

***RWMC Performance
Assessment/Composite
Analysis Monitoring Report -
FY-2002***

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ABSTRACT

US DOE Order 435.1, *Radioactive Waste Management*, Chapter IV and the associated implementation manual and guidance require monitoring of low-level radioactive waste (LLW) disposal facilities. The Performance Assessment/Composite Analysis (PA/CA) Monitoring program was developed and implemented to meet this requirement. This report presents the results of PA/CA monitoring projects that are available as of September 2002. The technical basis for the PA/CA program is provided in the PA/CA Monitoring Program document and a program description document (PDD) serves as the quality assurance project plan for implementing the PM program.

Subsurface monitoring, air pathway surveillance, and subsidence monitoring/control are required to comply with DOE Order 435.1, Chapter 4. Subsidence monitoring/control and air pathway surveillance are performed entirely by other INEEL programs – their work is summarized herein. Subsurface monitoring includes near-field (source) monitoring of buried activated beryllium and steel, monitoring of groundwater in the vadose zone, and monitoring of the Snake River Plain Aquifer. Most of the required subsurface monitoring information presented in this report was gathered from the results of ongoing INEEL monitoring programs. This report also presents results for several new monitoring efforts that have been initiated to characterize any migration of radionuclides in surface sediment near the waste.

SUMMARY

US DOE Order 435.1, *Radioactive Waste Management*, Chapter IV and the associated implementation manual and guidance require monitoring of low-level radioactive waste (LLW) disposal facilities. In particular, the following requirements of the Order must be addressed:

- The site-specific performance assessment (PA) and composite analysis (CA) shall be used to determine the media, locations, radionuclides, and other substances to be monitored,
- The environmental monitoring program shall be designed to include measuring and evaluating releases, migration of radionuclides, disposal unit subsidence, and changes in disposal facility and disposal site parameters which may affect long-term performance, and
- The environmental monitoring program shall be capable of detecting changing trends in performance to allow application of any necessary corrective action prior to exceeding the PA performance objectives.

The Performance Assessment/Composite Analysis (PA/CA) Monitoring Program was developed and implemented to meet these requirements for the Radioactive Waste Management Complex (RWMC). This report presents the results of PA/CA monitoring projects. Further interpretation in the context of the PA and CA will be accomplished during the Annual Review. A transition from calendar year to fiscal year reporting of radionuclide data has been implemented in this monitoring report, for consistency with the DOE Department of Environmental Management Integrated Planning, Accountability, and Budgeting System – Information System (IPABS-IS) requirements.

Subsurface monitoring, air pathway surveillance, and subsidence monitoring/control are required to comply with DOE Order 435.1, Chapter 4. The regional air surveillance programs at the INEEL have found no measurable airborne radioactivity that is associated with RWMC releases to air, and the amount of subsidence in 2002 was in the historical range for the SDA. Subsurface monitoring included near-field (source) monitoring of buried activated metal, monitoring of radionuclide concentrations in the vadose zone, and monitoring of the Snake River Plain Aquifer. The PA/CA monitoring program design includes monitoring of important sources as identified by the PA and CA modeling, i.e., activated steel and beryllium. Typical burial locations of activated beryllium and steel have been identified in SVR 20 and SVR 12, respectively, and a variety of sampling and measurement equipment has been installed at these locations. Vadose zone and aquifer monitoring are conducted using the large network of lysimeters and aquifer wells that have been installed in and around the SDA.

The PA and CA analyses indicate that C-14 is the primary contaminant of concern (COC). Carbon-14 is present in activated beryllium and steel, and H-3 is a contaminant of interest (COI) present in activated beryllium. The concentration of H-3 in soil surrounding activated beryllium at SVR 20, a typical activated beryllium disposal location, has been measured since 1995 by taking soil gas samples. Since 1995, H-3 concentrations in soil have increased by approximately a factor of 10. During 2001, the concentration of H-3 in soil moisture reached 3.5, 0.34, and 0.70 $\mu\text{Ci/mL}$ in soil 2.7, 4.5, and 6.2 m deep, respectively (the complete 2002 data set is not yet available). The concentration of H-3 in soil moisture

appears to fluctuate over the course of each year, and the fluctuations at each depth are correlated, suggesting that the concentrations at 2.7, 4.5, and 6.2 m are influenced similarly by soil conditions and/or source conditions. The concentration of H-3 in ambient air above the SVR 20 beryllium disposal location has been measured to help characterize the subsurface source term and to estimate atmospheric releases during the calendar year for compliance with the National Emission Standard for Hazardous Air Pollutants (NESHAP). The RWMC contributed 10% to 55% of the total annual INEEL dose to the hypothetical maximally exposed individual between 1995 and 2000, and continues to be a potential contributor to the reported dose. Estimated doses for RWMC air emissions have always been less than 0.1% of the 10 mrem/y standard. Releases for 2002 will be estimated in November, after most of the emissions have occurred.

The radioactive COCs and COIs identified during the PA, CA, and CERCLA evaluation process are C-14, Cl-36¹, I-129, Np-237, U-234, and U-238. Chlorine-36 is a radionuclide of concern for the PA/CA; however, no lysimeter or perched water samples from the RWMC vadose zone have been analyzed for Cl-36 to date. Perched water is periodically present in isolated lenses above the sediments comprising the B-C and C-D interbeds, located at depths below 140 feet. Samples are collected when there is sufficient water present to collect in the bailer. Lysimeter sampling is conducted to characterize the liquid from soil pores (soil moisture) in the vadose zone. A network of suction lysimeters was installed around the RWMC to allow repeated sampling from the sediments surrounding the waste and from the interbeds. Routine lysimeter sampling did not begin until 1997. Typically, only very small volumes of soil moisture are obtained from lysimeter samples (0 to 200 ml of water [0 to 7 oz]), and often it is not possible to draw a sample from lysimeters when the soil is relatively dry. Of the total sample volume collected, 50 ml (1.7 oz) is allotted for each separate analysis. When the sample volume is less than optimal, the actual volumes analyzed may be decreased, and the sensitivity of the measurement will be adversely affected.

Vadose zone sampling results have been summarized for the PA/CA COCs including C-14, Cl-36, H-3, I-129, Np-237, U-233/234, and U-238. There is a network of lysimeters and perched water wells in the vicinity of the RWMC where water samples are collected. The analytical results are presented by radionuclide for three different depth zones beneath the RWMC; shallow (0 to 35 feet), 35 to 140 feet, and deep (greater than 140 feet) beneath the land surface. Values are reported here only for analytical results that represent a positive detection² of COCs in the vadose zone – all other results are reported as not detected. Positive detections of COCs in vadose zone samples are compared with the maximum concentration level (MCL) for contaminants in an aquifer to provide a general guideline for the vadose zone concentrations. From 1997 through 2002 there were 13 detections (11 pCi/L - 134 pCi/L [MCL, 2,000 pCi/L]) out of 72 analytical sample results for C-14. The C-14 was detected in the shallow and deep lysimeter samples. No samples have been analyzed for Cl-36 from the vadose zone at the RWMC to date. For H-3, there were 31 detections (129 pCi/L - 9,100 pCi/L [MCL, 20,000 pCi/L]) out of 99 samples collected from 1997 through 2002. The highest concentrations are found in the shallow zone, but H-3 is found at all levels in the vadose zone. Only 3 detections (22 pCi/L - 53 pCi/L [MCL, 1 pCi/L]) for I-129 have been measured out of 69 sample results from 1997 through 2002. I-129 was only found in the shallow zone. Np-237 analyses didn't begin until 1999, and to date there have been no detections out of 62 sample results. Uranium-233/234 was detected at all depths in the vadose zone in 199 samples (0.53 pCi/L - 111 pCi/L [MCL, 27 pCi/L based on total naturally occurring uranium]) out of 202 sample

¹ Chlorine-36 was recently included in the analyte list, but has low priority. Typically, after portions of the lysimeter or perched water sample are allocated for higher priority analyses, the remaining volume is insufficient for Cl-36 analysis.

² The result from a sample measurement is considered positive if its value is greater than the sample-specific minimum detectable activity and is more than three times greater than its uncertainty.

results. Natural background concentrations of U-233/234 in the vadose zone at the INEEL are about 3 pCi/L. U-238 was also detected at all levels in the vadose zone in 174 (0.68 pCi/L - 52.8 pCi/L [MCL, 27 pCi/L total naturally occurring uranium]) out of 187 sample results collected from 1997 through 2002. Natural background concentrations of U-238 in the vadose zone at the INEEL are about 1.5 pCi/L. In summary; C-14, H-3, I-129, U-233/234, and U-238 were found in the shallow vadose zone (0 – 35 feet depths) at the RWMC. Tritium, U-233/234, and U-238 were found at depths from 35 to 140 feet. C-14, H-3, U-233/234, and U-238 were found at depths greater than 140 feet at the RWMC.

Aquifer sampling results have been summarized for the PA/CA COCs including C-14, Cl-36, H-3, I-129, Np-237, U-233/234, and U-238. There is a network of monitoring wells in the vicinity of the RWMC where aquifer water samples are collected. The analytical results are discussed for each radionuclide and directly compared with the MCL. Values are reported only for analytical results that were a positive detection – all other results are reported in this data summary as not detected. C-14 was detected at low levels (1.8 pCi/L – 42 pCi/L [MCL, 2,000 pCi/L]) in the aquifer from 1994 through 2002 in 24 out of 255 sample results. There were no detections of Cl-36 found in aquifer water collected from 2000 through 2001. Only 24 samples were analyzed for Cl-36. Tritium has been analyzed at the RWMC since 1975, and it has been detected in the aquifer at low to moderate levels (507 pCi/L – 5400 pCi/L [MCL, 20,000 pCi/L]) in 370 out of 895 sample results. I-129 was found in the aquifer from 1996 through 1999, but it was not detected from 2000 to date. Only 5 out of 268 sample results contained I-129 (0.59 pCi/L – 17.0 pCi/L [MCL, 1 pCi/L]). Analysis for Np-237 in the aquifer beneath the RWMC began in 1999. There were 211 samples collected from 1999 through 2002. No Np-237 was detected until 2002 when 3 samples had low concentrations of Np-237 (0.07 pCi/L – 0.38 pCi/L [MCL, 15 pCi/L total alpha]). U-233/234 sampling began in 1998. Low concentration levels were detected in 200 out of 202 sample results (0.40 pCi/L – 4.29 pCi/L [MCL, 27 pCi/L total naturally occurring U]). Typical aquifer background concentration for U-233/234 are 1.1 pCi/L in this area. U-238 sampling also began in 1998. Low concentration levels were detected in all 213 sample results (0.18 pCi/L – 0.78 pCi/L [MCL, 27 pCi/L total naturally occurring U]). Typical aquifer background concentration for U-233/234 are 1.1 pCi/L. In summary; C-14, H-3, I-129, Np-237, U-233/234, and U-238 have been detected in the aquifer beneath the RWMC.

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ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COC	Contaminant of concern
COI	Contaminant of interest
DATS	Discriminating Atmospheric Tritium Sampler
DOE	Department of Energy
EM	Environmental Monitoring
ER	Environmental Restoration
FY	Fiscal Year
INEEL	Idaho National Engineering and Environmental Laboratory
IPAB-IS	Integrated Planning, Accountability, and Budgeting System – Integrated System
L&V	Limitations and Validation
LLW	Low Level Waste
LSC	Liquid Scintillation Counting
NESHAP	National Emission Standard for Hazardous Air Pollutants
OIS	Optical Imaging System
PA/CA	Performance Assessment/Composite Analysis
PATS	Passive Airborne Tritium Sampler
PDD	Program Description Document
RWMC	Radioactive Waste Management Complex
SA	Specific Activity
SDA	Subsurface Disposal Area
SMO	Sample Management Office
SRPA	Snake River Plain Aquifer
SVR	Soil Vault Row
WAG	Waste Area Group
WM	Waste Management

NOMENCLATURE

Activated	Radioactivity caused by exposure to radiation, particularly neutrons.
Active pit	The SDA pit currently used for waste disposal.
Herculite [®]	Polyvinyl chloride/nylon mesh laminate used, e.g., as a tarpaulin.
Lysimeter	Instrument used to measure the matric potential of water in unsaturated soil.
Matric potential	A measure of the energy associated with retention of water at a location in a soil matrix.
Perched water	A zone of saturated subsurface media above the local aquifer.
Source environment	Waste and the material surrounding the waste where the properties of the material are substantially affected by the presence of the waste.
Specific activity	Activity of a specific radioisotope per gram of the element present in a material.
Surface sediment	The sediment overlying the first layer of bedrock.
Tedlar [®]	A chemical-resistant fluorocarbon plastic.
Type B probe	A soil probe that may be driven into the ground hydraulically, and carry soil monitoring instruments, used to minimize soil disturbance during emplacement of the instruments.
Vadose zone	The subsurface region overlying the local aquifer.

1. INTRODUCTION

The Idaho National Engineering and Environmental Laboratory (INEEL) Radioactive Waste Management Complex (RWMC) has been used for waste disposal operations since the late 1950s. The RWMC contains the historical Subsurface Disposal Area (SDA) as well as the operating low level waste (LLW) active pits. To comply with requirements of DOE Order 435.1, *Radioactive Waste Management* (DOE 1999), the potential future exposure of members of the public to radionuclides released from the RWMC must be evaluated and compared to disposal facility performance objectives. The performance evaluation is accomplished by modeling, as described in performance assessment (PA) reports (Maheras et al. 1994, Maheras et al. 1997, Case et al. 2000) and the Composite Analysis (CA) report (McCarthy et al. 2000). The RWMC also is one of the INEEL's primary waste area groups (WAGs). The Environmental Restoration (ER) program is responsible for conducting assessments of WAGs for INEEL's Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) response.

DOE Order 435.1 requires that the results of PA and CA modeling be used to design an environmental monitoring program for the disposal facility. The monitoring results are to be used to verify modeling assumptions, confirm that the model adequately represents actual conditions, and demonstrate compliance with the RWMC performance objectives. The required data streams for the RWMC PA/CA monitoring program are identified in the PA/CA Monitoring Program description (McCarthy et al. 2001). Most of the required information can be gathered from the results of ongoing INEEL monitoring programs, but several new monitoring efforts have been initiated to characterize the migration of radionuclides in surface sediment near the waste. Also, ER conducts measurements to evaluate environmental conditions at RWMC. The PA/CA monitoring program emphasizes coordinated planning of sampling efforts conducted by Waste Management (WM) and ER. The PA/CA monitoring program description presents the rationale for use of existing monitoring program results and for developing additional monitoring projects, as well as a detailed description of the environmental conditions at the RWMC and in the region surrounding the INEEL.

This report presents PA/CA monitoring program results through summer 2002. The report has relatively detailed information on measurements of C-14 and H-3 released from the beryllium waste that was buried in SDA Soil Vault Row 20 (SVR 20) in 1993. The monitoring at SVR 20 began in 1994, so sampling/analysis operations are relatively well established and there is sufficient data for trend analysis over several years. Several additional projects to characterize the source environment began in 2001, including active pit monitoring by WM and installation of Type B probes at a typical activated steel disposal location by ER. This report summarizes the results of sampling and analysis for the vadose zone (VZ) and aquifer monitoring projects, particularly those conducted by ER (Holdren et al. 2002).

A transition from calendar year to fiscal year reporting of radionuclide data has been implemented in this monitoring report, to be consistent with the DOE Department of Environmental Management Integrated Planning, Accountability, and Budgeting System – Information System (IPABS-IS). The aquifer and vadose zone data reported here are formatted by fiscal year, but are consistent with the data reported to date by ER, and include ER results through May 2002 to respond to the requirements of DOE Order 435.1. The analytical data and associated data qualifiers and data usage limitations are documented in the INEEL Environmental Restoration program's Limitations and Validation (L&V) reports. The L&V reports are archived by the Sample Management Office (SMO) and are available through the Optical Imaging System (OIS).

1.1 PA and CA Models

The PA and CA are conducted to demonstrate compliance with the performance objectives for low-level waste disposal identified in DOE Order 435.1. The performance objectives address potential exposures via ingestion, inhalation and external radiation. Thus, the presence of radionuclides in the air, on surface soil, and in groundwater is of interest for a monitoring program. The PA addresses wastes disposed in the active disposal pits and soil vaults since 1984 and the CA addresses wastes disposed in all of the pits, trenches, and soil vaults at the SDA as well as other potential sources outside of the SDA. In the context of monitoring groundwater, it will be difficult to distinguish between radionuclides that migrated from wastes disposed before 1984 and wastes disposed after 1984. Thus, the more comprehensive modeling conducted for the CA is the primary point of comparison for the monitoring program.

Carbon-14 was identified as the primary contaminant of potential concern (COPC) in the RWMC Performance Assessment and the CERCLA baseline risk assessment, because it is a major contributor to estimated dose from the groundwater pathway during the 1000-year post-release compliance evaluation period. The most recent PA and CA groundwater modeling was conducted assuming that C-14 does not migrate in gas phase. Therefore, fractional losses due to emission to the atmosphere were not considered, nor was the generally mitigating effect of more rapid subsurface dispersal by gas phase transport processes. The estimated doses for C-14 would be reduced nearly in direct proportion to the amount that escapes to the atmosphere. With respect to performance objectives, the dose potentially caused to members of the public by chronic release of C-14 to the atmosphere during the operational and institutional control periods of the SDA are less significant than the dose that is projected based on current modeling assumptions to occur over long times as a result of migration in groundwater. Also, it was assumed that C-14 is minimally affected by sorption. The modeled dose caused by C-14 is probably substantially overestimated because of these conservative assumptions. Monitoring data can help to determine whether the migration rates are being overestimated in the modeling.

Tritium, as tritiated water, was identified as a contaminant of interest (COI) because it reflects the corrosion of the beryllium and is relatively easy to measure. Also, H-3 does not react with the soil solid phase (unlike $^{14}\text{CO}_2$), so H-3 concentrations more directly reflect corrosion-driven releases than would $^{14}\text{CO}_2$ concentrations. Tritium is useful as a hydrological tracer and is of particular interest as a tracer of groundwater movement in the SRP aquifer at INEEL. The H-3 plume in the SRP aquifer caused by operation of the ICPP injection well has been used to calibrate and validate aquifer flow models for the PA and CA. Recent results from new monitoring wells have shown that waste buried in the SDA (in particular, activated beryllium) is likely to be the predominant source of H-3 measured in the aquifer in the immediate vicinity of the RWMC (McCarthy et al. 2001). A sufficient amount of H-3 migrates through the vadose zone to result in measurable concentrations in the aquifer below the RWMC, typically corresponding to about 5% of the maximum contaminant level (MCL). Characterization of the H-3 source term at RWMC may support modeling of gas phase water and contaminant transport, as well as the aquifer flow model.

1.2 PA and CA Monitoring Program Scope

Subsurface monitoring, air pathway surveillance, and subsidence monitoring/control are required to comply with DOE Order 435.1, Chapter 4. Regional air surveillance is conducted by

the longstanding INEEL environmental monitoring organizations.³ To date, the regional air surveillance programs have found no measurable airborne activity associated with RWMC releases to air. The BBWI Environmental Monitoring (EM) group conducts subsidence monitoring. The amount of subsidence in 2002 was in the historical range (Keck 2002) for the SDA⁴. The results of visual inspections are reported to WM operations organization, which is responsible for maintenance of the SDA cover.

The physical scope of subsurface monitoring by the PA/CA monitoring program is divided into the source (or near-field) environment, vadose zone (VZ), and Snake River Plain Aquifer (SRPA). The VZ and aquifer monitoring efforts represent a focused extension of longstanding programs – source monitoring is a relatively recent development that began with the activated beryllium monitoring project (Ritter and McElroy, 1999). The beryllium monitoring project continues under the PA/CA monitoring program, and a similar source monitoring project is underway for typical activated steel disposals. Active pit monitoring equipment is being installed as the pit is filled, but sampling and measurements will not be performed until cover material is placed over the waste pile where the instruments are located. The active pit monitoring project will provide site-specific information regarding the source environment for SDA pits.

1.3 PA /CA Monitoring Program Implementation and QA/QC

Program implementation and QA are described in a program description document (PDD-1117), formatted as a quality assurance project plan (INEEL 2001). The PDD cites BBWI Technical Procedures (TPRs) for field operations. Sampling projects conducted by ER follow approved field sampling and analysis plans.

1.4 Site Description

The INEEL is located in a semi-arid, high desert region in southeastern Idaho (Figure 1-1). During summer, low humidity, strong solar heating, and high air temperatures cause high evapotranspiration rates. During winter, daily average temperatures usually remain below freezing for 2 to 3 months and evapotranspiration is negligible. The average annual precipitation is 22 cm, and the peak monthly-averaged precipitation rate, 3.1 cm/month, usually occurs through May and June. About 30% of the annual precipitation falls as snow (Clawson et al., 1989). Typically, one or a few mid-winter and spring thaws result in runoff and infiltration. The relative proportions of runoff and infiltration depend upon soil conditions such as the moisture content of the soil, or whether the soil is frozen when the snow melt or rainfall occurs.

The surface sediments at the SDA are composed of silt, sand, clay, and gravel ranging from 0.6 to 7.0 m thick. The surface has been highly disturbed by grading operations over the last 10 years. The SDA is sparsely vegetated with bunchgrass and occasional invasive weeds. Currently, invasive annual and perennial weeds are the predominant vegetation in the vicinity of SVR 20. The surface sediments are deposited on basalt, and most of the subsurface consists of

³ Currently, regional air surveillance is conducted by the BBWI Environmental Monitoring program (e.g. see INEEL 2000, "1999 Environmental Monitoring Program Report, INEEL EXT-2000-00318, September 2000), and the Environmental Surveillance, Education, and Research program (e.g., see DOE 2000, "INEEL Site Environmental Report for Calendar Year 1998," DOE 12082(98), July 2000). The State of Idaho INEEL Oversight program also conducts regional air surveillance.

⁴ Personal communication with Linda Hodges, BBWI Environmental Monitoring group, September 16, 2002.

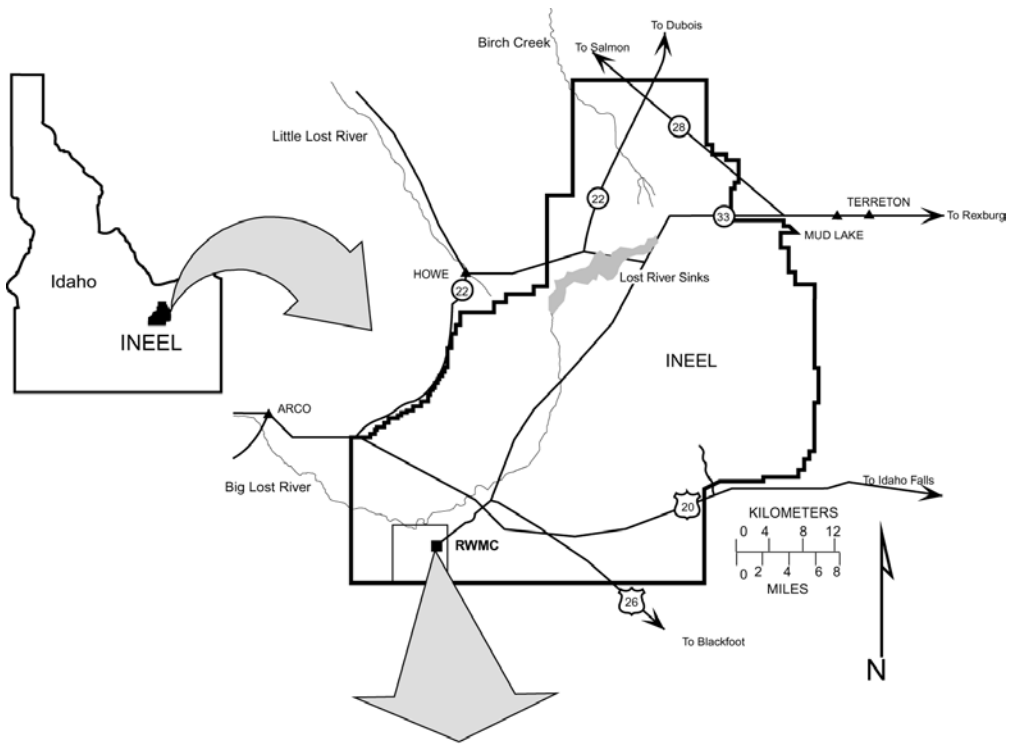


Figure 1-1. RWMC and its location (Photo is rotated with north to the left).

basalt flows interrupted by thin sedimentary interbeds. The basalts are often fractured, particularly at the boundaries of each flow. In the southeast section of the SDA where SVR 20 is located, the shallowest interbed is about 125 feet below land surface and the next interbed is located about 240 feet below land surface. Perched water is found above both interbeds.

The INEEL is situated over part of the SRPA, which is the saturated portion of a series of basalt flows and interlayered pyroclastic and sedimentary materials underlying the eastern Snake River Plain. The aquifer contains numerous, relatively thin basalt flows extending to depths of 1,070 m (3500 feet) below land surface. The SRPA also contains sedimentary interbeds that typically are discontinuous. Aquifer permeability is controlled by the distribution of highly fractured basalt flow tops, interflow zones, lava tubes, fractures, vesicles, and intergranular pore spaces. The variety and degree of interconnected water-bearing zones result in complex local flow patterns throughout the aquifer. The permeability of the aquifer varies considerably over short distances, but generally, a series of basalt flows will include several highly productive water-bearing zones. Numerous wells penetrate the water table in the region around the RWMC. Water level data from these wells are used to estimate the gradient and flow rate (McCarthy et al. 2001); however, interpretation of this information is complicated by the anisotropic and heterogeneous nature of the ESRP basalts. Flow direction generally is northeast to southwest, though local perturbations and seemingly anomalous behaviour have been observed.

More detailed information concerning the surface, vadose zone, and aquifer conditions at the RWMC and INEEL is available in the PA and CA monitoring program description (McCarthy et al. 2001). The groundwater investigation documented in the WAG 7 Groundwater Pathway Track 2 Summary Report (Burgess et al. 1994) also has detailed information concerning the VZ and SRPA.

2. SOURCE MONITORING PROJECTS

The source environment consists of the waste and backfilled soil that surrounds the waste. The groundwater contamination levels projected by modeling for the PA and CA are strongly affected by the rate of release from the waste forms and containers to the soil. The source environment is of particular interest for the PA/CA Monitoring Program because contaminants migrating from the waste are more likely to be detected earlier and at higher levels in the source environment than at any other location in the subsurface. Source measurements will provide the timeliest information for determining if facility performance meets expectations. Measurements in the source environment will support efforts to validate the source term model, which has a substantial influence on the results of the PA and CA models.

A relatively small number of waste types are of particular concern for the PA and CA. These include activated beryllium and activated steel. Typical disposals of these waste types have been identified for source monitoring.

2.1 Beryllium Disposal and Monitoring Methods

2.1.1 Description of Beryllium Blocks and Disposal Conditions

In July 1993, irradiated Advanced Test Reactor (ATR) beryllium reflector blocks (Figure 2-1) were taken to the SDA for disposal. Three shipments were made, each carrying two beryllium blocks. As a result of various fast and slow neutron reactions, the 6 blocks contained a total of 293,000 Ci of H-3 (predominantly as $^3\text{H}_2$, corrected for decay to 1993), on the order of 20 Ci of C-14 (Schnitzler 1995). The H-3 activity concentration in the beryllium was estimated to be about 3 Ci/cm^3 , decreasing by a factor of 2 for every 2.5-cm away from the fuel/beryllium interface (Maheras et al. 1994). Galvanized steel canal baskets were used to contain the blocks in each shipment. The beryllium and canal baskets were buried in Soil Vault Row 20, 315 ft from the east row marker.

The soil vault was constructed using a 150 cm diameter soil auger to remove soil from the surface to the basalt interface. The basalt interface was located about 5.9 m below the original grade. Basalt was removed from the bottom of the auger hole to reach a final depth of about 6.4 m, then approximately 60 cm of soil was placed at the bottom of the unlined hole. Bags made of Herculite[®] (polyvinyl chloride/nylon mesh laminate) were placed over the bottom of the cask and the beryllium blocks, contained in the canal baskets and Herculite[®] bags, were discharged into the auger hole. Approximately 15 cm of soil were placed over the canal baskets between each shipment. The positions of the Herculite[®] bags at burial were not controlled, so the open tops of the canal baskets are probably covered to varying degrees. The bottoms of the canal baskets, which have 56 6.4-mm diameter perforations, are almost certainly blocked by Herculite[®]. After the final shipment, the hole was backfilled to grade with native soil, covering the beryllium in the upper basket with about 200 cm of soil.

The H-3 and C-14 inventories in this and other activated beryllium disposals are a substantial fraction of the total C-14 and H-3 inventory of the RWMC. Beryllium in contact with INEEL soil corrodes at about the same rate as carbon steel⁵ (Adler-Flitton et al. 2001). Tritium

⁵ Results of corrosion testing of buried carbon steel and beryllium coupons show a maximum thickness loss rate of 0.460 mils per year and 0.327 mils per year, respectively, after 3 years of burial (Adler-Flitton et al. 2001).

and C-14 are released from the beryllium by corrosion, and form environmentally mobile compounds. The PA and CA modeling indicate that the C-14 in beryllium disposals in the SDA is one of the primary contributors to the total dose estimated for the SDA inventory.

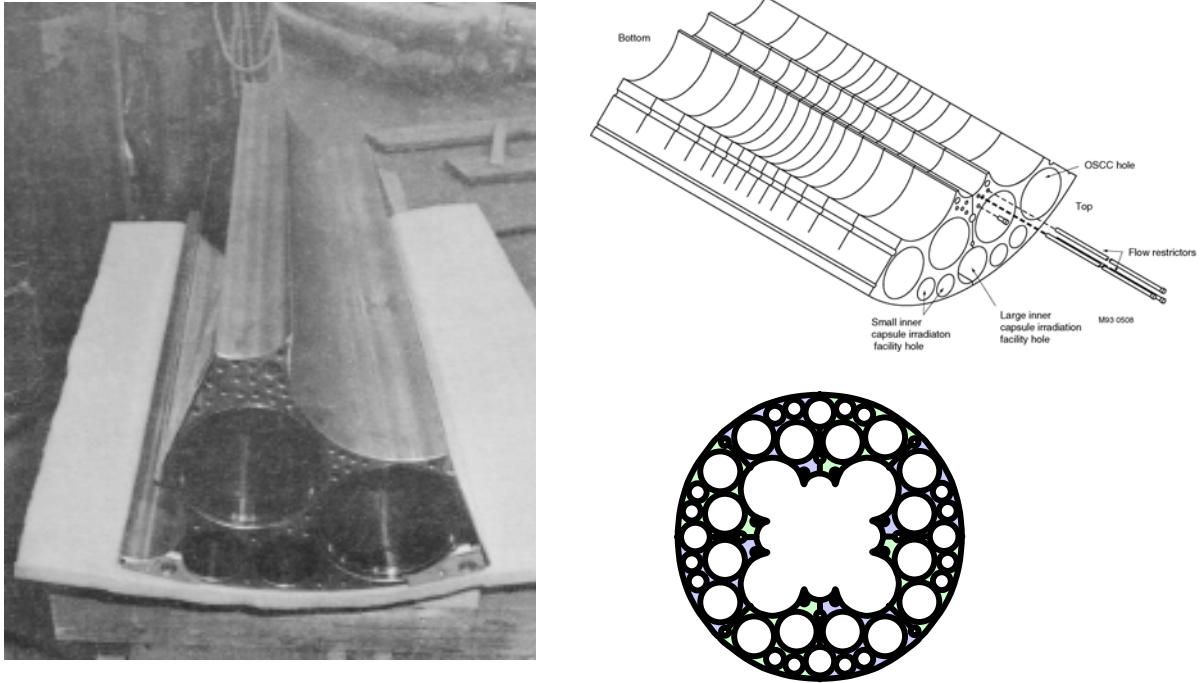


Figure 2-1. Photograph of an ATR beryllium reflector block, and isometric drawing showing stress-relief saw cuts, and the arrangement of the reflectors around the lobes of ATR reactor fuel.

The INEEL Waste Management (WM) department established a monitoring project to characterize the migration of H-3 and C-14 from the beryllium blocks that were buried in 1993. The programmatic purpose for the project was to provide supporting information for the RWMC PA, consistent with the prevailing DOE guidance and commitments made in the 1994 PA report (Maheras et al. 1994). Confirmation of the predicted rapid corrosion of buried beryllium was the first priority for the monitoring project. Sampling and analysis of released H-3 was used as a simple, practical method for characterizing the corrosion-driven release of radionuclides from the beryllium. The PA identified C-14 as the greatest potential contributor to dose of all radionuclides in the beryllium inventory. A limited number of measurements of C-14 specific activity in CO₂ in soil gas were performed during 1996 and 1997.

Other technical objectives for the original monitoring program were to (1) confirm that tritiated hydrogen is oxidized to tritiated water in the soil immediately surrounding the beryllium, (2) estimate the amounts of H-3 that migrate to the atmosphere and toward the Snake River Plain (SRP) aquifer, and (3) confirm that the calculated beryllium corrosion and radionuclide release models and rates used in the RWMC performance assessment are reasonable. Tritiated hydrogen is rapidly oxidized in surface soil (McFarlane et al. 1979). The ratio of tritiated hydrogen to

tritiated water vapor has been measured in soil gas samples taken near the beryllium. The results indicate that essentially all the released H-3 is oxidized near the point of release in the deeper subsurface environment, confirming a major PA modeling assumption. Efforts to measure the amount of H-3 migrating to the atmosphere directly above the beryllium have been relatively successful, but at present, there are no means for directly measuring H-3 that has moved downward beyond the surface sediments. The amounts of H-3 released to the soil and air are consistent with the estimated rate of corrosional release of H-3 from beryllium used in the 1994 PA report.

The beryllium monitoring program was incorporated into the more comprehensive PA/CA Monitoring program (McCarthy et al. 2001) in FY 2001. Some of the original objectives (see section 1.2) for monitoring the buried beryllium are being pursued through other studies, including corrosion testing of beryllium samples and meso-scale column studies of C-14 migration in soil. Controlled tests of beryllium coupon corrosion in RWMC soil (Adler-Flitton et al. 2001) provide confirmation of the estimated rate of beryllium corrosion used in the PA and CA. Results for more extensive testing may ultimately be useful for predicting corrosion rates for a range of disposal conditions. For now, the corrosion and release rate estimates at SVR 20 must be characterized by field measurements -- minor site-specific variations in the chemical and physical conditions near buried beryllium could greatly affect the actual rate.

The PA/CA monitoring plan calls for continued measurement of H-3 concentrations in air at SVR 20 to serve as a basis for estimating annual atmospheric emissions for compliance with the NESHAP. Releases must be estimated yearly for the INEEL NESHAP annual report (e.g., see DOE 1997). The RWMC contributed 10% to 55% of the total annual INEEL dose to the hypothetical maximally exposed individual between 1995 and 2000, and continues to be a potential contributor to the reported dose. Estimated doses for RWMC air emissions have always been less than 0.1% of the 10 mrem/y standard.

Although C-14 was identified in the PA and CA as a more important long-term problem than H-3, relatively few measurements have been made of C-14 concentration in environmental media near the buried beryllium. These measurements have established that C-14 is migrating from the beryllium and is present in soil gas and liquid. The total concentration of C-14 in soil near the sampling locations cannot be estimated from soil gas or liquid sampling because an unknown fraction of the C-14 may be present in the solid phase. Results of meso-scale column studies may provide a basis for estimating the amounts in all phases. In contrast to the relatively extensive H-3 monitoring, C-14 monitoring efforts have been limited by the relative difficulty of sampling and analysis. A new method was developed in 2001-2 to facilitate routine measurement of C-14 as $^{14}\text{CO}_2$ in soil gas. The new method may also be effective for measuring C-14 in ambient air.

2.1.2 Environmental conditions at SVR 20

Soil vault row 20 runs parallel to the interior perimeter road in the southeast corner of the SDA (see Figure 1-1), between the road and the southern fence. The south edge of the perimeter road lies partially over SVR 20. During 1984 and 1985 and again during 1992 and 1993, MgCl_2 dust suppressant was applied to roads in the SDA during the summer.⁶ During the winter, snow

⁶ Pre-decisional draft report, *The Effects of Salt Treatments on Unpaved Roads at a Radioactive Waste Management Site*, C. W. Bishop and L. C. Hull, INEEL/EXT-01-00173, October 2001.

from road clearing is often banked over SVR 20, E315'. This concentrates snowmelt directly over the soil vault, increasing the potential for infiltration. The banked snow also can cause ponding of runoff water from the road. Water infiltration was measured at well W06, about 60 m west of SVR 20 along the perimeter road. Well W06 is similarly affected by snow removal, and an estimated 56 cm of water infiltrated into the soil between the surface and the basalt interface at W06 over a 7 day period during the spring of 1993. Of this infiltrating water, an estimated 28 cm passed beyond the effective range of evapotranspiration, demonstrating the potential for enhanced deep infiltration along the road edge (McElroy 1993). During some years, vegetation has been removed from above SVR 20, substantially reducing the potential for transpiration. Currently, the vegetation includes deep-rooted annual and perennial plants which could effect transpiration from considerable depth (see Figure 2-2).

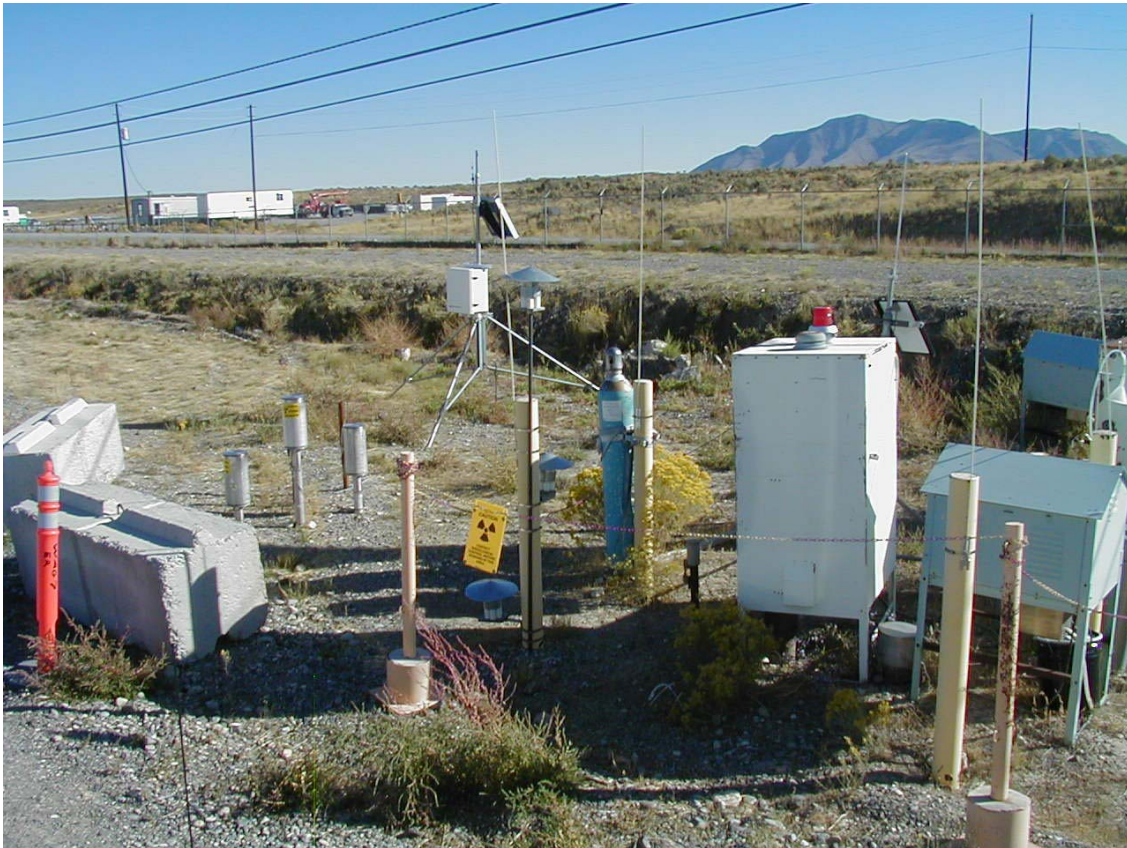


Figure 2-2. View of the location at SVR 20 where activated beryllium was buried in 1993.

2.1.3 Monitoring Equipment and Sample Collection at SVR 20

Subsurface monitoring

In 1994, sampling wells and instrumentation were installed at SVR 20 for the WM organization. Suction lysimeters were placed approximately 30 cm outside the auger hole, 2 m and 6 m belowgrade in well LYS-1 (designated RWMC-SC1-S-115 in the Comprehensive Well Survey). Thermistors were installed near the lysimeters to measure soil temperature 2 m and 6 m belowgrade. Neutron access tube (NAT) -17 (designated RWMC-NEU-S-110 in the Comprehensive Well Survey) was installed for soil moisture measurements. Soil gas sampling

ports were placed approximately 30 cm outside the auger hole at 2.7, 4.5, and 6.2 m belowgrade in Gas Sampling Port well -1 (GSP-1, which is designated RWMC-9AS-S-116 in the Comprehensive Well Survey). The GSP-1 sampling ports were installed as close as possible to the beryllium blocks to improve sensitivity for detecting trends in releases from the beryllium. The beryllium blocks, canal baskets, and the soil vault are shown schematically in Figure 2-3.

In 2001, the ER organization installed Type B probes at SVR 20 (Figure 2-4) as part of the CERCLA evaluations (Salomon 2001). The Type B probes at SVR 20 were configured as either vapor sampling ports or tensiometers. The new vapor sampling probes were installed at greater distances from the beryllium buried in SVR 20 to complement the existing instrumentation, and provide information that could be used to characterize lateral migration of H-3 and C-14 from the beryllium. The Type B tensiometer probes were installed to measure matric potential near the beryllium to determine hydraulic gradients and the direction of flow. If the hydraulic conductivity is known, the matric potential may be used to calculate the rate of flow.

Soil gas samples for H-3 analysis are collected using either of two methods. The samples from SVR 20 GSP-1 vapor ports usually are pumped through water-filled gas-washing bottles (bubblers) to extract H-3 from the samples. This grab-sampling method minimizes sample preparation/analysis costs, but is only suitable for measuring relatively high concentrations of H-3. Alternatively, gas samples are pumped through desiccants to collect the contaminated water vapor. ER uses desiccant collection for the Type B probes at SVR 20. The desiccant method, as performed by ER, is a long-term integrated sample. Analysis of the water desorbed from a desiccant trap provides a direct measurement of the concentration of H-3 per gram of soil moisture. Bubbler sampling provides a measurement of the total H-3 in the soil gas sample volume. The concentration of H-3 in the soil moisture may be calculated from the volumetric concentration in the sample and the ambient soil temperature at the sampling location because soil gas is saturated with water vapor. Thermistors were used to measure the temperature of subsurface soil during 1995 and 1996, and again in 1999. Based on these temperature measurements, the temperatures at the sampling depths are assumed to be the same on any particular date from year to year. The absolute humidity of the saturated pore gas was determined from published tables (Weast 1976) based on the soil temperature.

Sample volumes currently are determined using measurements of flow rate and sampling time. The H-3 concentration of water vapor in the soil gas is the same as the H-3 concentration in the soil liquid. The sampling and analysis methods for soil gas concentration measurements were refined so that beginning in 1997, the total uncertainty can be evaluated quantitatively for each sample and typically held to a maximum of 10 to 15% relative error.

A discriminating atmospheric tritium sampler (DATS) has been used to collect tritiated hydrogen gas and tritiated water vapor simultaneously (Griesbach and Stencil 1988) from soil gas samples. DATS sampling was not performed in 2002, but additional DATS sampling is planned to confirm that the ratio of H-3 in hydrogen gas and water vapor forms continues to be small. The DATS was designed for continuous facility stack monitoring, and is unnecessarily complicated for grab sampling. In the future, the DATS trap/oxidizer components may be used with simpler carrier gas and sample flow systems to facilitate field operations at the SDA.

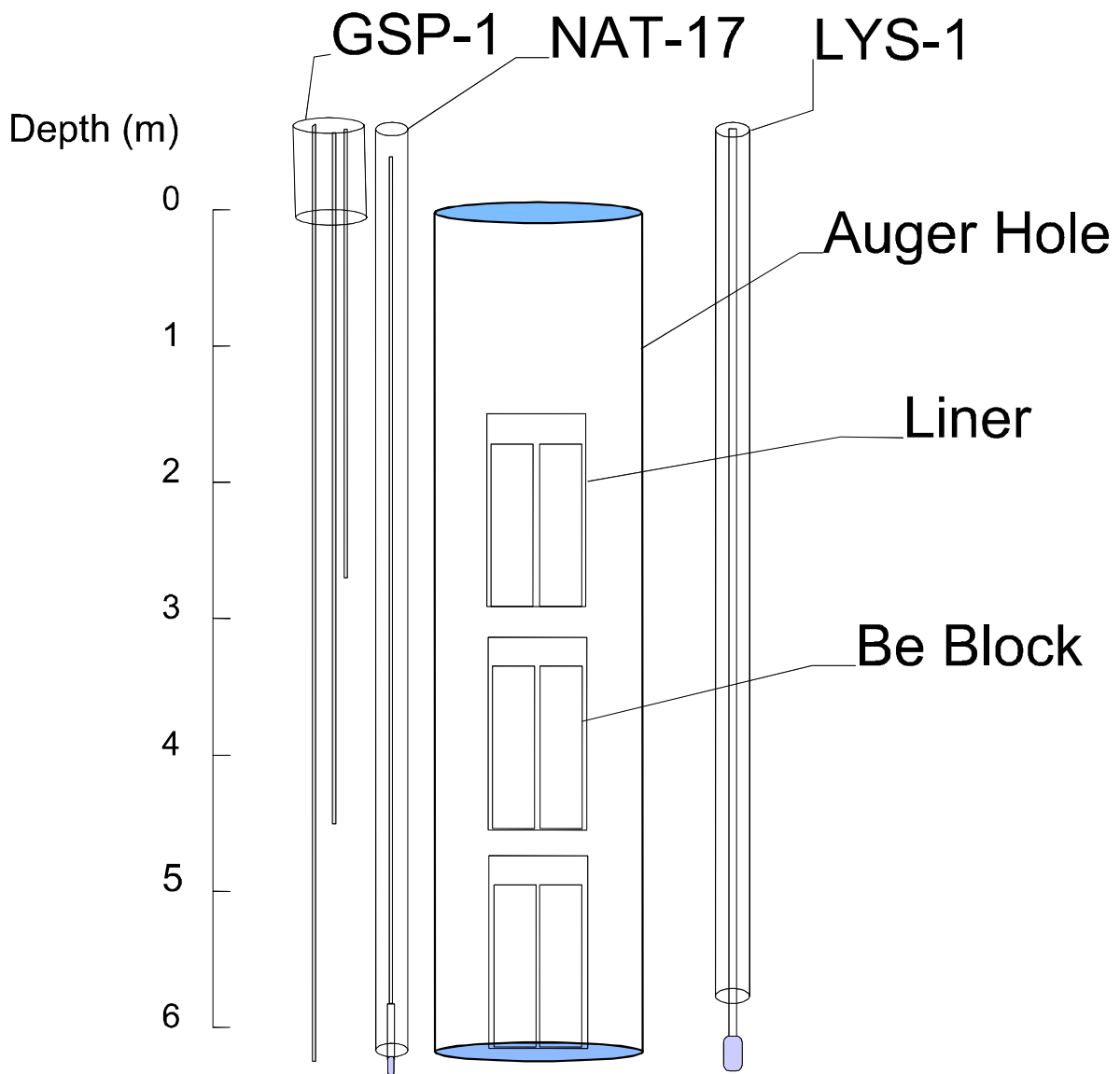


Figure 2-3. ATR beryllium blocks buried at SVR 20, 315 feet east of the row marker. (The sampling and instrumentation ports are shown to scale relative to depth only. The gas sampling ports (Well GSP-1) are thought to be at least 60 cm from the canal baskets and 30 cm outside of the auger hole. The inlets of these ports are 2.7, 4.5, and 6.2 m belowgrade. The canal baskets are shown stacked directly over each other, but most likely are offset somewhat. The canal baskets are contained in Herculite[®] bags. The Herculite[®] bags, thermistors, and shallow lysimeter in LYS-1 are not shown.)

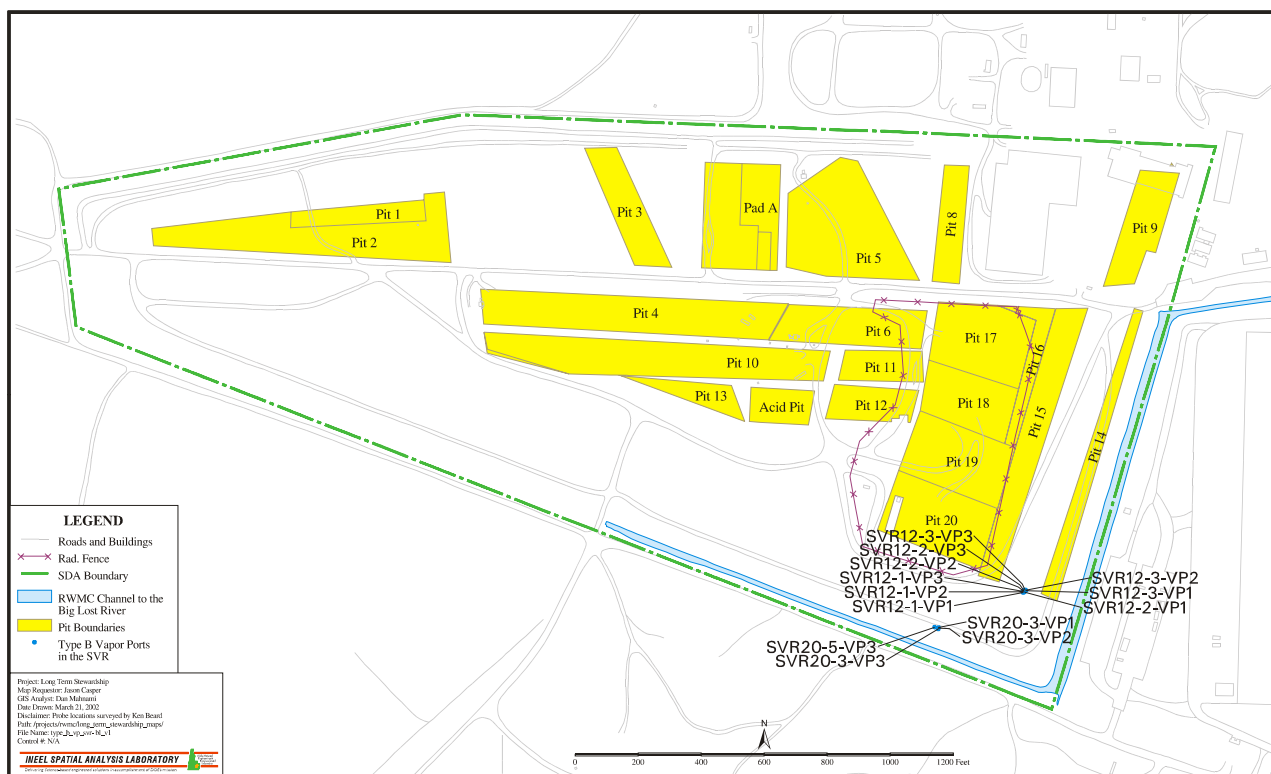


Figure 2-4. Locations of Type B probes installed at SVR 20 and SVR 12 in 2001.

Prior to 2002, soil gas samples were collected for $^{14}\text{CO}_2$ analysis by sorbing the CO_2 with caustic solutions in bubblers. Typical collection efficiencies were relatively low; however, stable carbon and C-14 are assumed to be trapped with equal efficiency in the caustic solutions, so low efficiency would not adversely affect the determination of sample specific activity (SA). The amount of carbonate trapped in the caustic solutions was determined by titration, and the C-14 activity was measured by liquid scintillation counting (LSC). The sample volume is not required for SA data reduction or interpretation.

A new method was developed during 2001-02 for sampling and analysis of $^{14}\text{CO}_2$ in soil gas samples. The samples are collected in 1 liter Tedlar® bags, and the sample volume and CO_2 concentration are measured to determine total carbon content. Then the bag is injected with approximately 12 ml of 0.5 N NaOH solution to sorb the CO_2 . Approximately 10 ml of the sorbant solution is recovered, mixed directly with a compatible liquid scintillation counting (LSC) cocktail, and counted. The method greatly reduces hazards in the field, analytical costs, and the overall cost per sample.

Ambient Air Monitoring

The INEEL Environmental Monitoring (EM) program has conducted continuous sampling for airborne H-3 at SVR 20 since 1995. A fixed sampler inlet was set at ~ 1 m above grade on the southwest barrier post that protects the LYS-1, GSP-1, and NAT-17. This location is approximately 1 m outside the backfilled auger hole, downwind with respect to the nighttime primary wind direction at the RWMC. The samples are collected continuously using desiccant

columns. The columns are collected when approximately 80% of the desiccant is saturated. Atmospheric humidity conditions vary through the year, so there is no definite collection period.⁷

Initial measurements by the EM group showed that H-3 releases were quite variable, and the concentration of H-3 in air above SVR 20 could range over several orders of magnitude, with peak concentrations occurring in late summer. The PA/CA monitoring program supplements the EM monitoring during summer and fall. Passive airborne H-3 samplers (Wood and Workman 1992, Wood 1996) are used to sample over one-week periods to develop more detailed release information. This sampling is conducted at 3 heights above grade, using housings attached to the northwest barrier post (Figure 2-5). This location is approximately on the edge of the backfilled auger hole, downwind with respect to the daytime primary wind direction.

2.1.4 Results of Sampling at SVR 20

Long-term Ambient Air Concentrations

INEEL Waste Management, Idaho State University/INEEL Oversight, and the EM program have measured airborne H-3 at various times since 1995. Results for all sampling are shown in Figure 2.6. The PA/CA Monitoring Program has used passive airborne tritium samplers (PATS) to collect samples 30 cm, 1 m, and 2 m above ground near the auger hole at SVR 20 during summer and fall of 2000, 2001, and 2002.

As of September 15, 2002, results for PATS used through August 22, 2002 have been reported. The 2002 peak is expected to occur sometime during late August through October, based on results of sampling in previous years. Based on 2002 results to date, the total annual emissions are comparable to emissions during 2000 and 2001. The seasonal variability of the emission rate is evident in the historical results; however, the results for sampling do not show any long-term trend in air concentration or emission.

⁷ The collection periods for the EM airborne HTO samples have ranged from a few weeks to 3 months, depending on humidity.



Figure 2-5. View of Passive Atmospheric Tritium Samplers (PATs) at SVR 20.

Characterization of Airborne H-3 Dispersion

The box model (Hanna et al. 1982) has been used to develop estimates of total emissions each year since 1995:

$$Q_a = C \times \left(\frac{z_i \times u_{bar}}{W} \right)$$

where:

- Q_a = steady state areal source strength ($\text{Ci s}^{-1} \text{ m}^{-3}$)
- C = atmospheric concentration (Ci m^{-3})
- z_i = mixing height (m)
- u_{bar} = annual average windspeed (m s^{-1})
- W = width of the area source along the direction of the wind (m).

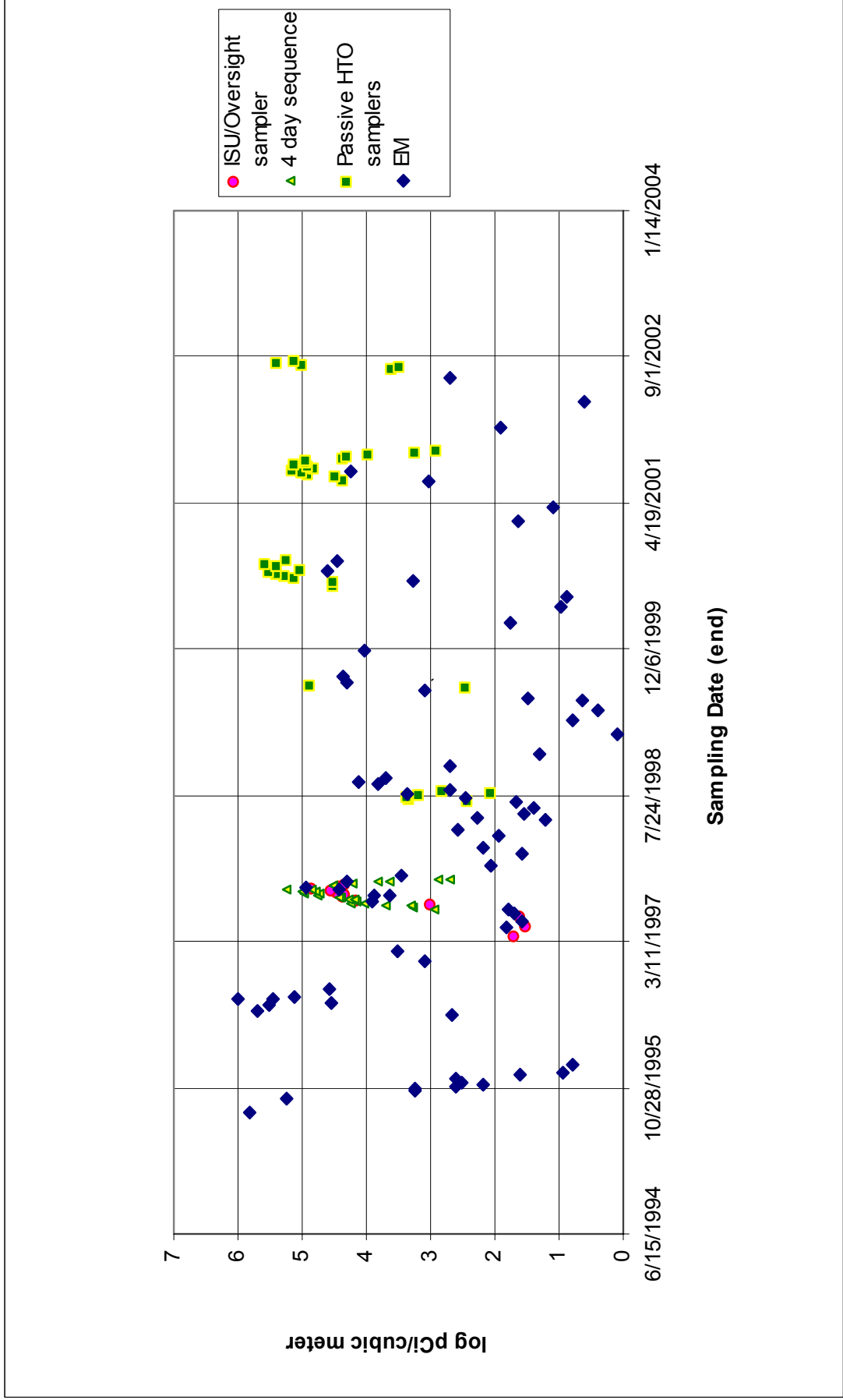


Figure 2-6. Airborne H-3 concentration above the beryllium blocks at SDA SVR 20.

Modeling results are usually more reliable if the model parameters are evaluated using site-specific information. Some of the parameters of the box model have been evaluated by field measurements at SVR 20. The average concentration of airborne H-3 has been evaluated by air sampling. Annual average windspeeds have been calculated using meteorological data provided by the National Oceanic and Atmospheric Administration.

Values have been assigned to the other parameters based on judgment and field observations. The source area has been treated as a 2 by 2 meter square -- a conservative interpretation of the results of surface soil sampling (Ritter and McElroy 1999), which indicate that the actual source area is probably most accurately estimated from the 1.5 m diameter surface of the backfilled auger hole. Ideally, the mixing height corresponds to a definite height over the source area where vertical dispersion is confined by, e.g., a persistent inversion, and beneath which the contaminant is well mixed. However, there are no mechanisms that would routinely confine vertical dispersion in the present physical situation. The mixing height was set at 2 m, assuming that turbulent diffusion would not cause appreciable vertical dispersion to elevations greater than the fetch. The H-3 measurement height was arbitrarily set at 1 m. The annual emissions for 1995 through 2001 were estimated using these assumptions (Table 2-1).

The results for PATS measurements at 30 cm and 1 m during 2000 and 2001 are presented in Figure 2-7. The ratios of concentrations measured at these elevations are relatively consistent from week to week and year to year, indicating that the estimated annual emissions are based on comparable measurements and may be used to evaluate the year-to-year variability of total releases from the soil to the atmosphere. Results for measurements at 2 m are omitted from Figure 2-7 for clarity; the 1 m/2 m concentration ratios are 0.24 ± 0.03 (n=9) and 0.21 ± 0.04 (n=15) for 2000 and 2001, respectively.

Table 2-1. Estimated annual emission of H-3 to air from buried activated beryllium at SVR 20.

Year	1995	1996	1997	1998	1999	2000	2001
Emission (Ci)	100	100	3	0.5	3	30	10

The 2000 and 2001 results of passive air sampling at 30 cm, 1 m, and 2 m reveal a consistent concentration gradient within the first 2 m above the surface, and were used to develop an alternate estimate of the amount of H-3 present in the air at SVR 20. The averaged concentrations were normalized relative to the concentration at 30 cm and plotted as a function of height (Figure 2-8). These data were well fit with an exponential function suggesting that a single process is the predominant cause of dispersion between the soil surface and 2 m elevation. The function was integrated and evaluated from ground surface to 2 meters above ground. Assuming a 1 pCi/cm^3 H-3 concentration exists 30 cm above the soil surface, the total H-3 activity between the surface and 2 m would be 78 pCi/cm^2 . This integrated areal concentration was used with the box model to determine that the total activity above a 2 m by 2 m area (to the 2-meter integration height) would be $3.1 \text{ } \mu\text{Ci}$. If the area of the 1.5 m diameter auger hole and a 2 m mixing height are used with the integrated air concentration, the estimated box inventory is $1.4 \text{ } \mu\text{Ci}$.

The previous box model calculations (Ritter and McElroy 1999) use H-3 concentration measurements from 1 m elevation, where the concentrations are 0.18 of the concentration at 30 cm. The results for the empirically determined box inventory and the judgment-based box modeling may be compared by assuming that a 0.18 pCi/cm^3 H-3 concentration exists at 1 m, corresponding to a 1 pCi/cm^3 concentration at 30 cm elevation. The calculated inventory for a 2 m by 2 m by 2m box volume containing a uniform 0.18 pCi/cm^3 H-3 concentration is $1.4 \text{ } \mu\text{Ci}$. This agreement indicates that the annual release estimates presented in Table 2-1 are reasonable.

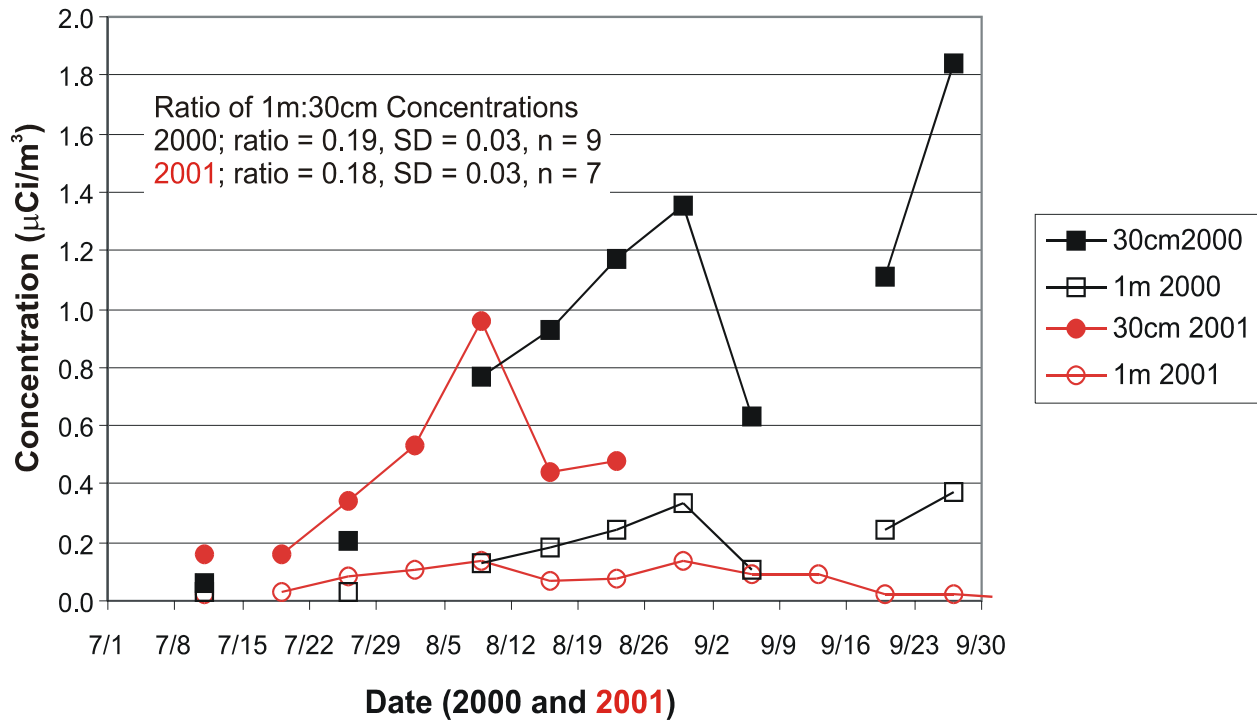


Figure 2-7. Airborne H-3 concentrations 30 and 100 cm above SVR 20 during 2000-01.

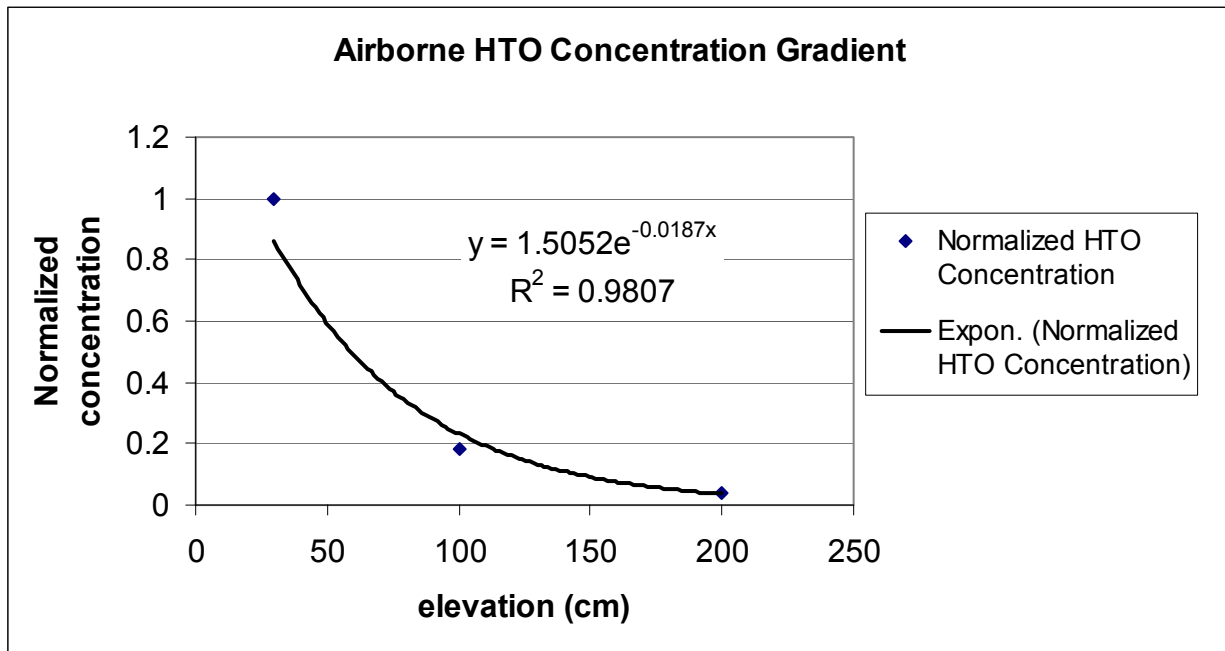


Figure 2-8. Plot of H-3 concentrations measured during 2000 and 2001 at 30, 100, and 200 cm above SVR 20. (The concentrations are normalized relative to the concentration at 30 cm.)

Airborne $^{14}\text{CO}_2$

A single grab air sample was collected at SVR 20 during FY2002 to confirm that worker exposure to airborne $^{14}\text{CO}_2$ is small relative to H-3 exposure (Ritter 2001) and to serve as a first test of the bag sampling method for atmospheric air samples. Preliminary results indicate that the airborne $^{14}\text{CO}_2$ concentrations are near or at the detection limit for the sampling/analysis method. The bag sampling method is still under development, and the routinely achievable minimum detectable concentration (MDC) has not yet been determined. Based on results for soil gas sampling with bags, the MDC is probably no greater than 1 nCi/m³, or on the order of 0.001% of the derived air concentration for $^{14}\text{CO}_2$.

2.1.5 H-3 in Soil Gas

Since 1996⁸, soil gas samples have been collected from the GSP-1 ports, located approximately 60 to 100 cm from the beryllium at depths of 2.7, 4.5, and 6.2 m. The samples directly represent the concentrations during the relatively brief sample collection periods in small (i.e., on the order of 10 L), irregularly shaped volumes of soil near the ports. Results for soil gas samples are summarized in Figures 2-9, 2-10, and 2-11. During 2001, the concentration of H-3 in soil moisture reached 3.5, 0.34, and 0.70 $\mu\text{Ci}/\text{mL}$ in soil 2.7, 4.5, and 6.2 m deep, respectively. The concentration of H-3 in soil moisture appears to fluctuate over the course of each year, with lower concentrations occurring during cool times of the year. The fluctuations at each depth are correlated (Holdren et al. 2002), suggesting that the concentrations at 2.7, 4.5, and 6.2 m are influenced similarly by soil conditions and/or source conditions. Over the period from 1996 through 2002, H-3 concentrations in soil increased at a progressively greater rate. This trend cannot continue indefinitely, but there is no indication that the concentrations will peak or plateau over the next few years.

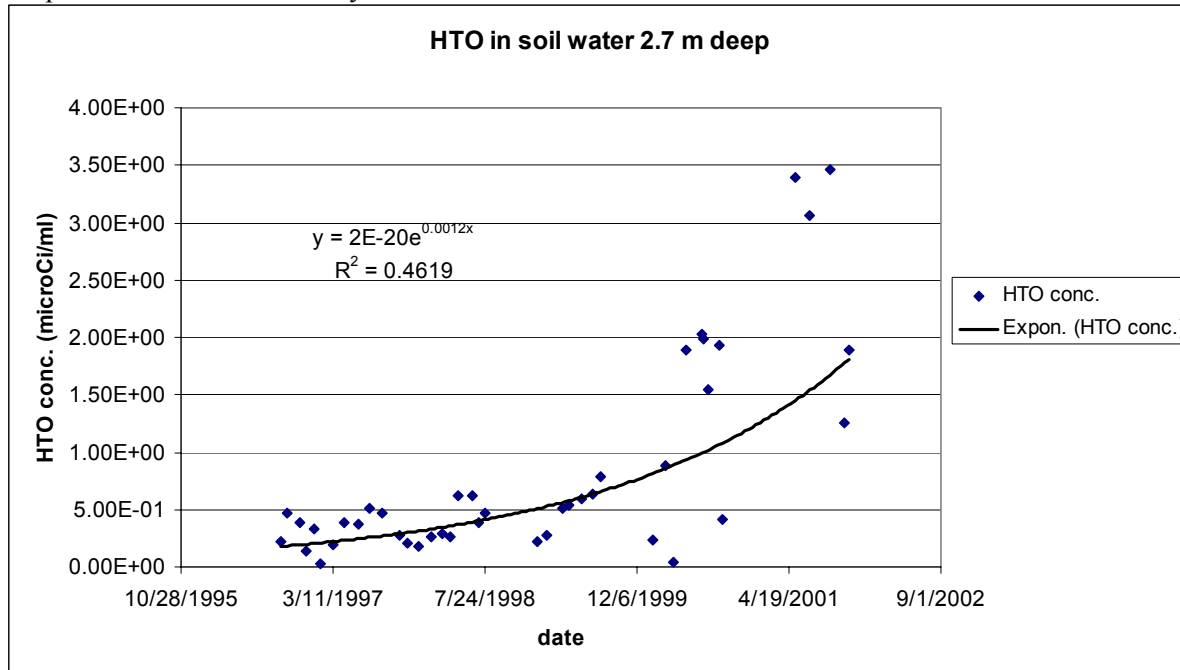


Figure 2-9. Tritium concentration in water vapor from the 2.7 meter deep GSP-1 soil gas sampling port.

⁸ The first samples were taken in 1995. No data were recovered for the 2.7-m deep sampling port because of problems during sample collection.

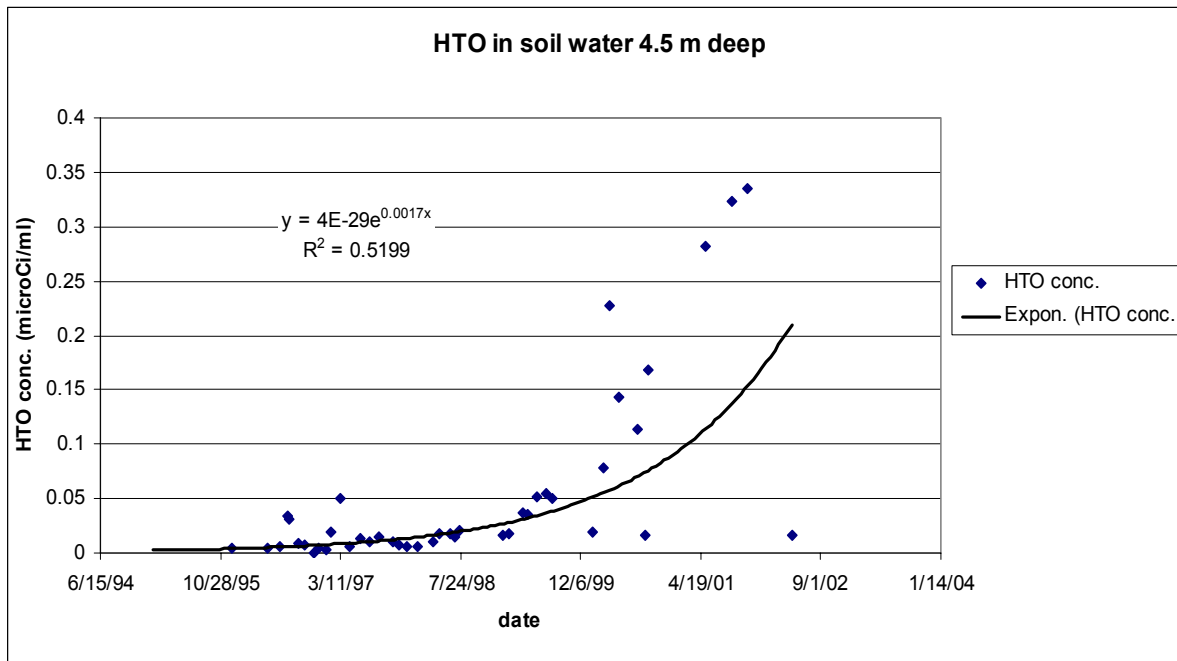


Figure 2-10. Tritium concentration in water vapor from the 2.7 meter deep GSP-1 gas sampling port.

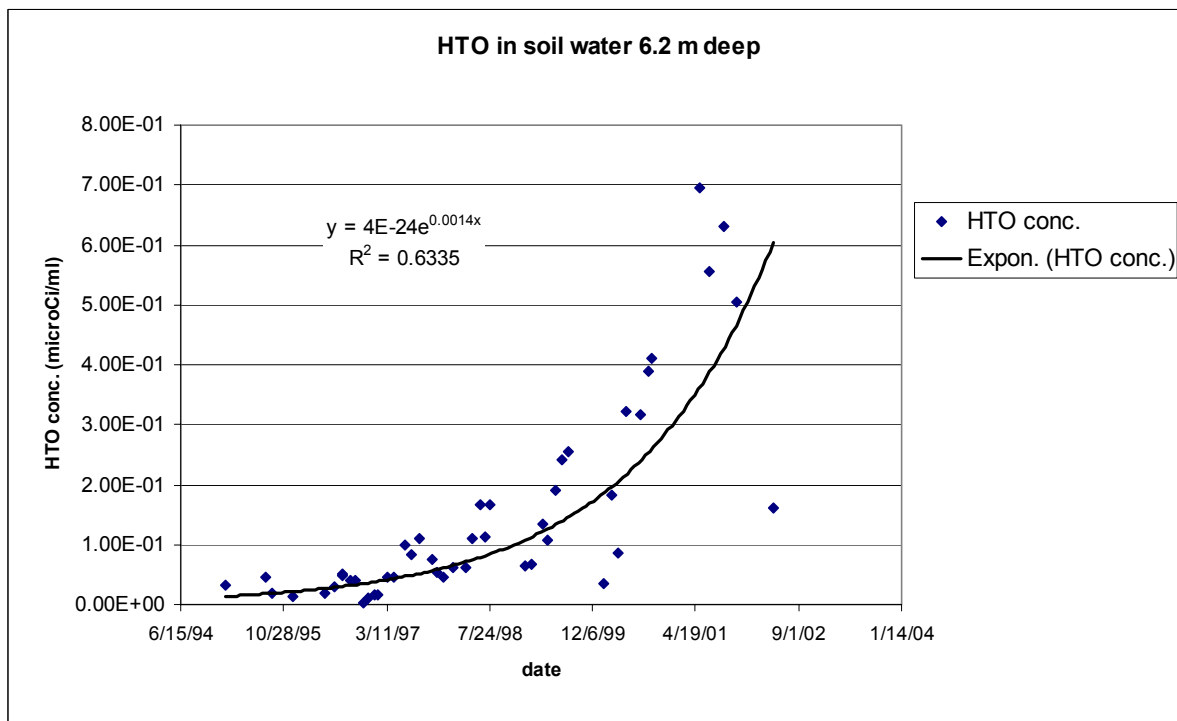


Figure 2-11. Tritium concentration in water vapor from the 2.7 meter deep GSP-1 gas sampling port.

2.1.6 Carbon-14 in Soil Gas

The SA of C-14 in CO₂ has been measured in grab samples of soil gas collected from the GSP-1 ports. Results for soil gas samples are summarized in Table 2-2. The results are for samples collected using caustic solutions in bubblers prior to 2000, and in Tedlar[®] bags after 2000.

Table 2-2. Summary of C-14 specific activity (pCi [¹⁴C]/g [C]) in CO₂ from soil gas samples collected at SVR 20.

Date	GSP1at 2.7 m depth	GSP1at 4.5 m depth	GSP1at 6.2 m depth	SVR 20-IPV-5-VP3 at 5.4 m depth
6/5/1996	1.70E+04		2.30E+04	
7/2/1996		3.40E+04	2.50E+04	
12/12/1996	1.30E+05	4.20E+04	3.30E+04	
11/12/1997	4.40E+04	2.00E+04	1.20E+04	
11/15/2001	3.64E+05	1.58E+05	2.45E+05	8.28E+04
2/20/2002				2.85E+04
5/2/2002	1.71E+05	1.45E+05	1.33E+05	
5/23/2002				3.10E+04
8/23/2002	1.34E+05	1.33E+05	1.37E+05	3.67E+04

The data are assumed to be comparable; however, the details of the bag sampling and analysis procedures are still in development. The procedures will be finalized in FY-2003 and then the overall reliability of the method will be evaluated. The comparability and interpretation of the data in Table 2-2 could potentially be affected by fluctuations in the ¹⁴CO₂ concentration in soil gas. To evaluate the homogeneity of C-14 SA, a sequence of 1 liter grab samples was collected from the 4.5 m deep port in GSP1. The results of analysis indicate that following a purge of no more than 2 L of soil gas, the SA may be determined reproducibly from a 1 liter volume grab sample. Based on these results, comparability of bag and bubbler results is not compromised by differences in sample volumes. The natural variability of C-14 SA in soil gas should be characterized for each port to evaluate the representativeness of individual grab samples.

The available data indicate that the C-14 SA of CO₂ in soil gas near the buried beryllium has increased by approximately 1 order of magnitude since the late 1990s. This increase is similar to the increase in H-3 concentration in soil water over the same period.

2.2 Activated Steel Disposal and Monitoring Methods

A large fraction of the total SDA inventory of C-14 is present in activated steel. The rate of release of C-14 from activated steel, presumably by corrosion, is being studied at SVR 12. Type B probes with vapor ports were installed in 2001, and initial sampling was conducted in 2002. The initial sampling results are being reviewed to verify that results of sampling/analysis are representative of soil concentrations, or to determine whether purging is required or the sampling protocol should be modified.

Results of C-14 monitoring in soil gas will be reviewed to determine whether ambient air sampling should be conducted, similar to the air sampling for H-3 above the activated beryllium in SVR 20.

2.2.1 SVR 12 surface environmental conditions

Soil vault row 12 runs parallel to the interior perimeter road along the east edge of the SDA (see Figure 2-11), approximately 15 m from the nearest road. The SVR 12 location is not likely to have been affected by roadway activities such as snow clearing and $MgCl_2$ applications. The area does not appear to be in an obvious runoff path, and there is little vegetation.

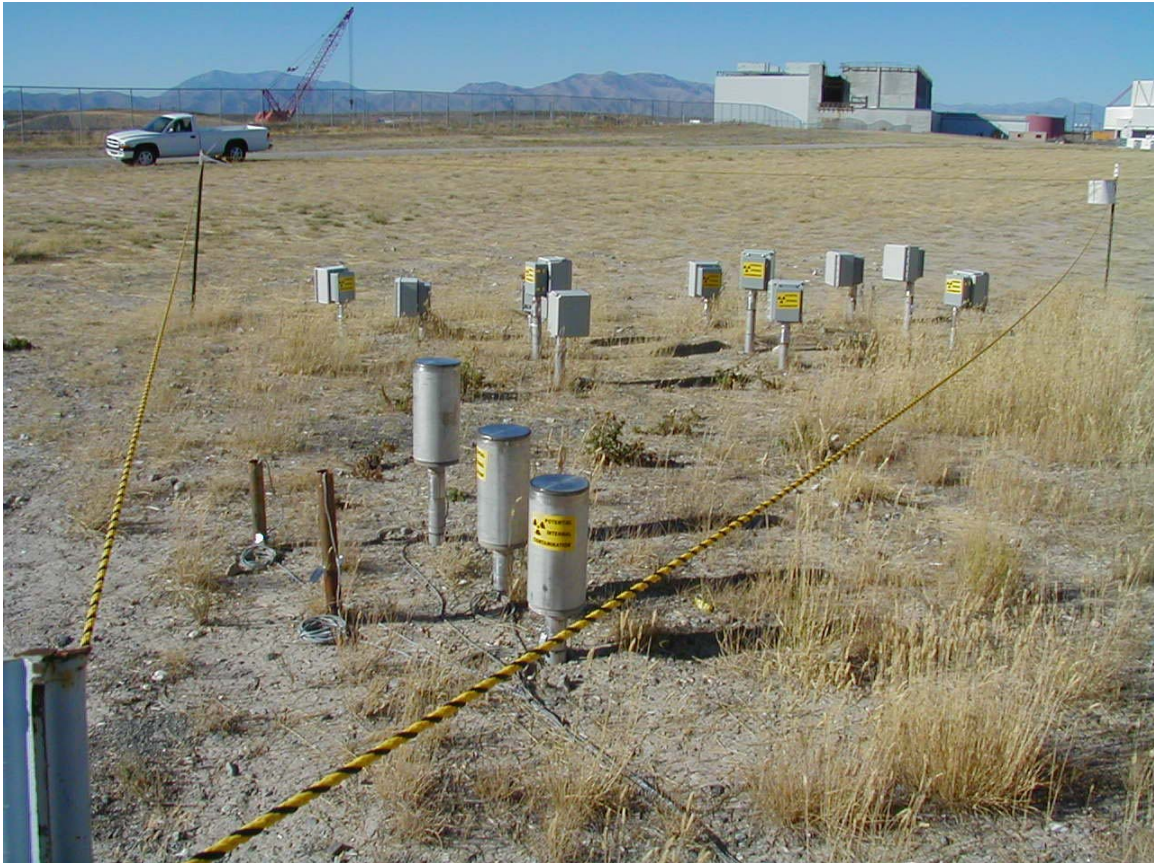


Figure 2-12. View of Type B probes at SVR 12, at an activated steel disposal location.

2.2.2 Description of Activated Steel and Disposal Conditions⁹

Soil Vault Row 12 contains numerous disposals of what is believed to be activated stainless steel. Information gathered through conversations with past and present INEEL staff indicate that these disposals are probably stainless steel end pieces from spent Experimental Breeder Reactor II (EBR-II) fuel elements and are highly irradiated. Spent fuel elements from EBR-II were sent to the INTEC for processing after use. The stainless steel end pieces were physically separated from the fuel in underwater basins at CPP-603 before disposal at RWMC. Ten shipments were sent from CPP-603 and placed in SVR-12. This material is expected to contain no beryllium. Discussion with personnel familiar with the subject disposals indicated that the material was disposed in cask inserts that were open at the top and perforated at the bottom. The perforations were designed to allow draining upon removal from the storage basin at CPP-603. Further information on the expected inventories is presented in the Field Sampling Plan for Monitoring Type B Probes for the Operable Unit 7-13/14 Integrated Probing Project (Salomon 2001).

RWMC operations staff indicated that the subject disposals were not made in auger holes, as is typical for high-activity waste) because of shallow soil conditions (Salomon 2001). Rather, a shallow hole was made with conventional excavation equipment and the cask inserts were placed in the excavation using a free air transfer technique. The transfer was done remotely because of high radiation fields. As a result, exact positioning of the waste was not possible.

It was also noted that the basalt surface at the disposal location was no deeper than 8 to 12 ft (2.5 to 4 m) below ground surface at the time of disposal. Because of subsequent flooding, approximately 10 ft (3 m) of fill were placed in an area near the subject disposal location.

2.2.3 Monitoring Equipment and Sample Collection at SVR 12

In 2001, the ER organization installed Type B probes at SVR 12 as part of the CERCLA evaluation of the inactive SDA (Salomon 2001). The Type B probes at SVR 12 are configured as either vapor sampling ports or tensiometers. The new vapor sampling probes were installed to provide information that could be used to characterize release rate and lateral migration of C-14 from the beryllium. The tensiometer probes were installed to measure matric potential near the beryllium to determine hydraulic gradients, the direction of flow, and if hydraulic conductivity is known, the rate of flow.

2.2.4 Sample Collection Methods

Soil gas samples are pumped from the Type B probes into 1 liter Tedlar® bags. The sample volume and CO₂ concentration are measured to determine total carbon content, and then the bag is injected with approximately 12 ml of 0.5 N NaOH solution to sorb the CO₂. Approximately 10 ml of the sorbant solution is recovered, mixed directly with an appropriate liquid scintillation cocktail, and counted.

⁹ Description from INEEL/EXT-2000-01435, Field Sampling Plan for Monitoring Type B Probes for the Operable Unit 7-13/14 Integrated Probing Project, Hopi Salomon. June 2001.

2.2.5 Results of Sampling at SVR 12

Soil gas samples were collected quarterly from the SVR 12 Type B probes. In general, the SA of $^{14}\text{CO}_2$ in soil gas near the activated steel appears to be at least 2 orders of magnitude less than the SA measured near activated beryllium in SVR 20.

3. VADOSE ZONE MONITORING

Lysimeter sampling is conducted to characterize the liquid from soil pores (soil moisture) in the vadose zone. Analyses for the constituents of interest have been prioritized for the purpose of CERCLA monitoring (Table 3-1). The priorities of the constituents were based on potential as: 1) a risk driver, 2) an early warning contamination indicator, and 3) a model calibration target (McCarthy et. al., 2001). Available sample liquid is split for analysis in the order of priority. Therefore, if a lysimeter sample is small in volume, then there may not be enough material to analyze for the lower priority radionuclides.

Networks of suction lysimeters were installed around the RWMC to allow repeated sampling from the sediments surrounding the waste and from the interbeds. Though the first lysimeter samples were collected at the INEEL in 1985, routine lysimeter sampling did not begin until 1997. The networks of lysimeters installed within the vadose zone around the RWMC are shown in Figures 3-1, 3-2, and 3-3. The lysimeters are grouped according to their depth below the land surface in the vadose zone: 0 to 35 feet (Figure 3-1), 35 to 140 feet (Figure 3-2), and greater than 140 feet (Figure 3-3).

3.1 Vadose Zone Radionuclide Sampling

Very small volumes of soil moisture are generally obtained from lysimeter samples (0 to 200 ml of water [0 to 7 oz]), and 50 ml (1.69 oz) of that total volume is generally allotted for each separate analysis. The detection limits vary in accordance with the sample volume available for analysis (i.e., detection limits increase as volumes decrease). Each analytical sample measurement is reported with an uncertainty value, σ . The uncertainty is a total of all the errors known to exist in the entire analytical process. The result from a sample measurement is determined to be either: 1) a non-detection, 2) a statistical detection, or 3) a positive detection, depending on its magnitude relative to its level of uncertainty. A measured value is considered a positive detection if its value is greater than the sample-specific minimum detectable activity and is more than three times greater than its uncertainty. If the measured value is between the uncertainty range of 2σ and 3σ , then it is considered to be a statistical detection (Holdren et al., 2002). Statistical detections are not included with the positive detections in this data summary. Results classified as statistical detections are questionable and are only used as estimated quantities.

Several constituents of interest were identified during the PA, CA, and CERCLA evaluation process (Table 3-1). These constituents are also being evaluated by OU 7-13/14 as part of the CERCLA process, and are identified priorities for monitoring in WAG 7. The radionuclides of interest for the PA and CA are C-14, Cl-36, I-129, Np-237, U-234, and U-238. Additionally, H-3 data collected at the RWMC may provide ancillary information in regard to contaminant migration in the vadose zone. Thus, H-3 data are included here even though H-3 was not considered a key radionuclide for the PA or CA.

Perched water is periodically present in isolated lenses above the sediments comprising the B-C and C-D interbeds, located at depths below 140 feet. Samples from the water perched above the C-D interbed are obtained with a bailer from Wells USGS-092 and 88-02D. These perched water wells have slow recharge rates and thin depths of water, often limiting the volume of water sample that can be collected. Samples are taken when there is sufficient water present to collect in the bailer, and split for analyses in the priority shown in Table 3-1.

Table 3-1. Constituents of interest identified in the PA, CA, and CERCLA evaluations for the vadose zone.

PA/CA	CERCLA - Lysimeter and Perched Water Sample Locations	
	Analysis Priority ¹	
C-14	C-14	1
Cl-36	Cl-36	12
I-129	I-129	9
Np-237	Np-237	5
U-234		
U-238		
	U and Pu isotopes, Am-241	4
	Tc-99	3
	H-3	10
	Volatile organics	11
	Gamma spectrometry	2
	Anions	6 ²
	Ni-59, Ni-63	7
	Metals	8

¹ from "Priority Analysis for Monitoring and Sampling at WAG 7", per personal communication with Don Koeppen, 9/24/02.

² One quarter per year, anions will be collected first to gather data for nitrates.

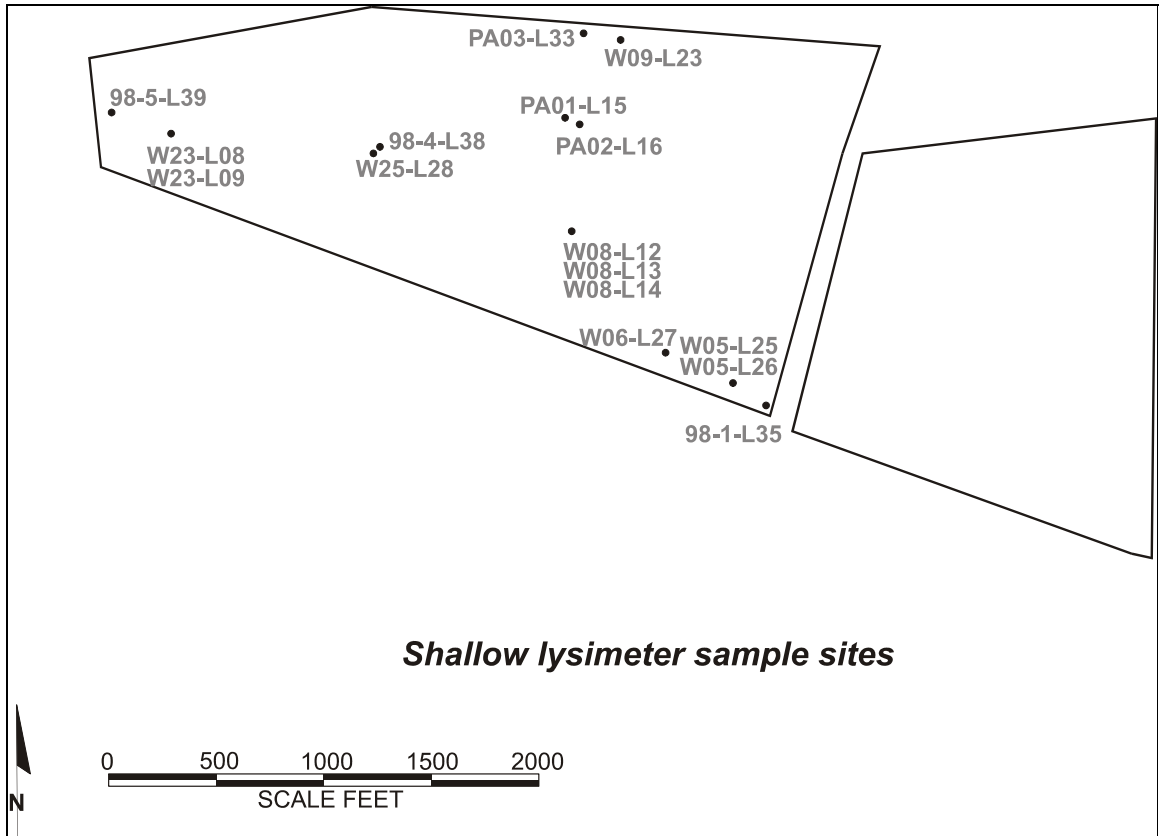


Figure 3-1. Lysimeters located within the shallow (0 to 35 ft) depth interval of the vadose zone at the RWMC.

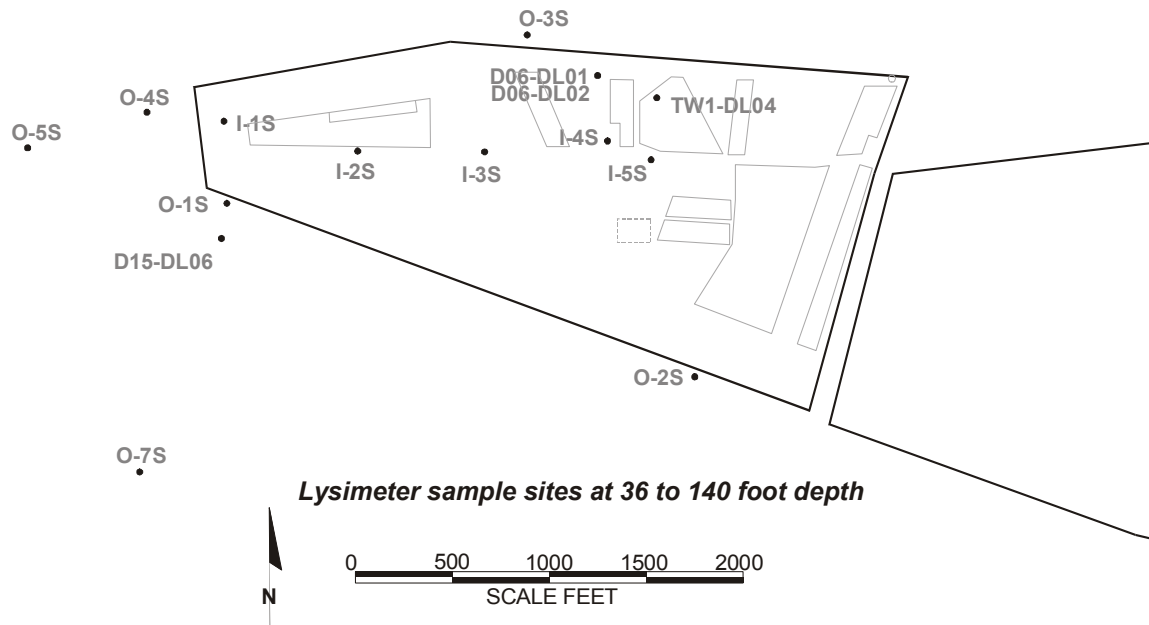


Figure 3-2. Lysimeters located in the 35 to 140-foot depth interval of the vadose zone at the RWMC.

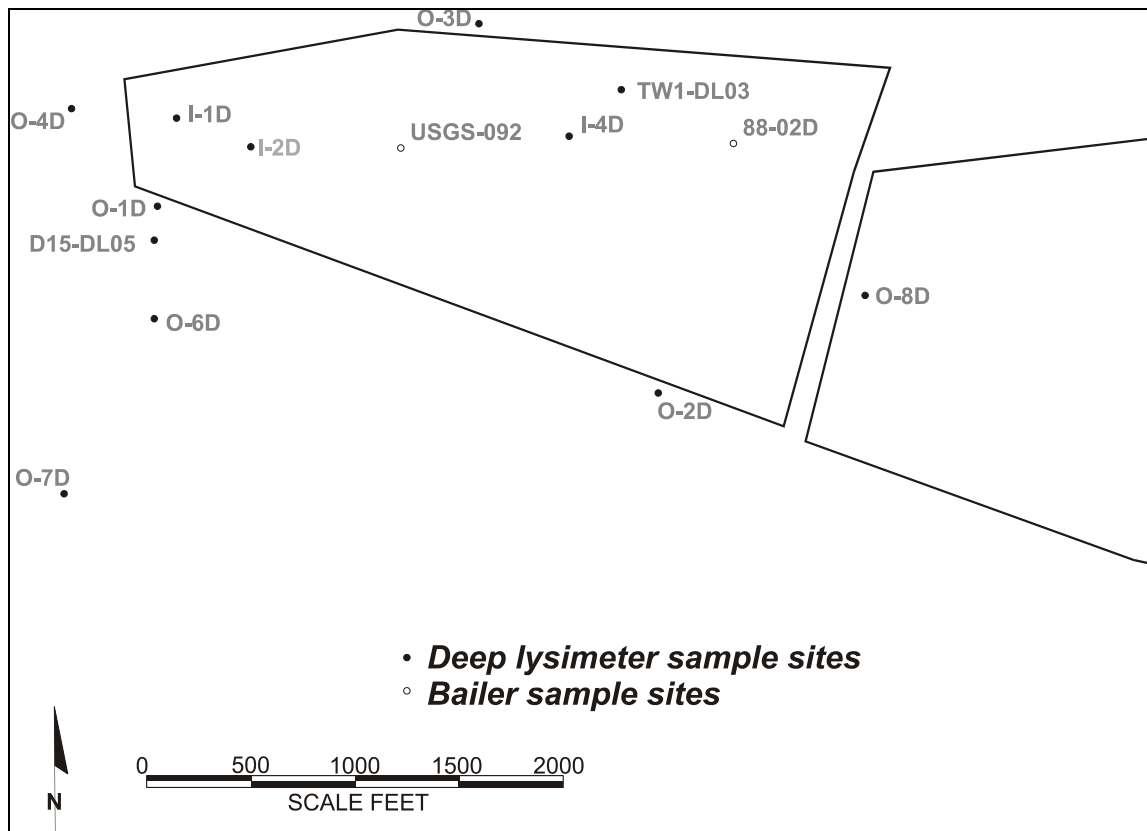


Figure 3-3. Lysimeters and bailers located at depths greater than 140 feet in the vadose zone at the RWMC.

3.2 Vadose Zone Radionuclide Sampling Results

Vadose zone sampling results¹⁰ at the RWMC are presented here for C-14, H-3, I-129, Np-237, U-233/234, and U-238. The PA/CA identified U-234 as a radionuclide of concern. However, the analytical results are discussed as a combination of U-233/234 because the radiological analytical methods can't distinguish between the U-233 and U-234 isotopes. Probably about 99% of the measured U-233/234 result is really U-234 based on measurements of isotope abundance. Cl-36 is a radionuclide of concern for the PA/CA, however, no analytical data from lysimeter or perched water samples from the vadose zone are available for Cl-36 at the RWMC to date.

Tables 3-1 through 3-6 summarize for C-14, H-3, I-129, Np-237, U-233/234, and U-238. The number of positive detections observed in each fiscal year versus the total number of sample results are listed along with the range in measured concentration. The maximum contaminant level (MCL) is shown for comparison to the detected concentrations in the vadose zone. Direct comparison with the MCL is only appropriate for aquifer concentration, however it can provide a general guideline for the vadose zone concentrations.

¹⁰ The analytical data and associated data qualifiers and data usage limitations are formally documented in INEEL Environmental Restorations program Limitations and Validations (L&V) reports. The L&V reports are archived by the SMO and scanned into the document control Optical Imaging System.

Table 3-2. Summary of Vadose Zone Sampling for C-14 at the RWMC from FY1997 – FY2002. The MCL for C-14 is 2000 pCi/L.

Sampling Range (ft below land surface)	Fiscal Year ¹	Number Detections/Number Sample Results ²	Concentration Range (pCi/L)
Lysimeters 0 – 35 ft.	1997	4/17	11--19
	1998	1/9	21.8
	1999	2/11	24 – 26
	2000	0/19	ND ³
	2001	NS ⁴	-
	2002	NS	-
Lysimeters 35 – 140 ft.	1997	0/1	ND
	1998	0/5	ND
	1999	NS	-
	2000	NS	-
	2001	NS	-
	2002	0/1	ND
Lysimeters > 140 ft.	1997	NS	-
	1998	NS	-
	1999	NS	-
	2000	NS	-
	2001	NS	-
	2002	NS	-
Perched Water Wells	1997	2/2	12 – 13
	1998	3/4	14 – 20
	1999	0/2	ND

Sampling Range (ft below land surface)	Fiscal Year ¹	Number Detections/Number Sample Results²	Concentration Range (pCi/L)
	2000	NS	-
	2001	1/1	134
	2002	NS	-

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² The result from a sample measurement is considered positive if its value is greater than the sample-specific minimum detectable activity and is more than three times greater than its uncertainty.

³ ND – sampled and analyzed, but no C-14 was detected.

⁴ NS – no valid sample results were obtained.

Table 3-3. Summary of Vadose Zone Sampling for H-3 at the RWMC from FY1976 – FY2002. The MCL for H-3 is 20,000 pCi/L.

Sampling Range (ft below land surface)	Fiscal Year ¹	Number Detections/ Number Sample Results ²	Concentration Range (pCi/L)
Lysimeters 0 – 35 ft.	1997	13/29	129 – 3270
	1998	3/8	328 – 7290
	1999	3/7	991 – 8650
	2000	3/12	815 – 9100
	2001	NS	-
	2002	NS	-
Lysimeters 35 – 140 ft.	1997	0/1	ND ³
	1998	2/6	1680 – 2520
	1999	1/1	2950
	2000	NS	-
	2001	NS	-
	2002	NS	-
Lysimeters > 140 ft.	1997	NS	-
	1998	NS	-
	1999	NS	-
	2000	NS	-
	2001	NS	-
	2002	NS	-
Perched Water Wells	1976 - 1996	0/28	ND
	1997	3/4	169 – 310
	1998	3/3	301 – 1570
	1999	0/2	ND

Sampling Range (ft below land surface)	Fiscal Year ¹	Number Detections/ Number Sample Results²	Concentration Range (pCi/L)
	2000	0/1	ND
	2001	0	-
	2002	0	-

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² The result from a sample measurement is considered positive if its value is greater than the sample-specific minimum detectable activity and is more than three times greater than its uncertainty.

³ ND – sampled and analyzed, but no H-3 was detected.

⁴ NS – no valid sample results were obtained.

Table 3-4. Summary of Vadose Zone Sampling for I-129 at the RWMC from FY1997 – FY2002. The MCL for I-129 is 1 pCi/L.

Sampling Range (ft below land surface)	Fiscal Year ¹	Number Detections/ Number Sample Results ²	Concentration Range (pCi/L)
Lysimeters 0 – 35 ft.	1997	0/20	ND
	1998	0/7	ND
	1999	2/9	29 – 53
	2000	1/18	22
	2001	NS	-
	2002	NS	-
Lysimeters 35 – 140 ft.	1997	0/1	ND
	1998	0/4	ND
	1999	NS	-
	2000	NS	-
	2001	NS	-
	2002	NS	-
Lysimeters > 140 ft.	1997	NS	-
	1998	NS	-
	1999	NS	-
	2000	NS	-
	2001	NS	-
	2002	NS	-
Perched Water Wells	1997	0/2	ND
	1998	0/3	ND

Sampling Range (ft below land surface)	Fiscal Year ¹	Number Detections/ Number Sample Results²	Concentration Range (pCi/L)
	1999	0/3	ND
	2000	0/1	-
	2001	NS	ND
	2002	0/1	ND

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² The result from a sample measurement is considered positive if its value is greater than the sample-specific minimum detectable activity and is more than three times greater than its uncertainty.

³ ND – sampled and analyzed, but no I-129 was detected.

⁴ NS – no valid sample results were obtained.

Table 3-5. Summary of Vadose Zone Sampling for Np-237 at the RWMC from FY2000 - FY2002. The MCL for Np-237 is 15 pCi/L (total alpha activity concentration).

Sampling Range (ft below land surface)	Fiscal Year ¹	Number of Detections/ Number of Samples Collected ²	Concentration Range (pCi/L)
Lysimeters 0 – 35 ft.	1997	NS	-
	1998	NS	-
	1999	NS	-
	2000	0/20	ND
	2001	0/8	ND
	2002	0/5	ND
Lysimeters 35 – 140 ft.	1997	NS	-
	1998	NS	-
	1999	NS	-
	2000	0/11	ND
	2001	0/5	ND
	2002	0/3	ND
Lysimeters > 140 ft.	1997	NS	-
	1998	NS	-
	1999	NS	-
	2000	0/2	ND
	2001	0/1	ND
	2002	0/4	ND
Perched Water Wells	1997	NS	-
	1998	NS	-

Sampling Range (ft below land surface)	Fiscal Year ¹	Number of Detections/ Number of Samples Collected ²	Concentration Range (pCi/L)
	1999	NS	-
	2000	0/1	ND
	2001	0/1	ND
	2002	0/1	ND

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² The result from a sample measurement is considered positive if its value is greater than the sample-specific minimum detectable activity and is more than three times greater than its uncertainty.

³ ND – sampled and analyzed, but no Np-237 was detected.

⁴ NS – no valid sample results were obtained.

Table 3-6. Summary of Vadose Zone Sampling for U-233/234 at the RWMC from FY1997 – FY2002. The MCL for U-233/234 is 27 pCi/L (based on total naturally occurring U concentration limit).

Sampling Range (ft below land surface)	Fiscal Year ¹	Number Detections/ Number Sample Results ²	Concentration Range ³ (pCi/L)
Lysimeters 0 – 35 ft.	1997	2/2	35.4 – 43.2
	1998	23/23	3.7 – 60.1
	1999	25/25	4.0 – 56.5
	2000	62/62	3.7 – 76.1
	2001	8/8	5.2 – 87.0
	2002	5/5	2.4 – 125
Lysimeters 35 – 140 ft.	1997	3/3	8.5 – 84.4
	1998	11/11	1.7 – 97.4
	1999	2/2	86.1 – 90.2
	2000	18/18	1.7 – 111
	2001	5/5	1.8 – 7.3
	2002	2/2	3.9 – 17.3
Lysimeters > 140 ft.	1997	NS ⁴	-
	1998	NS	-
	1999	NS	-
	2000	NS	-
	2001	0/1	ND ⁵
	2002	3/3	0.9 – 1.9
Perched Water Wells	1997	NS	-
	1998	1/1	6.9
	1999	4/5	0.53 – 7.5

Sampling Range (ft below land surface)	Fiscal Year ¹	Number Detections/ Number Sample Results²	Concentration Range³ (pCi/L)
	2000	4/5	1.3 – 6.7
	2001	NS	-
	2002	1/1	3.8

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² The result from a sample measurement is considered positive if its value is greater than the sample-specific minimum detectable activity and is more than three times greater than its uncertainty.

³ Soil moisture background for U-233/234 at the INEEL is 3 pCi/L (Holdren et. al., Draft 2002, Figure 4-45).

⁴ ND – sampled and analyzed, but no U-233/234 was detected.

⁵ NS – no valid sample results were obtained.

Table 3-7. Summary of Vadose Zone Sampling for U-238 at the RWMC from FY1997 – FY2002. The MCL for U-238 is 27 pCi/L (total naturally occurring U concentration limit).

Sampling Range (ft below land surface)	Fiscal Year ¹	Number Detections/ Number Sample Results ²	Concentration Range ³ (pCi/L)
Lysimeters 0 – 35 ft.	1997	2/2	25.7 – 34.2
	1998	24/24	2.6 – 39.5
	1999	25/25	3.1 – 41.2
	2000	63/63	0.3 – 45.5
	2001	7/7	3.6 – 53.0
	2002	5/5	1.5 – 52.8
Lysimeters 35 – 140 ft.	1997	3/3	7.2 – 49.4
	1998	8/8	1.1 – 48.9
	1999	5/5	0.68 – 48.6
	2000	19/20	1.3 – 52.6
	2001	3	0.87 – 4.7
	2002	2/3	1.67 – 9.44
Lysimeters > 140 ft.	1997	NS ⁴	-
	1998	NS	-
	1999	NS	-
	2000	0/1	ND ⁵
	2001	0/1	ND
	2002	0/3	0.9
Perched Water Wells	1997	NS	-
	1998	1/2	1.1

Sampling Range (ft below land surface)	Fiscal Year ¹	Number Detections/ Number Sample Results²	Concentration Range³ (pCi/L)
	1999	2/5	1.2 – 4.7
	2000	4/5	0.37 – 3.2
	2001	NS	-
	2002	1/1	3.2

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² The result from a sample measurement is considered positive if its value is greater than the sample-specific minimum detectable activity and is more than three times greater than its uncertainty.

³ Soil moisture background for U-238 at the INEEL is 1.5 pCi/L (Holdren et. al., Draft 2002, Figure 4-49).

⁴ ND – sampled and analyzed, but no U-238 was detected.

⁵ NS – no valid sample results were obtained.

4. AQUIFER MONITORING

Groundwater monitoring activities have been ongoing at the INEEL for many years. Long-term groundwater monitoring was initially provided by the USGS, using wells sparsely distributed around the INEEL. The USGS wells near the RWMC were drilled and installed between 1971 and 1987. Approximately 10 years ago, the INEEL M&O contractor began to install wells in the vicinity of the RWMC in order to obtain more detailed information regarding water flow and contaminant transport in the immediate vicinity of the RWMC. The locations of the USGS and M&O contractor monitoring wells are shown in Figure 4-1. The ongoing monitoring in the vicinity of the RWMC and the USGS monitoring provide a basis for evaluating contaminant concentration trends.

4.1 Aquifer Radionuclide Sampling

Groundwater samples are collected on a quarterly basis from the monitoring wells around the RWMC. The samples are collected as required for the Operable Unit 7-13/14 Routine Monitoring Program. INEEL data were obtained from the Monitoring Database for Risk Assessment (MDRA), and USGS data were obtained from the INEEL Hydrogeologic Data Repository. There are 16 aquifer monitoring wells sampled by the WAG 7, and eight additional aquifer wells monitored by the USGS. The WAG 7 wells were drilled and installed between 1992 and 2000.

The analyses chosen for the aquifer water samples are based on the identified constituents of interest for the PA, CA, and CERCLA evaluations at the RWMC. Radionuclides of interest for the PA and CA are the same as in the vadose zone; C-14, Cl-36, I-129, Np-237, U-234, U-238, and H-3.

As of April 2001, the groundwater concentration data was most recently compiled and reported in a interoffice memorandum¹¹. More recent analytical data and associated data qualifiers and data usage limitations are formally documented in INEEL Environmental Restoration's program L&V reports. The L&V reports are archived by the SMO and scanned into the document control Optical Imaging System.

Quality assurance steps were implemented to ensure that the sample data are of the highest quality. Each analytical sample measurement is reported with an uncertainty value, σ . The uncertainty is a total of all the errors known to exist in the entire analytical process (Holdren et al. 2002). The result from a sample measurement is determined to be either: 1) a non-detection, 2) a statistical detection, or 3) a positive detection, depending on its level of uncertainty. A positive detection is defined as a measured value greater than the sample-specific minimum detectable activity that is more than three times greater than its uncertainty. If the measured value is between 2σ and 3σ , then it is considered to be a statistical detection. The statistical detections are treated as non-detections in this data summary.

¹¹ Internal correspondence concerning trend analysis for groundwater data from RWMC perimeter wells, 2001.

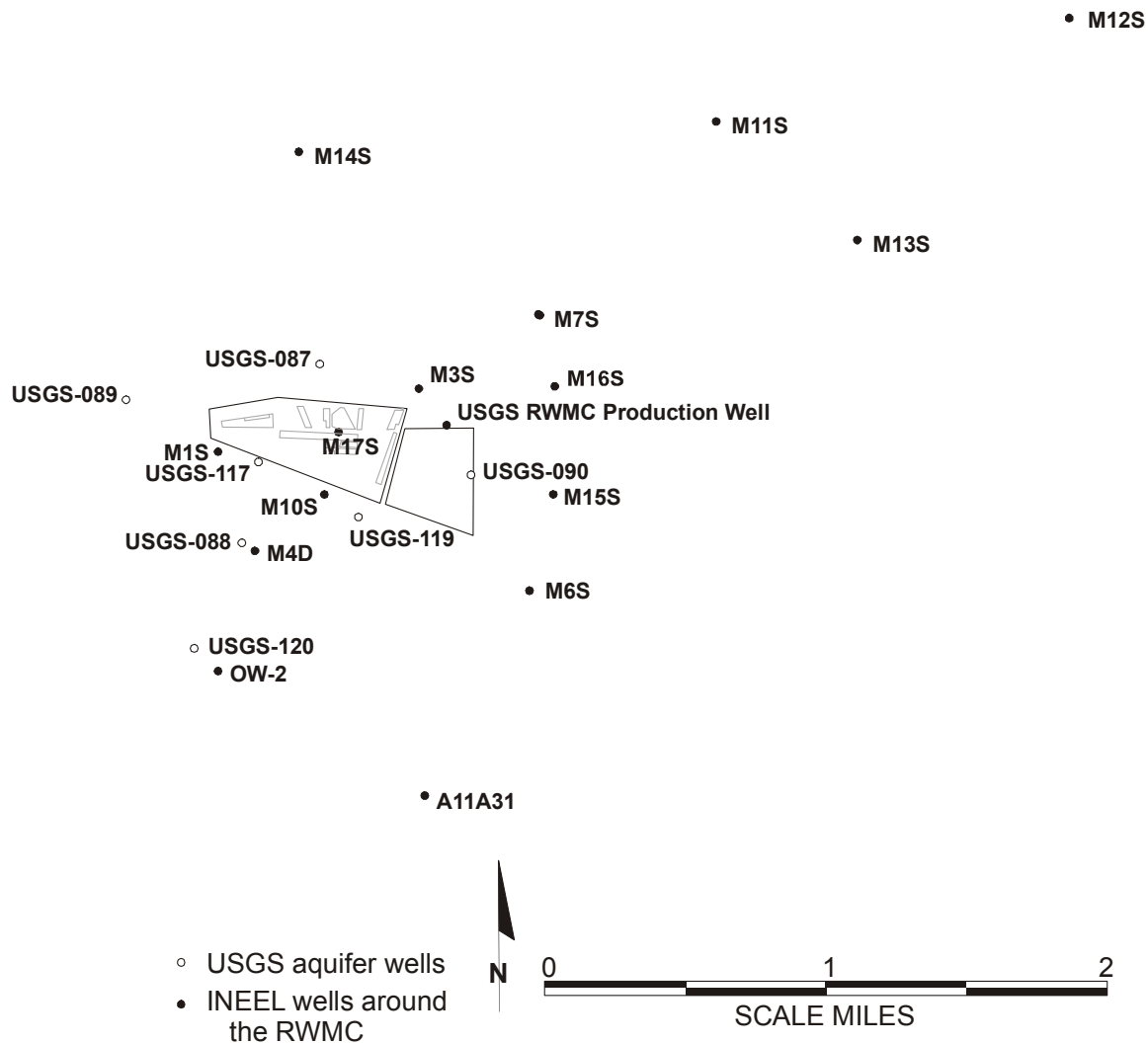


Figure 4-1. Location of aquifer monitoring wells near the RWMC.

4.2 Aquifer Radionuclide Sampling Results

Aquifer sampling results at the RWMC are presented here (Tables 4-1 through 4-7) for C-14, Cl-36, H-3, I-129, Np-237, U-233/234, and U-238. The number of positive detections observed in each fiscal year versus the total number of positive detection, non-detection (ND) and statistical detection results are listed, along with the range in measured concentration.

Table 4-1. Summary of Aquifer Sampling for C-14 at the RWMC from FY1994 – FY2002. The MCL for C-14 is 2000 pCi/L.

Fiscal Year¹	Number Detections/ Number Sample Results²	Concentration Range (pCi/L)
1994	1/7	5.7
1995	1/26	28
1996	0/21	ND ³
1997	0/7	ND
1998	2/23	3.0 – 6.7
1999	3/31	4.4 – 10.9
2000	9/46	1.8 – 5.3
2001	5/49	2.8 – 42
2002	3/45	3.1 – 7.5

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² This summary includes all samples that resulted in valid results. The difference between the number of sample results and number of detections is equal to the number of “ND” results

³ ND – sampled and analyzed, but no C-14 was detected.

Table 4-2. Summary of Aquifer Sampling for Cl-36 at the RWMC from FY2000 – FY2002. The MCL for Cl-36 is 1850 pCi/L.

Fiscal Year ¹	Number Detections/ Number Sample Results²	Concentration Range (pCi/L)
1994	NS ³	-
1995	NS	-
1996	NS	-
1997	NS	-
1998	NS	-
1999	NS	-
2000	0/15	ND ⁴
2001	0/9	ND
2002	NS	-

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² This summary includes all samples that resulted in valid results. The difference between the number of sample results and number of detections is equal to the number of “ND” results

³ NS – no valid sample results were obtained.

⁴ ND – sampled and analyzed, but no Cl-36 was detected.

Table 4-3. Summary of Aquifer Sampling for H-3 at the RWMC from FY1975 – FY2002. The MCL for H-3 is 20,000 pCi/L.

Fiscal Year¹	Number Detections/ Number Sample Results²	Concentration Range (pCi/L)
1975	6/22	750 – 2400
1976	11/19	1000 – 2000
1977	13/20	800 – 5400
1978	6/10	800 – 2000
1979	8/18	800 – 2100
1980	7/15	1000 – 2300
1981	10/18	800 – 1900
1982	10/18	800 – 2300
1983	8/17	1100 – 2000
1984	11/19	1300 – 2100
1985	7/15	1200 – 1900
1986	9/17	1000 – 2200
1987	13/25	1300 – 1900
1988	7/26	1000 – 2300
1989	12/32	1000 – 1900
1990	11/38	1000 – 1900
1991	5/6	1500 – 1800
1992	10/29	900 – 1600
1993	12/30	1400 – 1800
1994	21/59	900 – 1900

Fiscal Year ¹	Number Detections/ Number Sample Results²	Concentration Range (pCi/L)
1995	19/57	700 – 2300
1996	20/53	600 – 2600
1997	10/24	700 – 1910
1998	18/52	760 – 1990
1999	29/73	880 – 1860
2000	34/77	688 – 1860
2001	23/63	533 – 1730
2002	20/43	507 – 1740

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² This summary includes all samples that resulted in valid results. The difference between the number of sample results and number of detections is equal to the number of “ND” results

Table 4-4. Summary of Aquifer Sampling for I-129 at the RWMC from FY1994 – FY2002. The MCL for I-129 is 1 pCi/L.

Fiscal Year ¹	Number Detections/ Number Sample Results ²	Concentration Range (pCi/L)
1994	0/7	ND ³
1995	0/28	ND
1996	1/22	17.
1997	1/7	1.7
1998	2/24	0.59 – 1.0
1999	1/37	1.47
2000	0/53	ND
2001	0/53	ND
2002	0/37	ND

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² This summary includes all samples that resulted in valid results. The difference between the number of sample results and number of detections is equal to the number of “ND” results

³ ND – sampled and analyzed, but no I-129 was detected.

Table 4-5. Summary of Aquifer Sampling for Np-237 at the RWMC from FY1999 – FY2002. The MCL for Np-237 is 15 pCi/L (total alpha radioactivity concentration limit).

Fiscal Year ¹	Number Detections/ Number Sample Results²	Concentration Range (pCi/L)
1994	NS ³	-
1995	NS	-
1996	NS	-
1997	NS	-
1998	NS	-
1999	0/46	ND ⁴
2000	0/55	ND
2001	0/62	ND
2002	3/48	0.07 – 0.38

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² This summary includes all samples that resulted in valid results. The difference between the number of sample results and number of detections is equal to the number of “ND” results

³ NS – no valid sample results were obtained.

⁴ ND – sampled and analyzed, but no Np-237 was detected.

Table 4-6. Summary of Aquifer Sampling for U-233/234 at the RWMC from FY1998 – FY2002. The MCL for U-233/234 is 27 pCi/L (based on the concentration limit for total naturally occurring U activity).

Fiscal Year ¹	Number Detections/ Number Sample Results²	Concentration Range³ (pCi/L)
1994	NS ⁴	-
1995	NS	-
1996	NS	-
1997	NS	-
1998	18/18	0.45 – 1.65
1999	22/22	0.42 – 1.54
2000	52/53	0.40 – 1.56
2001	62/63	0.50 – 4.29
2002	46/46	0.45 – 1.68

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² This summary includes all samples that resulted in valid results. The difference between the number of sample results and number of detections is equal to the number of “ND” results

³ Typical aquifer background concentration for U-233/234 is 1.1 pCi/L (Holdren et. al 2002).

⁴ NS – no valid sample results were obtained.

Table 4-7. Summary of Aquifer Sampling for U-238 at the RWMC from FY1994 – FY2002. The MCL for U-238 is 27 pCi/L (total naturally occurring U concentration limit).

Fiscal Year ¹	Number Detections/ Number Sample Results²	Concentration Range³ (pCi/L)
1994	NS ⁴	-
1995	NS	-
1996	NS	-
1997	NS	-
1998	18/18	0.22 – 0.74
1999	33/33	0.21 – 0.75
2000	53/53	0.22 – 0.72
2001	63/63	0.23 – 2.12
2002	46/46	0.18 – 0.78

¹ Fiscal year spans from October 1 – September 30 (example: 10/1/96 – 9/30/97 is Fiscal Year 1997).

² This summary includes all samples that resulted in valid results. The difference between the number of sample results and number of detections is equal to the number of “ND” results

³ Typical aquifer background concentration for U-238 is 1.1 pCi/L (Holdren et. al. 2002).

⁴ NS – no valid sample results were obtained.

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