------------ Uranium ---MCL------------------ 14
 0  6  6  238.03  3.12E+05  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Uranium'  1.00E+12  0.    3.00E+01           (card14b) cname thalf kda dcf
$  ------------------------ Zinc ---Secondary MCL-------- 15
 0  16  16  65.39  1.80E+08  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Zinc'  1.00E+12  0.    5.00E+03               (card14b) cname thalf kda dcf
```

COC Radionuclide Risk Assessment
Input File - MTR-rad-risk-final-rev3.par

```
MTR Radionuclide Risk Assessment for rad COCs - Risk - ignore corrosion 3-23-07
2 1 0 1 1                               (Card 2)  imode,itype,idisp,kflag,idil
1 1 2 1 1                               (Card 3)  imodel,isolve,isolveu,imoist,imoistu
6 12 0.001                              (Card 4)  jstart jmax eps
70. 2.555E+04 2.0  350.  30.  0.0001    (Card 5)  bw,at,wi,ef,ed,dlim
0.   0.                                 (Card 6)  x0,y0
39.6 39.6 0.01                          (Card 7) l,w,perc
5.2  1.5                                (Card 8b) thicks, rhos, (source term values)
0.30                                    (Card 8c) thetas (source term mc)
18.3  1.5  2.92                         (Card 9)  depth,rhou,axu
0.30                                    (Card 9a) thetau
9.0 4.0  0.10  76.  15.                 (Card 10) ax,ay,az,b,z(well screen thickness)
57.0  0.10  1.9                         (Card 11) u,phi,rhoa
1                                       (Card 12a)nrecept
19.8  0.0                               (Card 12b)xrec yrec
8                                       (Card 14) ncontam
$  ------------------------- C-14 ------------------------ 1
 0  0.1  0.1  14  3.32E+00  0. 1.00E+06  0. (card14a) nprog kds kdu zmw qi rmi sl other
'C-14'  5.70E+03  0.004  1.55E+00          (card14b) cname thalf kda dcf
$  ------------------------- Cl-36 ----------------------- 2
 0  0  0  36  3.20E-02  0. 1.00E+06  0.     (card14a) nprog kds kdu zmw qi rmi sl other
'Cl-36'  3.01E+05  0  3.30E+00              (card14b) cname thalf kda dcf
$  ------------------------- H-3 ------------------------- 3
 0  0  0  3  2.22E+02  0. 1.00E+06  0.      (card14a) nprog kds kdu zmw qi rmi sl other
'H-3'  1.23E+01  0  5.07E-02                (card14b) cname thalf kda dcf
$  ------------------------ I-129 ------------------------ 4
 0  0  0  129  6.25E-04  0. 1.00E+06  0.    (card14a) nprog kds kdu zmw qi rmi sl other
'I-129'  1.57E+07  0  1.48E+02              (card14b) cname thalf kda dcf
$  ------------------------- Pu-239 ------------------------ 5
$ Note: I simulated as U-235 also, but the simulation as Pu-239 is more accurate and
$       more conservative.
 3 140 140  239  1.84E-01  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-239'  2.41E+04  5.6   1.35E+02          (card14b) cname thalf kda dcf
$2  6.  6.  235  6.30E-06  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'U-235'  7.04E+08  0.24  6.96E+01           (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  22  1.73E+02            (card14b) cname thalf kda dcf
'Ac-227'  2.18E+01  18  2.01E+02            (card14b) cname thalf kda dcf

$  ------------------------- Pu-239 (as U-235)-------------- 5
$ Note: I simulated as U-235 also, but the simulation as Pu-239 is more accurate and
$       more conservative. Activity is Pu-239 act. times ratio of half lives.
 2  6.  6.  235  6.30E-06  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-239(as U-235)'  7.04E+08  0.24  6.96E+01           (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  22  1.73E+02            (card14b) cname thalf kda dcf
'Ac-227'  2.18E+01  18  2.01E+02            (card14b) cname thalf kda dcf

$  ------------------------- Pu-240 ------------------------ 6
$ Note: I simulated it as Pu-240 but simulating as U-236 is both more accurate and
$       more conservative.
 4 140 140  240  6.78E-02  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
 'Pu-240'  6.56E+03  5.6   1.35E+02          (card14b) cname thalf kda dcf
'U-236'  2.34E+07  0.24  6.70E+01           (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  4  1.01E+02             (card14b) cname thalf kda dcf
'Ra-228'  1.60E+03  4  1.04E+03             (card14b) cname thalf kda dcf
'Th-228'  1.91E+00  4  1.07E+02             (card14b) cname thalf kda dcf


$  ------------------------- Pu-240 as U-236 ------------------------ 6
$ Note: I simulated it as Pu-240 but simulating as U-236 is both more accurate and
$       more conservative. Activity is Pu-240 act. times ratio of half lives.
 3   6. 6.  236  1.90E-05  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-240(as U-236)'  2.34E+07  0.24  6.70E+01           (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  4  1.01E+02             (card14b) cname thalf kda dcf
'Ra-228'  1.60E+03  4  1.04E+03             (card14b) cname thalf kda dcf
'Th-228'  1.91E+00  4  1.07E+02             (card14b) cname thalf kda dcf
```

COC Radionuclide Risk Assessment – Sensitivity Analysis Input File - aq-Kd-0-MTR-rad-risk-final-rev3.par

```
MTR Radionuclide Risk Assessment for rad COCs - Risk - ignore corrosion 3-23-07
$ Here we set all aquifer Kd values to zero.
2 1 0 1 1                               (Card 2)  imode,itype,idisp,kflag,idil
1 1 2 1 1                               (Card 3)  imodel,isolve,isolveu,imoist,imoistu
6 12 0.001                              (Card 4)  jstart jmax eps
70. 2.555E+04 2.0  350.  30.  0.0001    (Card 5)  bw,at,wi,ef,ed,dlim
0.   0.                                 (Card 6)  x0,y0
39.6 39.6 0.01                          (Card 7) l,w,perc
5.2  1.5                                (Card 8b) thicks, rhos, (source term values)
0.30                                    (Card 8c) thetas (source term mc)
18.3  1.5  2.92                         (Card 9)  depth,rhou,axu
0.30                                    (Card 9a) thetau
9.0 4.0  0.10  76.  15.                 (Card 10) ax,ay,az,b,z(well screen thickness)
57.0  0.10  1.9                         (Card 11) u,phi,rhoa
1                                       (Card 12a)nrecept
19.8  0.0                               (Card 12b)xrec yrec
8                                       (Card 14) ncontam
$  ------------------------- C-14 ----------------------- 1
 0  0.1  0.1  14  3.32E+00  0. 1.00E+06  0. (card14a) nprog kds kdu zmw qi rmi sl other
'C-14'  5.70E+03  0.0    1.55E+00          (card14b) cname thalf kda dcf
$  ------------------------- Cl-36 ----------------------- 2
 0  0  0  36  3.20E-02  0. 1.00E+06  0.     (card14a) nprog kds kdu zmw qi rmi sl other
'Cl-36'  3.01E+05  0. 3.30E+00             (card14b) cname thalf kda dcf
$  ------------------------- H-3 ----------------------- 3
 0  0  0  3  2.22E+02  0. 1.00E+06  0.      (card14a) nprog kds kdu zmw qi rmi sl other
'H-3'  1.23E+01  0. 5.07E-02               (card14b) cname thalf kda dcf
$  ------------------------- I-129 ----------------------- 4
 0  0  0  129  6.25E-04  0. 1.00E+06  0.    (card14a) nprog kds kdu zmw qi rmi sl other
'I-129'  1.57E+07  0. 1.48E+02             (card14b) cname thalf kda dcf
$  ------------------------- Pu-239 ----------------------- 5
$ Note: I simulated as U-235 also, but the simulation as Pu-239 is more accurate and
$       more conservative.
 3 140 140  239  1.84E-01  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-239'  2.41E+04  0.    1.35E+02         (card14b) cname thalf kda dcf
'U-235'  7.04E+08  0.    6.96E+01          (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  0.  1.73E+02           (card14b) cname thalf kda dcf
'Ac-227'  2.18E+01  0.  2.01E+02           (card14b) cname thalf kda dcf

$  ------------------------- Pu-239 (as U-235)-------------- 5
$ Note: I simulated as U-235 also, but the simulation as Pu-239 is more accurate and
$       more conservative. Activity is Pu-239 act. times ratio of half lives.
 2  6.  6.  235  6.30E-06  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-239(as U-235)'  7.04E+08  0.    6.96E+01  (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  0.  1.73E+02           (card14b) cname thalf kda dcf
'Ac-227'  2.18E+01  0.  2.01E+02           (card14b) cname thalf kda dcf

$  ------------------------- Pu-240 ----------------------- 6
$ Note: I simulated it as Pu-240 but simulating as U-236 is both more accurate and
$       more conservative.
 4 140 140  240  6.78E-02  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-240'  6.56E+03  0.    1.35E+02         (card14b) cname thalf kda dcf
'U-236'  2.34E+07  0.    6.70E+01          (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  0. 1.01E+02            (card14b) cname thalf kda dcf
'Ra-228'  1.60E+03  0. 1.04E+03            (card14b) cname thalf kda dcf
'Th-228'  1.91E+00  0. 1.07E+02            (card14b) cname thalf kda dcf

$  ------------------------- Pu-240 as U-236 ----------------------- 6
$ Note: I simulated it as Pu-240 but simulating as U-236 is both more accurate and
$       more conservative. Activity is Pu-240 act. times ratio of half lives.
 3   6. 6.  236  1.90E-05  0. 1.00E+06  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-240 (as U-236)'  2.34E+07  0.    6.70E+01 (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  0. 1.01E+02            (card14b) cname thalf kda dcf
'Ra-228'  1.60E+03  0. 1.04E+03            (card14b) cname thalf kda dcf
'Th-228'  1.91E+00  0. 1.07E+02            (card14b) cname thalf kda dcf
```

COC Nonradionuclide Assessment
Input File - MTR-NonRN-conc-final-rev3.par

```
MTR nonradionuclide nonrad risk assessment - conc/MCL - 3/23/2007
$ Based largely on Track 2 screening approach (track 2 defaults used, DOE-ID 1994).
$ Change infilt from 10 cm/y to 1 cm/y
$ Add dispersivity in both the vadose zone and aquifer
$ Non-RNs screened based on predicted peak concentration (vs MCL or alternative).
4 1 0 1 1                                (Card 2)  imode,itype,idisp,kflag,idil
1 1 2 1 1                                (Card 3)  imodel,isolve,isolveu,imoist,imoistu
6 12 0.001                               (Card 4)  jstart jmax eps
$ when comparing to MCLs the ed and dlim must both be 1.
70. 2.555E+04 2.0  350.   1.  1.0        (Card 5)  bw,at,wi,ef,ed,dlim (c / MCL of interest)
0.   0.                                  (Card 6)  x0,y0
39.6 39.6 0.01                           (Card 7)  l,w,perc
5.2  1.5                                 (Card 8b) thicks, rhos, (source term values)
0.30                                     (Card 8c) thetas (source term mc)
18.3  1.5  2.92                          (Card 9)  depth,rhou,axu
0.30                                     (Card 9a) thetau
9.0 4.0  0.10  76.  15.                  (Card 10) ax,ay,az,b,z(well screen thickness)
57.0  0.10  1.9                          (Card 11) u,phi,rhoa
1                                        (Card 12a)nrecept
19.8  0.0                                (Card 12b)xrec yrec
8                                       (Card 14) ncontam
$  --- Aluminum ---secondary MCL range 50 - 200 mg/m^3 use minimum -------- 2
 0  250  250  26.98  1.26E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Aluminum'  1.00E+12  10  5.00E+01               (card14b) cname thalf kda dcf
$  ------------------------ Barium(andcompounds) --MCL------------------- 4
 0  50  50  137.33  1.45E+12  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Barium(andcompounds)'  1.00E+12  2  2.00E+03     (card14b) cname thalf kda dcf
$  ------------------------ Beryllium(andcompounds) --MCL------------------- 5
 0  250  250  9.01  2.15E+09  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Beryllium(andcompounds)'  1.00E+12  10  4.00E+00  (card14b) cname thalf kda dcf
$  ------------------------ Chromium ---MCL (Total)-------- 7
 0  1.2  1.2  52.00  1.59E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Chromium'  1.00E+12  0.048  1.00E+02             (card14b) cname thalf kda dcf
$  ------------------------ Copper(andcompounds) ---action level--------- 8
 0  20  20  63.55  2.93E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Copper(andcompounds)'  1.00E+12  0.8  1.30E+03 (card14b) cname thalf kda dcf
$  ------------------------ Lead ---action level---------------------- 9
 0  100  100  207.20  1.22E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Lead'  1.00E+12  4  1.50E+01                    (card14b) cname thalf kda dcf
$  ---------------- Manganese(andcompounds) ----secondary MCL------------- 10
 0  50  50  54.94  5.61E+09  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Manganese(andcompounds)'  1.00E+12  2  5.00E+01  (card14b) cname thalf kda dcf
$  ------------------------ Nickel ---Remanded MCL--------- 11
 0  100  100  58.69  9.79E+09  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Nickel'  1.00E+12  4  1.00E+02                   (card14b) cname thalf kda dcf
```

COC Nonradionuclide Assessment – Sensitivity Analysis Input File - aq-kd-0-MTR-NonRN-conc-final-rev3.par

```
MTR nonradionuclide nonrad risk assessment - conc/MCL - sensitivity - Aquifer Kd=0 - 3/23/2007
$ Based largely on Track 2 screening approach (track 2 defaults used, DOE-ID 1994).
$ Change infilt from 10 cm/y to 1 cm/y
$ Add dispersivity in both the vadose zone and aquifer
$ Non-RNs screened based on predicted peak concentration (vs MCL or alternative).
4 1 0 1 1                                (Card 2)  imode,itype,idisp,kflag,idil
1 1 2 1 1                                (Card 3)  imodel,isolve,isolveu,imoist,imoistu
6 12 0.001                               (Card 4)  jstart jmax eps
$ when comparing to MCLs the ed and dlim must both be 1.
70. 2.555E+04 2.0  350.   1.  1.         (Card 5)  bw,at,wi,ef,ed,dlim (c / MCL of interest)
0.   0.                                  (Card 6)  x0,y0
39.6 39.6 0.01                           (Card 7)  l,w,perc
5.2  1.5                                 (Card 8b) thicks, rhos, (source term values)
0.30                                     (Card 8c) thetas (source term mc)
18.3  1.5  2.92                          (Card 9)  depth,rhou,axu
0.30                                     (Card 9a) thetau
9.0 4.0  0.10  76.  15.                  (Card 10) ax,ay,az,b,z(well screen thickness)
57.0  0.10  1.9                          (Card 11) u,phi,rhoa
1                                        (Card 12a)nrecept
19.8  0.0                                (Card 12b)xrec yrec
8                                       (Card 14) ncontam
$  --- Aluminum ---secondary MCL range 50 - 200 mg/m^3 use minimum -------- 2
 0  250  250  26.98  1.26E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Aluminum'  1.00E+12   0. 5.00E+01               (card14b) cname thalf kda dcf
$  ------------------------ Barium(andcompounds) --MCL------------------- 4
 0  50  50  137.33  1.45E+12  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Barium(andcompounds)'  1.00E+12  0. 2.00E+03     (card14b) cname thalf kda dcf
$  ------------------------ Beryllium(andcompounds) --MCL------------------- 5
 0  250  250  9.01  2.15E+09  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Beryllium(andcompounds)'  1.00E+12  0.  4.00E+00  (card14b) cname thalf kda dcf
$  ------------------------ Chromium ---MCL (Total)-------- 7
 0  1.2  1.2  52.00  1.59E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Chromium'  1.00E+12  0.0    1.00E+02             (card14b) cname thalf kda dcf
$  ------------------------ Copper(andcompounds) ---action level--------- 8
 0  20  20  63.55  2.93E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Copper(andcompounds)'  1.00E+12  0.   1.30E+03 (card14b) cname thalf kda dcf
$  ------------------------ Lead ---action level---------------------- 9
 0  100  100  207.20  1.22E+10  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Lead'  1.00E+12  0. 1.50E+01                    (card14b) cname thalf kda dcf
$  ---------------- Manganese(andcompounds) ----secondary MCL------------- 10
 0  50  50  54.94  5.61E+09  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Manganese(andcompounds)'  1.00E+12  0. 5.00E+01  (card14b) cname thalf kda dcf
$  ------------------------ Nickel ---Remanded MCL--------- 11
 0  100  100  58.69  9.79E+09  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Nickel'  1.00E+12  0. 1.00E+02                   (card14b) cname thalf kda dcf
```