DOH 320-029

Environmental Radiation Program

Hanford Environmental Oversight Program 2000 Data Summary Report

Washington State Department of Health

Environmental Health Programs

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Summary

The Washington State Department of Health (DOH) has operated an environmental radiation monitoring program since 1961. The early program looked primarily at atmospheric fallout and off-site environmental impacts related to Hanford operations. Currently, the DOH conducts radiological surveillance in many geographical areas of the state and routinely splits (co-samples) environmental samples with state licensed and federal environmental monitoring programs.

Since 1985, the Washington State Department of Health's Hanford Environmental Oversight Program has participated with the U.S. Department of Energy (DOE) in the collection of environmental samples on or near the Hanford Site. The purpose of the program is to independently verify the quality of DOE environmental monitoring programs at the Hanford Site, and to assess the potential for public health impacts. This report is a summary of the data collected for the Hanford Environmental Oversight Program in 2000.

The Oversight Program's objectives are met through collection and analyses of environmental samples and interpretation of results. DOH samples are either split or co-located with samples collected by the DOE contractors. In 2000, samples of air, groundwater, surface water, riverbank seep water, drinking water, discharge water, soil, sediment, food and farm products, fish and wildlife, and vegetation were collected. In addition, dosimeters measuring ambient external radiation levels were collected.

Generally there is very good agreement between DOH and DOE contractor data. The good agreement between this limited split data gives confidence that the remainder of DOE's environmental radiation data is valid.

Discrepancies between DOH and DOE data historically appear for strontium 90 (Sr-90) and uranium isotopes in solid samples such as soil, sediment, fish, and wildlife. This trend continues in 2000. The discrepancy in reported results is not random, but takes the form of a consistent bias indicating a systematic difference in a laboratory procedure. The uranium discrepancy is understood as due to a difference in laboratory analytical methods. The cause of the strontium discrepancy is not understood at this time and is currently under investigation.

Results for most DOH samples are consistent with background. A few samples had concentrations elevated above background which are attributed to Hanford operations, however, in most cases the results are consistent with historical trends. For example, technetium 99 (Tc- 99), strontium 90 (Sr-90), iodine 129 (I-129), uranium isotopes, and tritium were detected above background levels in some Hanford Site groundwater wells in 2000. Strontium 90 and uranium isotopes in some Columbia River water samples were also greater than background, but at concentrations well below water quality standards. While Hanford Site operations have resulted in radionuclides entering the environment, the DOH Oversight Program's data indicate that public exposure to radioactivity from Hanford is far below regulatory limits.

Contents

Acronyms

ALARA	As Low As Reasonably Achievable
ALE	Arid Land Ecology Reserve
CFR	Code of Federal Regulations
CSB	Canister Storage Building
CVDF	Cold Vacuum Drying Facility
DOE	Department of Energy (United States)
DOH	Department of Health (Washington State)
DNR	Department of Natural Resources
DWS	Drinking Water Standard
EML	Environmental Measurement Laboratory
LLD	Lower Limits of Detection
MAPEP	Mixed Analyte Proficiency Evaluation Program
MDA	Minimum Detectable Activity
NCRP	National Council on Radiation Protection and Measurements
PHL	Public Health Laboratories
PNNL	Pacific Northwest National Laboratory
PUREX	Plutonium Uranium Extraction Facility
QATF	Quality Assurance Task Force of the Pacific Northwest
SI	International Scientific Units
TEDF	Treated Effluent Disposal Facility
TLD	Thermoluminescent Dosimeters
TPA	Tri-Party Agreement
TWRS	Tank Waste Remediation System
USDOE	U.S. Department of Energy
WAC	Washington Administrative Code

1. Introduction

Chapter 70.98 of the Revised Code of Washington designates the Department of Health (DOH) as the state agency with the responsibility to protect human health and the environment from the effects of ionizing radiation. To meet this legislative mandate, the Department conducts radiological monitoring throughout the state. The Department places emphasis on major nuclear facilities with known or potential radiological impacts associated with the facility operations, decommissioning, or cleanup. This report summarizes environmental radiation sampling results from the Department of Health's Hanford Environmental Oversight Program.

From 1943 until the mid 1980s, the primary mission of the U.S. Department of Energy's (DOE) Hanford Site was the production of plutonium for nuclear weapons. Operations resulted in releases of radioactivity to the environment. Today, weapons production operations have ceased, and the current mission of the Site includes cleanup of legacy contamination. However, radioactive contamination remains and continues to move through the environment. DOE has extensive monitoring programs to characterize and track contamination. The primary purpose of the DOH Hanford Environmental Oversight Program is to provide oversight of the DOE monitoring programs.

The primary objectives of the oversight program are:

- To independently verify the quality of the U.S. Department of Energy (DOE) monitoring programs at the Hanford Site by conducting split, co-located, and independent sampling at locations which have the potential to release radionuclides to the environment or locations which may be impacted by such releases.

- To use the DOH oversight data to assess impacts to the public. (With the primary role of oversight, the DOH monitoring program is not intended to completely characterize environmental radiation from the Hanford Site, nor is it intended to find and report the highest environmental contaminant concentrations. Therefore, assessment of impacts to the public based on DOH data do not necessarily represent worst-case scenarios).

- To address public concerns related to environmental radiation at Hanford.

This report presents the results of environmental radiation measurements made by the Washington State Department of Health's Hanford Environmental Oversight Program for the calendar year 2000.

Section 2 describes the Hanford Environmental Oversight Program, including a discussion of laboratory qualifications and how to interpret the results presented in this report. Environmental results are presented in Section 3. Tutorial information on radiation is found in Appendix A. The Laboratory *a priori* lower limits of detection are listed in Appendix B. Appendix C lists a glossary of radiation terms. Appendix D is a list of analytes.

2. The Hanford Environmental Oversight Program Description

The Oversight Program’s objectives (see Section 1. Introduction) are met through collection and analyses of environmental samples and interpretation of results. DOH samples are either split or co-located with samples collected by the DOE contractors. In 2000, samples were split with the Pacific Northwest National Laboratory (PNNL), Duratek, Waste Management Federal Services NW (WMFS), and Bechtel Hanford Inc. (BHI).

Split samples are prepared by dividing a sample into two parts. Co-located samples are those samples that are collected adjacent to the DOE contractor sample. In each case, the DOH sample is sent to the Washington State Public Health Laboratory (PHL) in Shoreline, Washington for radiochemical analysis. Results of the DOH analyses are compared to the DOE contractor results to assess the quality of the federal monitoring program at the Hanford Site. In addition, the results are compared to historical data to identify trends, and are used to identify impacts to public health and the environment.

2.1 Laboratory Qualifications

Analytical techniques are based on laboratory standard operating procedures (Appendix B). The PHL serves as a regional reference laboratory and, as such, operates under a rigorous quality assurance program. This program contains quality control elements, which help ensure the laboratory's high analytical proficiency and accuracy. Laboratory quality control includes analysis of samples distributed by the federal government's quality assurance programs; split samples distributed on a smaller scale between cooperating federal, state and private laboratories; and internal procedures relating to the counting facilities and analytical techniques. Collectively, the PHL’s quality assurance program encompasses:

- Personnel requirements and qualifications
- Quality control
- Sample handling and custody requirements
- Analytical methods
- Equipment calibration and maintenance
- Data reporting
- Records management and archiving
- Corrective action

The PHL participates in three intercomparison programs: DOE’s Environmental Measurement Laboratory (EML) intercomparison, the Mixed Analyte Proficiency Evaluation Program (MAPEP), and the Quality Assurance Task Force of the Pacific Northwest (QATF) intercomparison. These programs provide an independent check of laboratory proficiency for analyzing environmental samples. Additionally the laboratory proficiency is checked through the analysis of standard reference samples. Reference material is generally any environmental media containing known quantities of radioactive material in a solution or homogenous matrix.

2.2 Interpretation of Results

Environmental radiation data are reported as the number of radiation decays per minute per unit quantity of sample material. Most results are reported in units of picocuries. A picocurie equals 2.22 decays per minute. Airborne radioactivity is expressed as picocuries per cubic meter (pCi/m3); radioactivity in liquids such as water and milk is expressed as picocuries per liter (pCi/L); and radioactivity in solid material such as soil, vegetation, and food is expressed as picocuries per gram (pCi/g). Ambient gamma radiation is expressed as radiation exposure, measured in milli-Roentgens per day (mR/day). Radiation dose is explained in Appendix A.

2.2.1 Uncertainty in Radioactivity Measurements

All radioactivity measurements have an associated uncertainty. Counting uncertainty is the dominant source of measurement uncertainty. Counting uncertainty is an estimate of the possible range of radioactivity results due to the fact that radioactive decay is a random process. The uncertainties reported within this report are primarily counting uncertainties, although for gamma-emitting radionuclides the uncertainty associated with calibrating the detector is included. The uncertainties are given as "2-sigma" uncertainty. A 2-sigma uncertainty means that one is 95% confident that the true concentration in the sample lies somewhere between the measured concentration minus the uncertainty and the measured concentration plus the uncertainty.

2.2.2 Detection Limits

The laboratory is capable of measuring very small amounts of radioactivity in environmental samples, but there is a limit below which a sample's radiation cannot be distinguished from background radiation. This limit is called the lower limit of detection, and depends on several factors including the sample size, analytical method, counting time, and background radiation. Appendix C lists the typical lower limits of detection that are achievable by the PHL.

2.2.3 Background and Negative Results

The environmental results are reported as net sample activity, which is defined as gross sample activity minus background activity. Gross sample activity and background activity are measured separately. Gross sample activity results from the sum of radioactivity in the environmental sample and background radiation originating from sources outside of the sample. Background activity is measured by counting the radioactivity in a blank sample.

A negative net sample activity is occasionally reported for environmental samples. When the amount of radioactivity in the sample is very small, the random nature of radioactive decay may result in a gross sample activity that is less than the background activity. In this case, the net result will be negative. In most cases, negative results have an associated uncertainty range that includes zero activity. A negative result indicates that radioactivity in the sample was not detected at concentrations above the detection limit.

The net sample activity represents the best estimate of the true value of the sample activity. Therefore, to prevent biased reporting, DOH reports the net sample activity even when the result is negative (as opposed to reporting a value of "zero" or "not detected"). The negative results are included in statistical analyses of data to look for systematic bias in laboratory procedures and to provide a more accurate measure of analytical detection limits.

2.2.4 Techniques for Comparison of DOH and DOE Contractor Data

Since the primary purpose of the DOH Hanford Environmental Oversight Program is to verify DOE environmental monitoring programs, DOH either splits samples or collects co-located samples with DOE contractors. The DOH and DOE samples are independently analyzed and the results compared. Two techniques are used to compare the data; qualitative comparisons and linear regression analysis.

2.2.4.1 Qualitative Comparisons

All of the co-located or split data are sorted by sample type and analyte. Then, for each sample type and analyte, all of the DOH and DOE contractor data for each sample location are plotted on a graph and visually inspected to qualitatively assess the agreement of the data. The results of the assessment are discussed in the text of the report. When necessary or helpful to the reader, figures of the graphical representation of the data are included in the report.

2.2.4.2 Regression Analysis

In addition to qualitative assessment, linear regression analysis is used to compare DOH and DOE data when appropriate. In this report, regression analysis is carried out when a) there is a sufficient amount of data to analyze, b) the data are consistently greater than the detection limit, and c) the data are sufficiently correlated.

Assuming there is a sufficient amount of data above the detection limit for a meaningful regression analysis, each of the split or co-located DOH and DOE results for a given sample type and analyte are formed into an (x, y) pair. The x-value represents the DOH result and the y-value represents the DOE result for a particular sample. The paired data for all samples of a given sample type and analyte are plotted on a two-dimensional scatter plot. The correlation coefficient R is then calculated for the set of (x, y) pairs. R can vary from -1 to +1. A value near ± 1 implies a strong correlation, while a value near 0 implies a weak or no correlation.

If the two data sets are sufficiently correlated (in this report, the criterion is $R > 0.75$), the best-fit straight line that describes the relationship between the two monitoring programs is determined. The parameters that describe the straight line are the slope and y-intercept. The functional form of the straight line is $y = ax + b$, where a is the slope and b is the y-intercept.

If the results between the DOH and DOE monitoring programs were in perfect agreement, the slope of the best-fit line would be 1, and the y-intercept would be 0. A zero value for the y-intercept means that if DOH measures zero activity, then DOE also measures zero for the same sample. A non-zero y-intercept indicates an overall offset between DOH and DOE results. The slope is simply the ratio of the DOH and DOE results.

If a regression analysis is carried out, a scatter plot (x, y paired data) of the DOH and DOE split or co-located data is presented in this report. Also shown in the plot are straight lines representing the ideal case where the data sets are in perfect agreement, and the best-fit straight line. The slope and y-intercept of the best-fit straight line are shown in the plot legend.

If the two data sets are not sufficiently correlated ($R < 0.75$), it is not meaningful to find a best-fit straight line describing the relationship between the two data sets. In this case, the comparison is limited in this report to a qualitative assessment.

3. Environmental Monitoring Results

This section presents the DOH and DOE contractor results for the Hanford Environmental Oversight Program. The types of samples collected are intended to encompass all of the potential public exposure pathways. These samples include air (Section 3.1); groundwater, riverbank seep water, surface water, drinking water, and discharge water (Section 3.2); dosimeters measuring external gamma radiation (Section 3.3); soil and sediment (Section 3.4); food and farm products (Section 3.5); fish and wildlife (Section 3.6); and vegetation (Section 3.7). Each of these sample types is discussed in the sub-sections below. Note that the figures for each sub-section are located at the end of the sub-section.

In addition to planned sampling events, environmental samples were collected associated with the Hanford Wildfire of June, 2000. These results are summarized in a report that can be found on the Department's web site at the following address: http://www.doh.wa.gov/ehp/rp/wildfire.html

3.1 Air Monitoring

Major Findings:

- The DOH and DOE contractor results are in good agreement.
- Most of the gross beta results are consistent with background air concentrations.
- Co-60; Cs-134, 137; U-234, 235, 238; and Pu-238 results are below detection limits.
- Two Pu-239/240 results were slightly above detection limits.

3.1.1 Purpose and General Discussion

Atmospheric releases of radioactive material from the Hanford Site are a potential source of human exposure. The Department of Health and DOE contractors monitor radioactivity in air to determine if the Hanford Site is contributing to airborne contamination. DOH collects air samples that are co-located with PNNL and Duratek. The primary purpose of the DOH program is to provide oversight of the DOE monitoring program. In addition, Hanford impacts are evaluated by comparing radioactivity in air at locations upwind and downwind of operating and contaminated facilities.

Sources of Hanford airborne emissions include resuspension of contaminated soil (caused by, for example, wind or cleanup activities) and escape of radioactive gasses. Sources of natural airborne radioactivity include radon gas and its decay products, resuspension of soil containing natural radioactivity such as uranium, and radioactive atoms generated in the atmosphere by interactions with cosmic radiation. Natural sources lead to airborne gross beta concentrations ranging from 0.01 to 0.1 pCi per cubic meter of air.

3.1.2 Monitoring Locations

DOH collects air samples co-located with PNNL at five locations. These locations include the Wye Barricade, Benton City and Station 8, which are in the prevailing downwind direction of most Hanford Site operating and contaminated facilities. Air sampling locations were also co-located at an area downwind of the 200 Area (200ESE), and at the Yakima Barricade which is upwind of operating and contaminated facilities. DOH also collects air samples co-located with Duratek at the Wye Barricade and three locations near operating facilities that have the potential to emit radionuclides to the air. These locations include a tank farm in the 200 Area (C Farm), the environmental restoration disposal facility (ERDF), and the K Area fuel storage basins (KE Basin). All the DOH co-located air sampling sites are shown in Figure 3.1.1.

3.1.3 Monitoring Procedures

Airborne particles are sampled by continuously drawing air through a filter. DOH collects the filter at each sample location once a week, while PNNL and Duratek collect their co-located filters every other week (bi-weekly). The filters are stored for three days and then analyzed for gross beta activity. The storage period allows naturally occurring short-lived radionuclides to decay that would otherwise obscure detection of radionuclides potentially present from Hanford Site emissions.

The amount of radioactive material collected on a filter in a one or two week time period is typically too small to accurately detect concentrations of individual radionuclides. In order to increase the sensitivity and accuracy so that individual radionuclide concentrations can be determined, the weekly (or bi-weekly) filter samples for a three or six-month period are dissolved and combined into quarterly or semi-annual composite samples. The composite samples are analyzed for gamma emitting radionuclides and isotopes of uranium and plutonium. A summary of the monitoring program is shown in Table 3.1.1.

Type of Air Sample	DOH / PNNL	DOH / Duratek
Weekly (or Bi-Weekly) Filter	Gross Beta	Gross Beta
Quarterly Composite Filter	Co-60; Cs-134, 137; U-234, 235, 238	
Semi-Annual Composite Filter		Co-60; Cs-134, 137; Pu-238, 239/240; U-234, 235, 238

Table 3.1.1 Radionuclides Monitored in Air Samples

3.1.4 Comparison of DOH and Contractor Data

The DOH and PNNL gross beta results are generally in good agreement. The data at the Wye Barricade are shown in Figure 3.1.2. The two data sets follow the same trend. In general, the two data sets are not expected to match identically because the DOH and DOE contractor sampling frequencies are different and therefore the results correspond to an averaging of the air concentration over different time periods. The agreement between the DOH and PNNL gross beta results at the other sampling locations is similar to that at Wye Barricade.

The DOH and Duratek gross beta results are also in good agreement. The data at Wye Barricade, KE Basin, and C Farm are shown in Figures 3.1.3 – 3.1.5. The two data sets at each site follow the same trend. The results at KE Basin and C Farm indicate a single anomalously high DOH result at each site. The Duratek data does not corroborate these DOH results.

Regression analysis was carried out to quantify the degree of agreement between DOH and PNNL results for gross beta activity. Regression analysis was not carried out for the DOH and Duratek data because, although the data sets are generally in good agreement, the correlation between the two data sets is not strong enough to produce a meaningful best-fit straight line.

DOH vs. PNNL and DOH vs. Duratek scatter plots for co-located gross beta results are shown in Figures 3.1.6 and 3.1.7. The x-coordinate of each point represents the DOH result, while the y-coordinate represents the DOE contractor result. Ideally, if the DOH and DOE contractor results were identical, all the points would fall on the straight line with slope equal to unity and y-intercept equal to zero (shown as the solid black line in the figures). Regression analysis was used to fit a straight line to the DOH vs. PNNL data (blue dashed line), and the resulting slope and y-intercept quantifies the agreement between the two data sets.

The DOH and PNNL data are highly correlated, and the agreement between the two data sets is very good. The slope of 0.92 for the best-fit straight line indicates good agreement. The y-intercept of 0.0007 pCi/m3 is not significant relative to the range of uncertainties in the results, indicating there is not a significant offset between the two data sets.

The DOH and DOE contractor results for Co-60, Cs-134, Cs-137, U-234, U-235, U-238, Pu-238, and Pu-239/240 are all in good agreement. The DOH and PNNL Cs-137 results are shown in Figure 3.1.8, and the DOH and Duratek Pu-238 and Pu-239/240 results are shown in Figures 3.1.9 and 3.1.10. There is not a sufficient quantity of data to conduct a meaningful regression analysis for these radionuclides.

3.1.5 Discussion of Results

The gross beta results at all sites show a trend of higher concentration during the winter months, typically October through February. These higher gross beta activities are attributed to increased concentrations of radon daughter products due to decreased atmospheric mixing during the winter months when there is decreased atmospheric heating. The annual cycle of increased gross beta activity in the winter months can easily be seen in Figure 3.1.11, which shows gross beta activity at Wye Barricade from 1988 through 2000.

For the year 2000, most of the weekly DOH gross beta results ranged between 0.002 and 0.07 pCi/m3, with an annual average of 0.02 pCi/m3. The only gross beta activity outside this range is an anomalous result of 0.52 pCi/m3 at C Farm (Figure 3.1.5), which is approximately 25 times greater than the annual average. An additional anomalous result occurred in May, 2000 at KE Basin (Figure 3.1.4), where a result of 0.06 pCi/m3 was found at a time of the year when the results are typically 0.02 pCi/m3.

Gross beta results from locations upwind and downwind of the Hanford Site are compared to determine if Hanford is impacting air quality. Yakima Barricade is an upwind location, while Wye Barricade, Benton City, and Station 8 are downwind locations where the public may potentially be exposed. The minimum, maximum, and annual average concentrations for these sites are shown in Table 3.1.2, along with the results for locations on the Hanford Site (200 ESE, C Farm, ERDF-SE, and KE Basin).

Weekly air samples at 200 ESE and Benton City were collected July through December, while samples at all other sites were collected over the entire year. Air concentrations vary with the seasons, and are typically higher during the fall and winter (see Figure 3.1.2). Therefore, the average concentrations at 200 ESE and Benton City are slightly higher than at sites where samples were collected over the entire year. The average air concentration at upwind sites (Yakima Barricade) and downwind sites (Wye Barricade and Station 8) are not significantly different, indicating that Hanford is not impacting air quality at locations where the public may be exposed.

Site	DOH			Contractor			
	Min	Max	Ave.	Name	Min	Max	Average
200 ESE	0.0091	0.056	0.020*	PNNL	0.0086	0.055	0.024
Benton City	0.0074	0.059	0.020*	PNNL	0.0095	0.050	0.023
C Farm	0.0057	0.52	0.026	Duratek	0.0061	0.096	0.019
ERDF-SE	0.0052	0.058	0.017	Duratek	0.0068	0.061	0.017
KE Basin	0.0056	0.060	0.017	Duratek	0.0055	0.050	0.017
Station 8	0.0059	0.066	0.017	PNNL	0.0057	0.040	0.014
WYE B.	0.0020	0.069	0.017	PNNL	0.001	0.045	0.015
				Duratek	0.0075	0.051	0.017
Yakima B.	0.0051	0.052	0.015	PNNL	0.0077	0.034	0.015

* Weekly air samples at 200 ESE and Benton City were collected only from July through December in the year 2000. Samples at all other sites were collected for the entire year.

Table 3.1.2 Summary Statistics for Gross Beta in Air (Weekly Filter) Results (pCi/m^3)

The DOH results for Co-60, Cs-134, Cs-137, U-234, U-235, U-238, and Pu-238 concentrations in air are all below laboratory detection limits and are generally consistent with zero concentration. The Cs-137 data are shown in Figure 3.1.8 and the Pu-238 data are shown in Figure 3.1.9. For Pu-239/240 (Figure 3.1.10), four of the six results are below the detection limit. However, one result at ERDF-SE and one result at KE Basin are above detection limits. The ERDF-SE result of 6×10^{-6} pCi/m3 is slightly greater than the detection limit of 4×10^{-6} pCi/m3, and the KE Basin result of 1.3×10^{-5} pCi/m3 is 2.6 times greater than the detection limit of 5×10^{-6} pCi/m3.

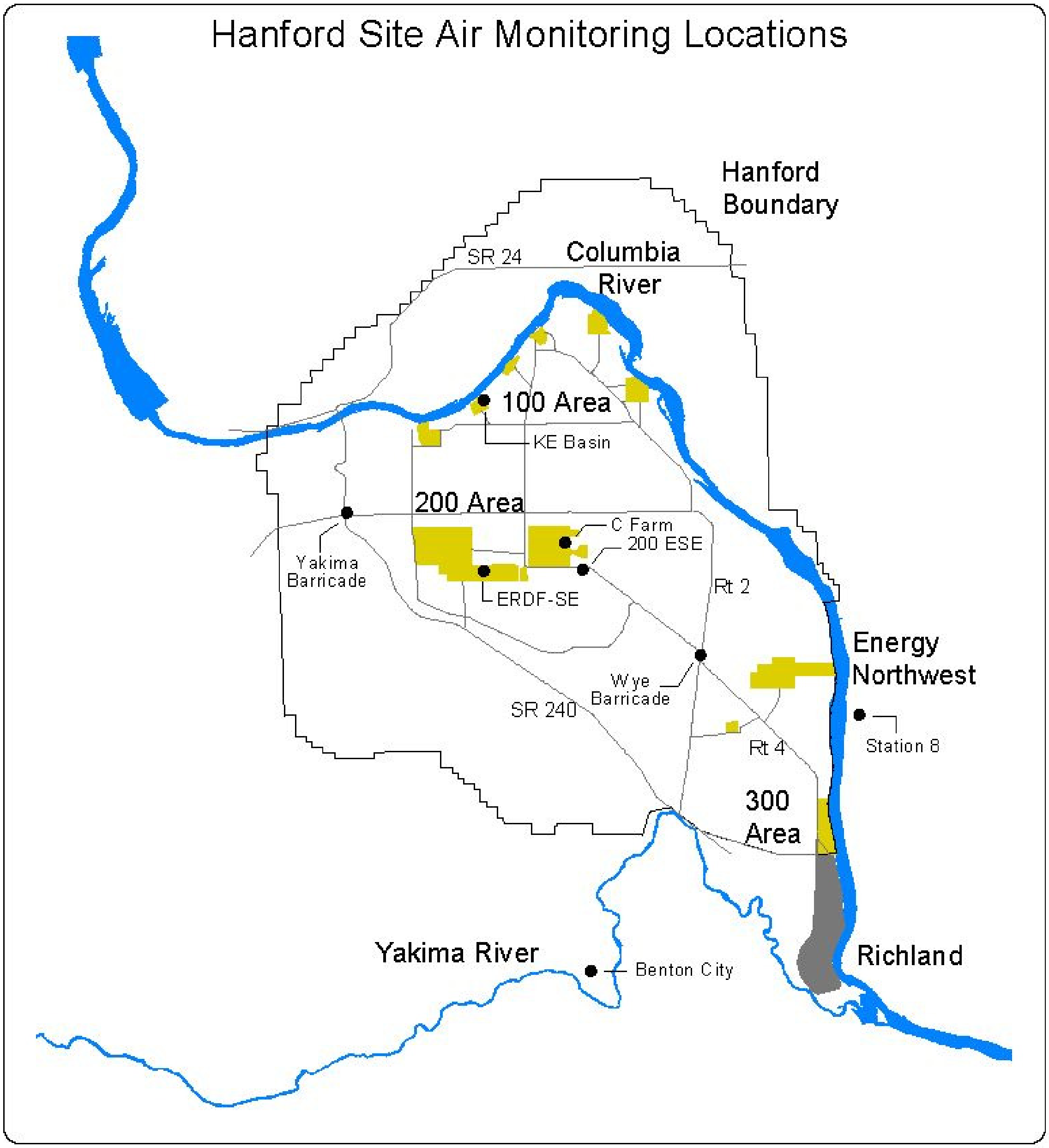

Figure 3.1.1   Air Monitoring Locations

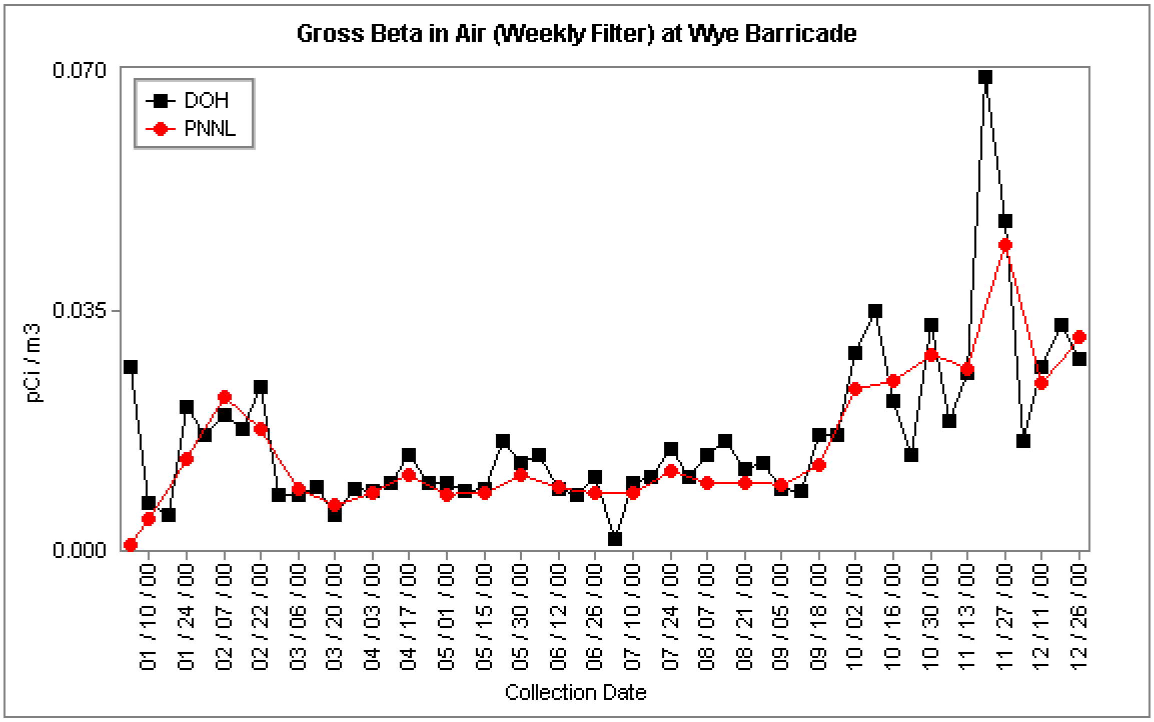

Figure 3.1.2 DOH and PNNL Gross Beta in Air (Weekly Filter) at Wye Barricade

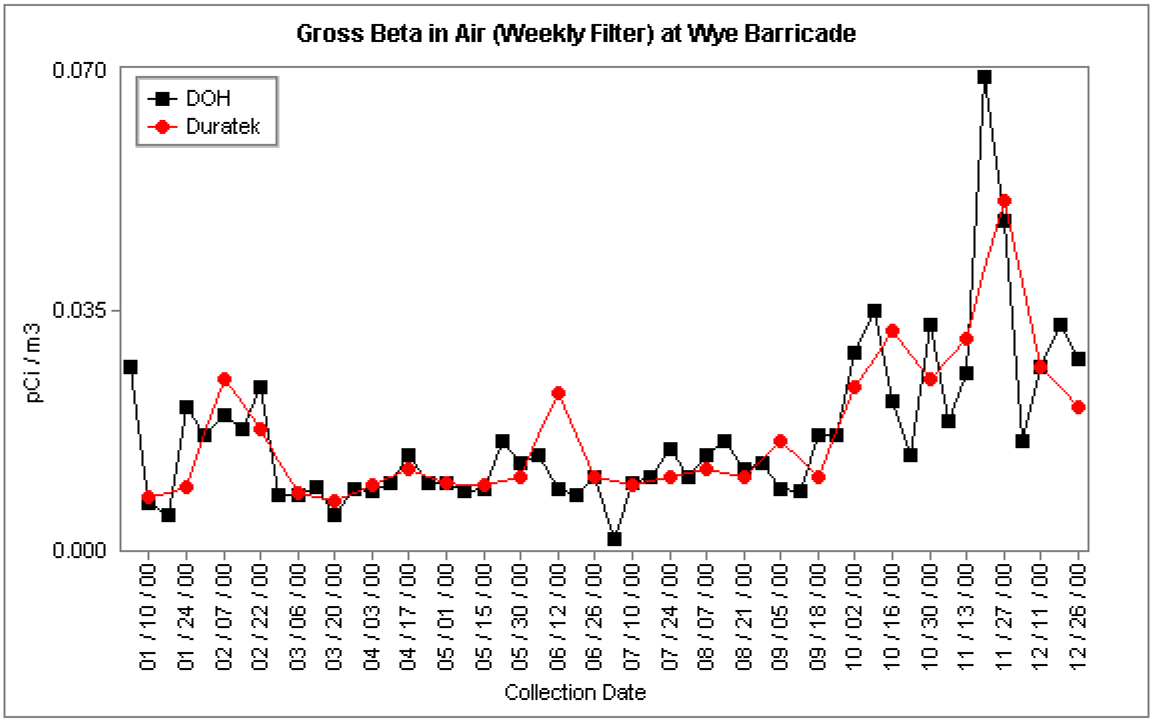

Figure 3.1.3 DOH and Duratek Gross Beta in Air (Weekly Filter) at Wye Barricade

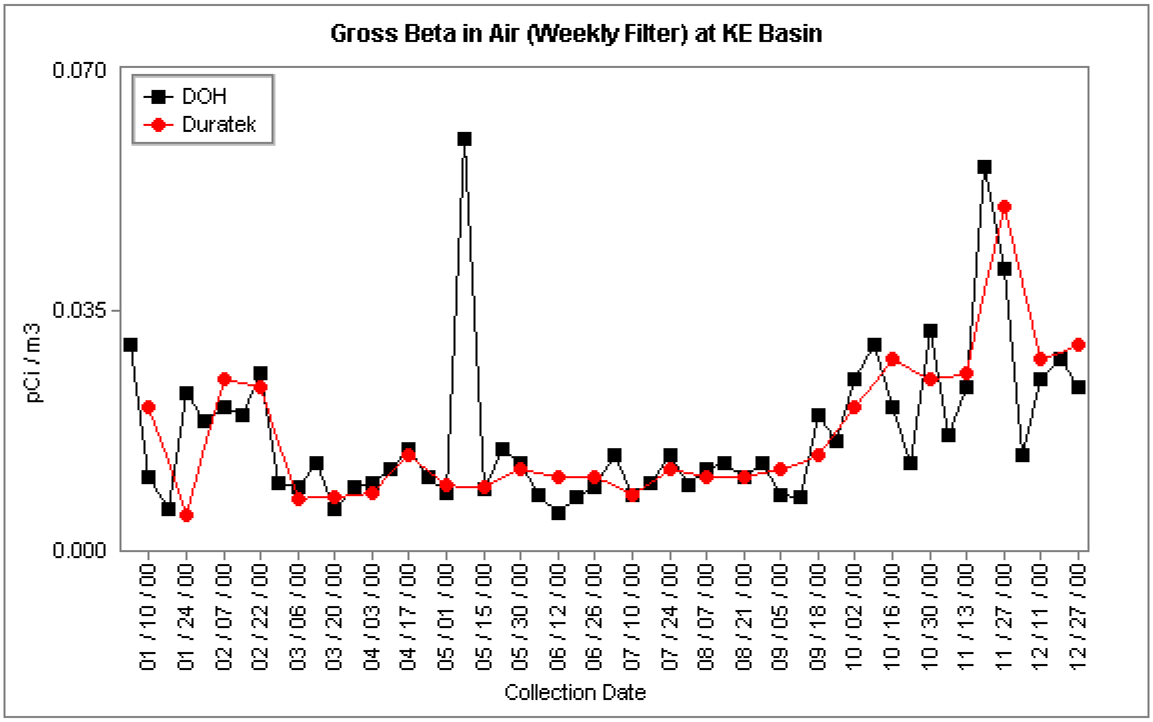

Figure 3.1.4 DOH and Duratek Gross Beta in Air (Weekly Filter) at KE Basin

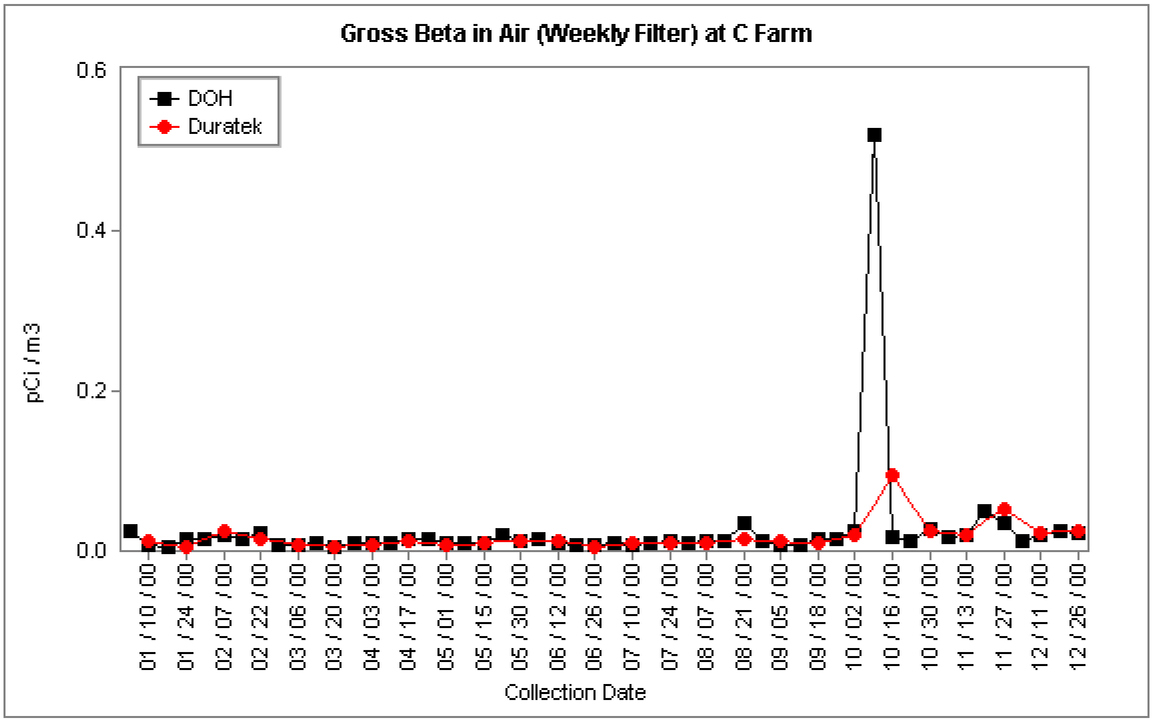

Figure 3.1.5 DOH and Duratek Gross Beta in Air (Weekly Filter) at C Farm

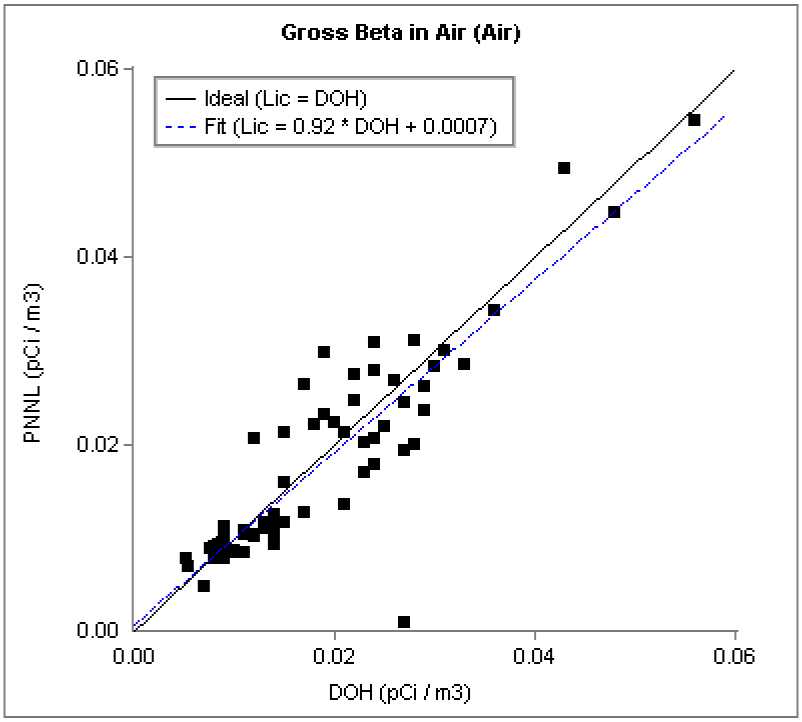

Figure 3.1.6 DOH vs. PNNL Gross Beta in Air Results
The solid black line represents the ideal hypothetical case where DOH and contractor results are identical. The blue-dashed line is the best straight-line fit to the data.

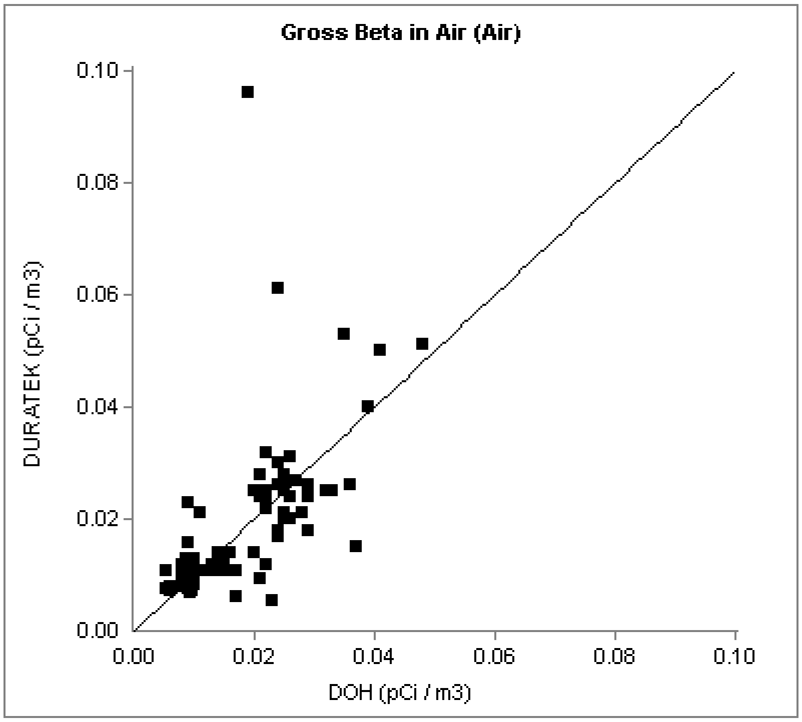

Figure 3.1.7 DOH vs. Duratek Gross Beta in Air Results
The solid black line represents the ideal hypothetical case where DOH and contractor results are identical. The blue-dashed line is the best straight-line fit to the data.

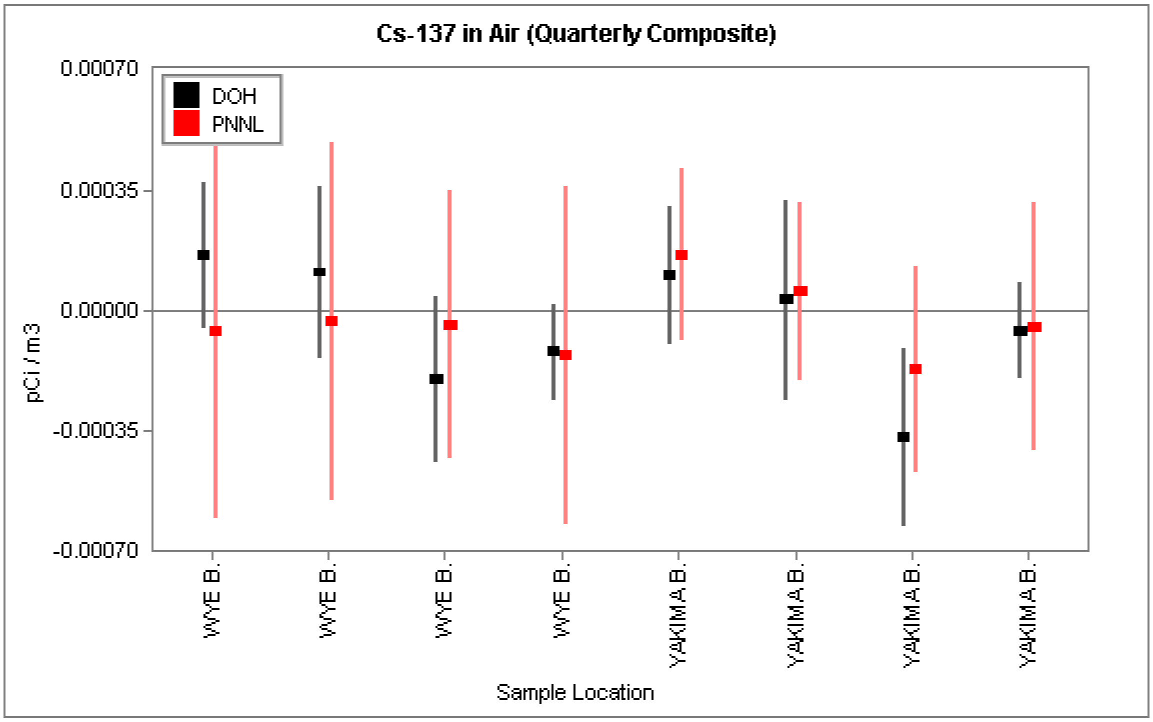

Figure 3.1.8 DOH and PNNL Results for Cs-137 in Air (Quarterly Composite)

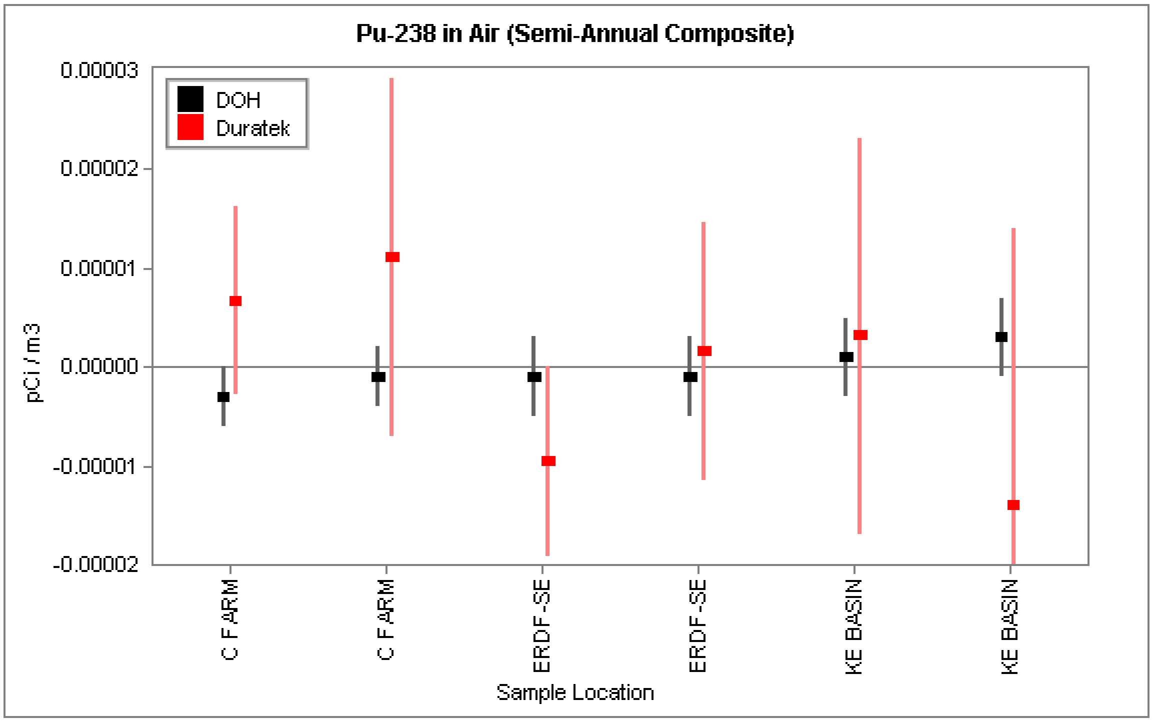

Figure 3.1.9 DOH and Duratek Results for Pu-238 in Air (Semi-Annual Composite)

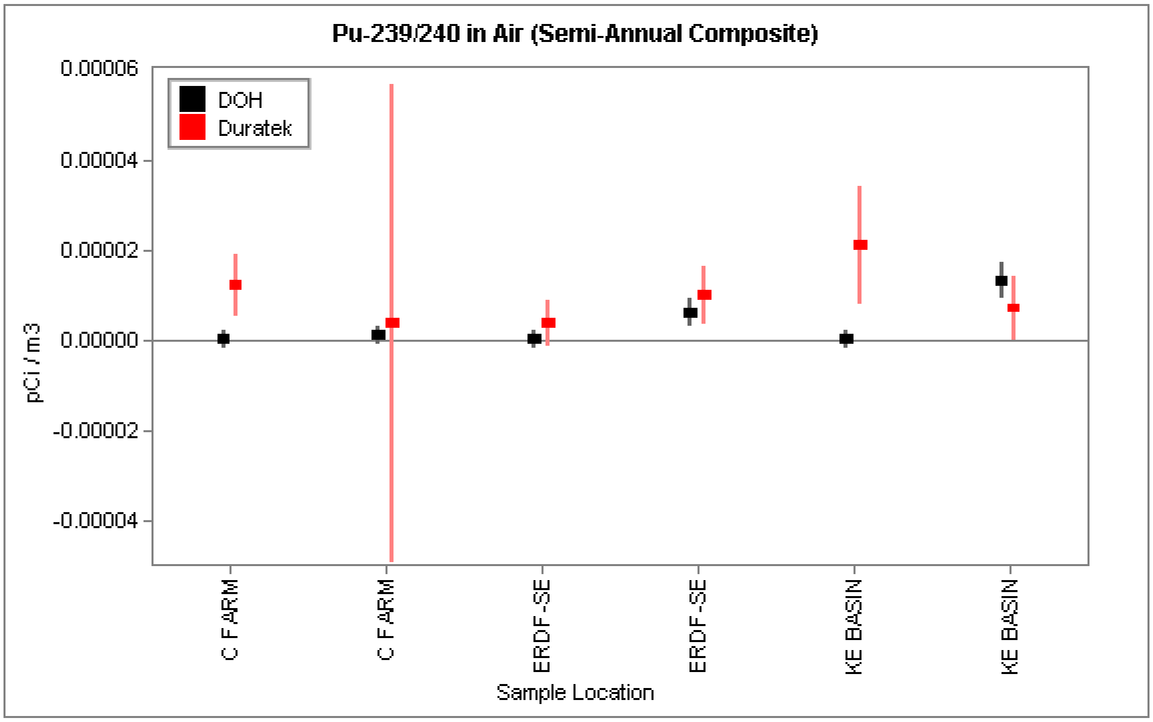

Figure 3.1.10 DOH and Duratek Results for Pu-239/249 in Air (Semi-Annual Composite)

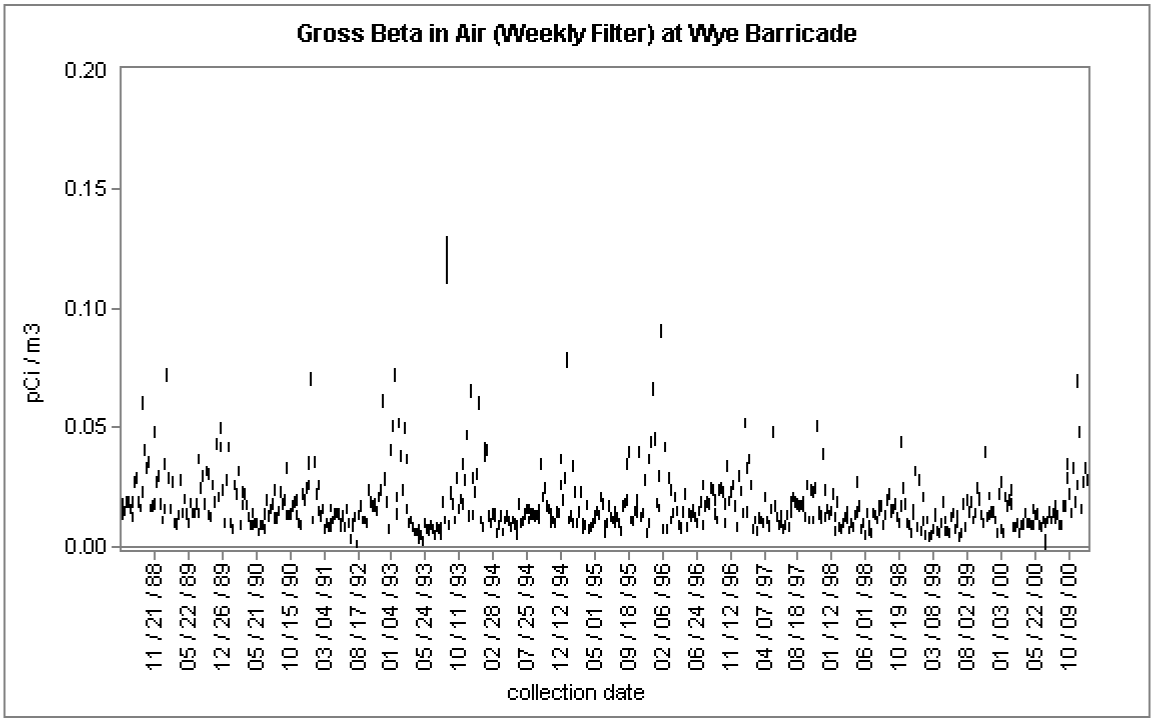

Figure 3.1.11 DOH Historical Results for Gross Beta in Air (Weekly Filter) at Wye Barricade

3.2 Groundwater, Riverbank Seep, and Surface Water Monitoring

Major Findings:

- There is good agreement between DOH and DOE results for H-3, U-234 and U-238. The agreement is only fair for Tc-99 and agreement is poor for gross beta. DOH will investigate the discrepancies for Tc-99 and gross beta and discuss the findings in a future report.
- Groundwater results are consistent with historical results and show a decreasing trend for tritium in FFTF drinking water and ground water across the Hanford Site.
- Seep Samples show contaminants are entering the Columbia River, but at levels that are expected based on past sampling.
- Surface water samples are similar to historical data.

3.2.1 Purpose and General Discussion

Operations at the Hanford Site have resulted in contaminated groundwater and Columbia River water. Radioactive contaminants have leached from waste sites in the soil to groundwater beneath the Site, and then have migrated with groundwater to the Columbia River. Occasionally, groundwater entering the Columbia River takes the form of riverbank seeps. Human exposure to contaminants can occur directly through ingestion of, or swimming in, contaminated water; or indirectly through ingestion of plants, animals, or fish that have been exposed to contaminated water. Radioactive contaminants are monitored by collecting samples from inland groundwater wells, riverbank seeps, and Columbia River water.

DOE contractors monitor radioactivity in water to track contaminant plumes in groundwater, and to evaluate impacts to the public and environment. The primary purpose of the DOH program is to provide oversight of the more extensive DOE monitoring program. While the DOH program does not sample enough groundwater wells to track groundwater plumes, the riverbank seep and Columbia River data is adequate to understand impacts to the public.

3.2.2 Monitoring Locations

Groundwater

Most well locations sampled by DOH are on the Hanford Site, either within contaminated plumes near contaminated facilities, waste sites, or along the Columbia River shoreline. A few of the well locations are off the Hanford Site, located just south of Hanford in the northern part of Richland and just across the Columbia River in Franklin County. One well, 699-49-100C, is located up-gradient from contaminated plumes and serves as a background location for comparison purposes. Figure 3.2.1 shows the location of the DOH groundwater sampling sites.

Groundwater sampling is conducted in the 100, 300, 400 and 600 Areas of the Hanford Site. The 100 Area consists of nine retired reactors as well as support facilities such as fuel storage basins, liquid effluent disposal facilities, retention basins and burial grounds. At the 100K Area, groundwater is sampled to evaluate potential changes as spent nuclear fuel, shield water, and sludge are removed from the 100KE Fuel Storage Basin.

The 300 Area is adjacent to the Columbia River and other municipal, industrial, and agricultural activities. This area contained nuclear fuel fabrication facilities that provided fuel to the reactors located in the 100 Area. Groundwater contains tritium originating from the 200 Area and uranium originating from the 300 Area fuel fabrication activities. The primary objective of the groundwater collection in the 300 Area is to monitor contaminants at the southern boundary of the Hanford Site, which is in close proximity to the City of Richland's drinking water wells.

The 400 Area is the location of the Fast Flux Facility, a liquid sodium cooled test reactor that ceased operation in 1993 and is currently being deactivated. The primary objective of groundwater monitoring in this area is limited to assessing impacts to the primary drinking water source for this area from tritium originating in the 200 East Area. In addition to sampling one of the groundwater wells that is used for partial makeup of the drinking water, the drinking water itself was analyzed.

The 600 Area includes all the land outside the operational areas of the Hanford Site. Most of the wells sampled by DOH lie within this area. The major objective of sampling 600 Area groundwater is to assess the nature and extent of plumes originating in the 200 Area and to evaluate their offsite impacts.

Riverbank Seeps

Historically, the predominant areas for discharge of riverbank seep water to the Columbia River were located at the 100N Area, the Old Hanford Townsite, and the 300 Area. In 2000, riverbank seep samples were collected at the 100N Area, river mile 28.2 (Old Hanford Townsite), and river mile 42.2 (300 Area). In addition, seeps at the 100F, 100H, and 100K Areas were also sampled.

Surface and Discharge Water

Columbia River water samples were collected from Priest Rapids Dam, the100N Area, the 300 Area, and the Richland Drinking Water intake. The Priest Rapids Dam location is upstream of the Hanford Site while the Richland Drinking Water sample location is downstream. A comparison of contaminant concentrations at these two sites gives an indication of Hanford's impact on the Columbia River.

DOH conducts effluent monitoring at the 310 Treated Effluent Disposal Facility (TEDF) as acknowledged in the Aquatic Lands Sewer Outfall Lease No. 20-013357. This agreement, between the Department of Natural Resources (DNR) and DOE requires DOH to ensure that river and effluent concentrations do not exceed applicable standards for radioactivity.

The TEDF was constructed as part of a Tri-Party Agreement Milestone to cease discharges to the 300 Area Process Trenches. The facility began operation in December 1994 and effluent sampling has been conducted by the DOH and Duratek since that time.

3.2.3 Monitoring Procedures

Groundwater

DOH groundwater samples were collected by DOE contractors who follow standard operating procedures that call for purging the well prior to sampling. Groundwater samples were collected from the upper, unconfined aquifer. The samples were analyzed for radionuclides that are most likely present in the area based on previous sampling and review of radiological contaminants present nearby. Most samples were analyzed for gross alpha, gross beta, tritium, and gamma-emitting radionuclides. Specific analyses for strontium, iodine, and uranium were added where appropriate.

Groundwater from 20 wells was sampled during 2000. One drinking water tap was also sampled. The well names and analytes are listed in Table 3.2.1.

Well Name	Analytes	Number of Samples
199-F5-1	Gross alpha, beta; tritium; Co-60; Cs-137; Sr-90; Tc-99; uranium	1
199-K-109A	Tritium; Sr-90	2
199-K-27	Gross alpha, beta; tritium; Sr-90	1
199-N-14	Gross alpha, beta; tritium	1
399-1-17A	Gross alpha, beta; tritium; uranium	1
499-S1-8J	Gross alpha, beta; tritium; Co-60; Cs-137; Sr-90; Tc-99; uranium	1
FFTF Drinking Water	Gross alpha, beta; tritium; Sr-90	1
618-11 C3264	Tritium; Tc-99	1
618-11 C3265	Tritium; Tc-99	1
699-10-E12	Gross alpha, beta; tritium; Co-60; Cs-137; Sr-90; Tc-99	1
699-26-33	Gross alpha, beta; tritium; Co-60; Cs-137; Sr-90; Tc-99	1
699-31-31	Tritium; Co-60; Cs-137; Sr-90; Tc-99	1
699-35-70	Gross alpha, beta; tritium; Co-60; Cs-137; Tc-99; I-129; uranium	2
699-38-65	Gross alpha, beta; tritium; Co-60; Cs-137; Tc-99; I-129	1
699-41-1A	Gross alpha, beta; tritium; Co-60; Cs-137; Sr-90; Tc-99; I-129	1
699-42-E9B	Gross alpha, beta; tritium; Co-60; Cs-137; I-129; uranium	1
699-49-100C	Gross alpha, beta; tritium; Co-60; Cs-137;	1
699-60-60	Gross alpha, beta; tritium; Co-60; Cs-137; Sr-90; Tc-99	1
699-S30-E15A	Gross alpha, beta; tritium	1
699-S34-E10	Tritium	1
699-S37-E14	Gross alpha, beta; tritium	1

Table 3.2.1 Groundwater Samples

Riverbank Seeps

Columbia River seep samples were collected in the fall when the river flow is typically the lowest. This is done to ensure that riverbank seep water contains primarily groundwater instead of Columbia River water stored in the riverbank during high flow rates. The seeps have a very small flow rate and are collected with the aid of a small pump. All seep samples were split with PNNL in the field and analyzed as unfiltered samples. Samples were analyzed for gamma-emitting radionuclides, strontium 90, technetium 99 and isotopic uranium as appropriate (Table 3.2.2).

Sample Location	Analytes	Number of Samples
100F 207-1	Gross alpha, beta; tritium; Co-60; Cs-137; K-40; Sr-90; uranium	1
100H 153-1	Gross alpha, beta; tritium; Co-60; Cs-137; K-40; Sr-90; Tc-99; uranium	1
100K	Gross alpha, beta; tritium; Co-60; Cs-137; Sr-90	1
100N 8-13	Gross alpha, beta; tritium; Co-60; Cs-137; Sr-90	1
300 RM 28.2	Gross alpha, beta; tritium; Co-60; Cs-137; K-40; Sr-90; Tc-99; uranium	1
300 RM 42.2	Gross alpha, beta; tritium; Co-60; Cs-137; Sr-90; Tc-99; uranium	1

Table 3.2.2 Columbia Seep Sample Locations and Analytes

Surface and Discharge Water

Columbia River surface water is monitored by collecting samples at several points spanning the width of the river. This technique is known as transect sampling. Columbia River transect samples were collected during a joint sampling trip with PNNL. Samples were split in the field and analyzed unfiltered. Typically gross alpha, gross beta, tritium and nitrates were analyzed. Strontium 90, Tc-99, and uranium isotopes were analyzed where appropriate based on previous sampling. In addition, discharge from the 310 Treated Effluent Disposal Facility was collected by Duratek and delivered to DOH for analysis (Table 3.2.3).

Sample Location	Analytes	Number of Samples
100N Area	Tritium; Sr-90; uranium	5
300 Area	Tritium; Sr-90; uranium	5
Priest Rapids Dam	Gross alpha, beta; tritium; Sr-90; Tc-99; uranium	2
Richland Pumphouse	Gross alpha, beta; tritium; Sr-90; Tc-99; uranium	2
310 TEDF Discharge	Gross alpha, beta; tritium; Co-60; Cs-137	2

Table 3.2.3 Surface Water and Discharge Water Samples

3.2.4 Comparison of DOH and Contractor Data

In 2000, the DOH Hanford Oversight Program split groundwater, surface water, drinking water, and riverbank seep water samples with PNNL. Because laboratory techniques to analyze all these different types of water samples are identical, the regression analysis included all of the water samples. Regression analysis was carried out to quantify the degree of agreement between DOH and PNNL water results for the following radionuclides: Gross Beta, H-3, Tc-99, U-234, and U-238. The data for all other radionuclides measured in water samples did not meet the criteria for conducting regression analysis.

DOH vs. PNNL scatter plots for split water samples are shown in Figures 3.2.2 through 3.2.5. The x-coordinate of each point represents the DOH result, while the y-coordinate represents the PNNL result. Ideally, if the DOH and PNNL results were identical, all the points would fall on the straight line with slope equal to unity and y-intercept equal to zero (shown as the solid black line in the figure). Regression analysis was used to fit a straight line to the data (blue dashed line), and the resulting slopes and y-intercepts quantify the agreement between DOH and PNNL results.

The comparison of DOH and PNNL Gross Beta results is shown in Figure 3.2.2. The data are highly correlated, however the agreement between the two data sets is poor. The slope of 0.49 for the best-fit straight line indicates a factor of two discrepancy between DOH and PNNL results. The y-intercept of 2.5 pCi/L is smaller than the typical uncertainty in the results, and therefore is not indicative of an offset between the two data sets.

The comparison of DOH and PNNL tritium (H-3) results is shown in Figure 3.2.3. The data are highly correlated, and the agreement between the two data sets is quite good. The slope of 0.92 for the best-fit straight line indicates good agreement. The y-intercept of 467 pCi/L is not significant relative to the range of uncertainties in the results, indicating there is not a significant offset between the two data sets.

The comparison of DOH and PNNL Tc-99 results is shown in Figure 3.2.4. The data are reasonably correlated, and the agreement between the two data sets is fair. The slope of 1.22 for the best-fit straight line indicates only fair agreement. The y-intercept of approximately 4 pCi/L is not significant relative to the range of uncertainties in the results, indicating there is not a significant offset between the two data sets.

The comparison of DOH and PNNL U-238 results is shown in Figure 3.2.5. The data are highly correlated, and the agreement between the two data sets is excellent. The slope of 0.99 for the best-fit straight line indicates excellent agreement. The y-intercept of 0.1 pCi/L is not significant relative to the range of uncertainties in the results, indicating there is not a significant offset between the two data sets. The regression analysis for U-234 (not shown) also indicates excellent agreement (slope = 0.98, y-intercept = 0.2 pCi/L) between DOH and DOE.

In summary, there is good agreement between DOH and DOE results for H-3, U-234, and U-238. The agreement is only fair for Tc-99, and agreement is poor for gross beta. DOH will investigate the discrepancies for Tc-99 and gross beta, and discuss the findings in a future report.

3.2.5 Discussion of Results

Groundwater

Concentrations of tritium ranged from less than detectable to 380,000 pCi/L with the highest value found in well 699-35-70 (Figure 3.2.6). Tritium is a highly mobile contaminate and is found throughout a wide area beneath the Hanford Site. Tritium concentration in well 699-35-70 has typically been high and is influenced by the tritium plume emerging from the 200 Area. Over the past decade, DOH has observed a steady decline in the tritium concentration at this location (Figure 3.2.7) as well as in groundwater from 199-K-27, 399-1-17A, 499-S1-8J, 699-35-70, 699-38-65 and 699-41-1A.

Concentrations of I-129 in groundwater ranged from less than detectable to 36 pCi/L with the highest value found at the 699-35-70 well. From 1998 through 2000, I-129 concentrations in this well have ranged from 7 to 36 pCi/L.

Concentrations of Sr-90 in groundwater (Figure 3.2.8) ranged from less than detectable to 5780 pCi/L in one sample from 199-K-109A. Historical data indicate that the Sr-90 levels at this location are declining.

Results of uranium analysis of groundwater from the 300 Area indicate that the concentrations are declining after the discharge to the process trenches was discontinued in 1997 (Figure 3.2.9).

Drinking water for the 400 Area Fast Flux Test Facility (FFTF) is obtained from two groundwater wells. The water at this location is contaminated with tritium and is monitored to ensure that Environmental Protection Agency (EPA) Drinking Water Standards are not exceeded. Historical tritium results for one of the wells contributing to drinking water, 499-S1-8J, are shown in Figure 3.2.10. Also shown in the figure are historical tritium results for tap water at the FFTF. Tritium concentrations in tap water track well with changes in groundwater concentration. The tritium drinking water limit is 20,000 pCi/L, and FFTF drinking water is approximately 20% of the allowable limit (Figure 3.2.10).

Riverbank Seeps

Analysis of Columbia River seeps did not yield any surprises. Evidence of contaminated groundwater entering the Columbia River at traditional locations was observed. Tritium concentrations in seep water ranged from 200 to 70,700 pCi/L with the high value found at the 28.8-mile sampling site near the Old Hanford Townsite (Figure 3.2.11). Tritium concentrations at this location exceed the Washington State surface water quality standard (Washington Administrative Code Chapter 173-201A) of 20,000 pCi/L.

Sr-90 was found in the riverbank seep sample at 100H Area at near the surface water quality standard for Sr-90 of 8 pCi/L. The distribution of this radionuclide is expected to be very localized and as such, would be quickly diluted by the volume of the Columbia River.

Technetium 99 was detected in seep samples at river mile 28.2 (Old Hanford Townsite) and 42.2 (300 Area), with concentrations of 80 and 16 pCi/L, respectively. Historical data indicate that the concentrations are declining (Figure 3.2.12).

Uranium was detected in seep samples at river mile 28.2 and at 42.2, with concentrations of 2.9 and 44.3 pCi/L, respectively. Historical data show that uranium concentrations in the 300 Area riverbank seep water are remaining constant (Figure 3.2.13).

Surface Water

DOH has been collecting composited surface water samples upstream of Hanford (Priest Rapids Dam) and downstream (Richland Pumphouse) since 1987. Historical tritium concentrations at Priest Rapids Dam (PR Dam) and the Richland Pumphouse Water Treatment Plant (STA 29, WTP) are shown in Figure 3.2.14. Results of analysis show that there may be a very slight increase in tritium levels downstream as compared to upstream but the levels of tritium are only a small fraction of the EPA Drinking Water Standard (0.1%) and are therefore not a public health concern.

DOH collected Columbia River transect data at the 100N Area and the 300 Area. At each location, DOH collected samples at five points spanning the width of the river. The Sr-90, tritium, and uranium results are all similar to background concentrations at Priest Rapids Dam.

Radionuclide discharge concentrations from the 310 TEDF were all well below the prescribed limits as set by the Department of Natural Resources. Tritium was the only radionuclide detected in 2000, and its concentration is consistent with historical trends. Historical tritium results are shown in Figure 3.2.15 for 1995 through 2000.

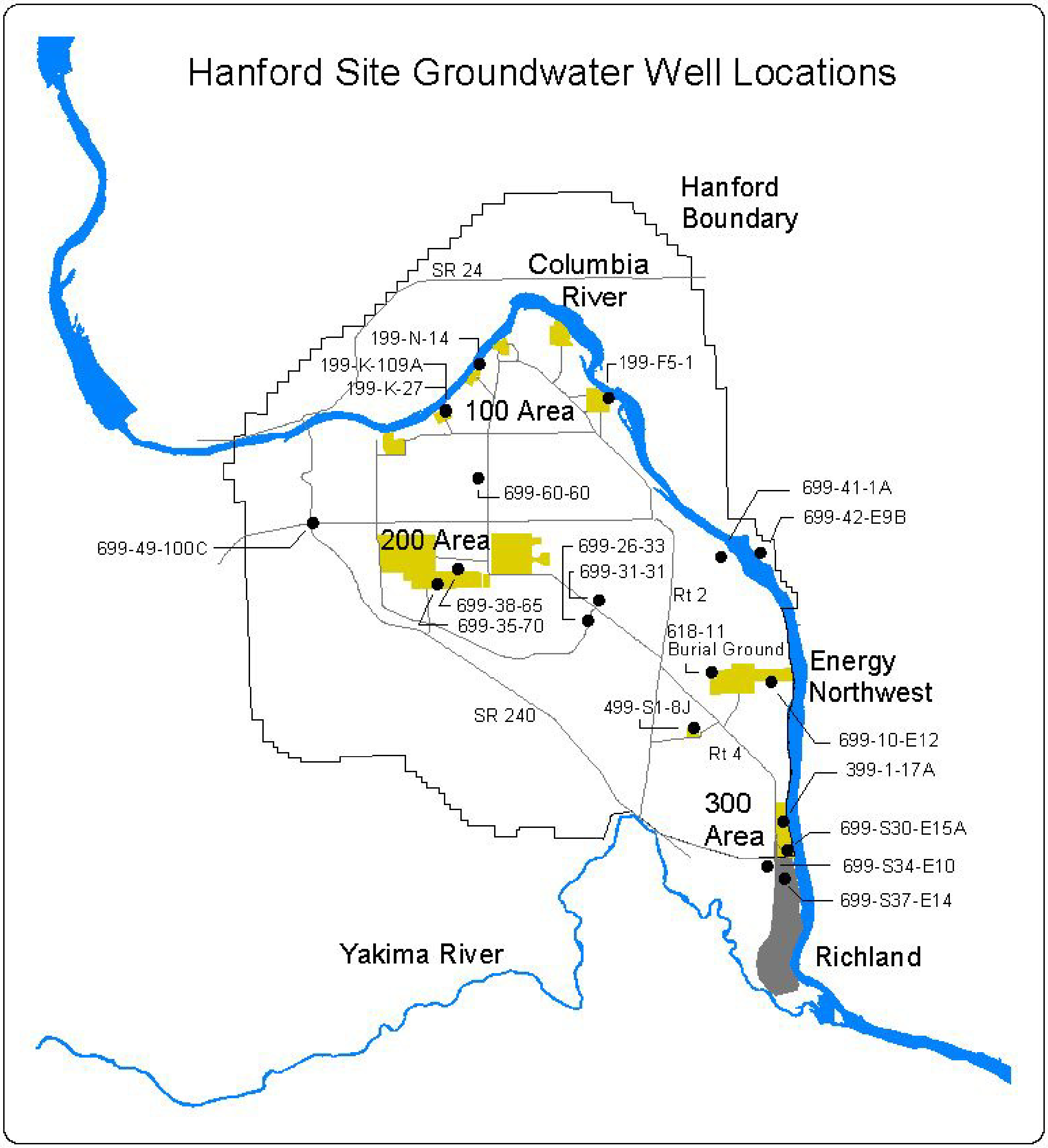

Figure 3.2.1 Groundwater Monitoring Locations

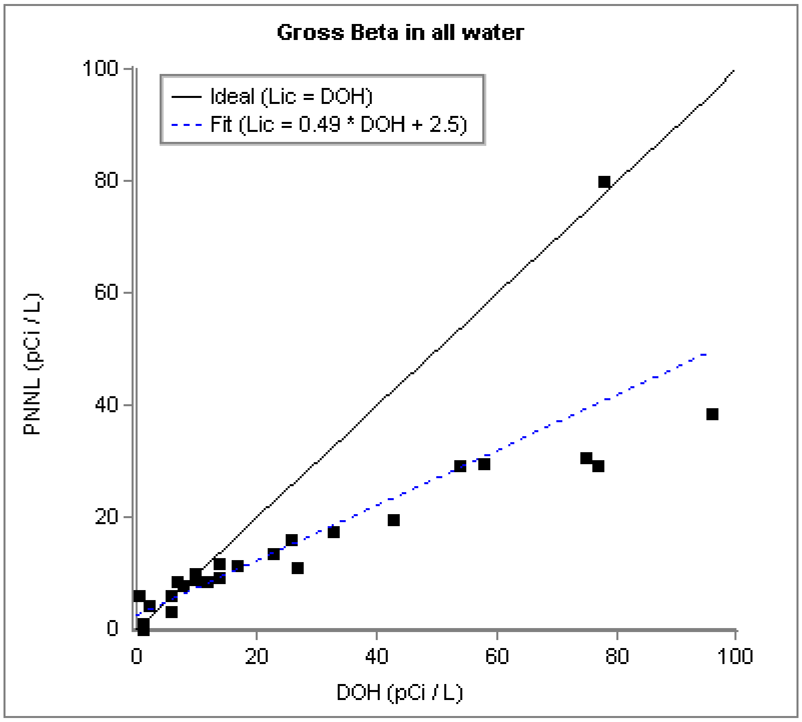

Figure 3.2.2 DOH vs. PNNL split Gross Beta Water Results
The solid black line represents the ideal hypothetical case where DOH and PNNL results are identical. The blue dashed line is the best straight line fit to the data.

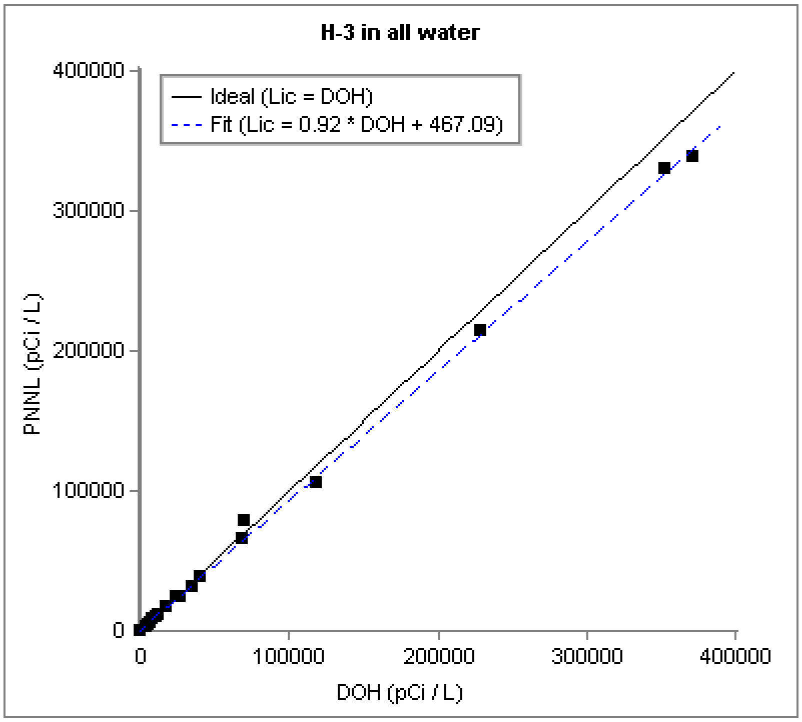

Figure 3.2.3 DOH vs. PNNL Split H-3 Water Results
The solid black line represents the ideal hypothetical case where DOH and PNNL results are identical. The blue dashed line is the best straight line fit to the data.

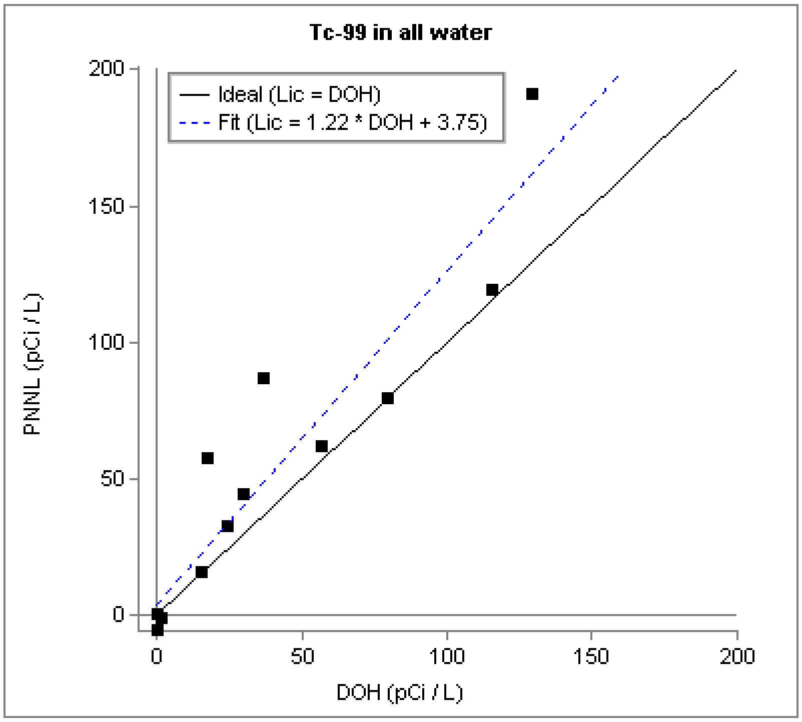

Figure 3.2.4 DOH vs. PNNL Split Tc-99 Water Results
The solid black line represents the ideal hypothetical case where DOH and PNNL results are identical. The blue dashed line is the best straight line fit to the data.

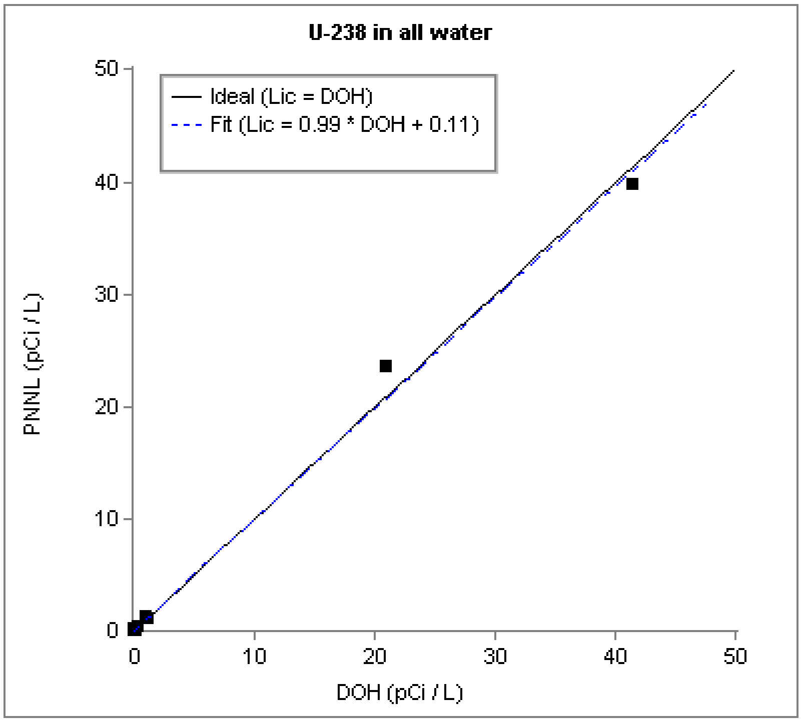

Figure 3.2.5 DOH vs. PNNL Split U-238 Water Results
The solid black line represents the ideal hypothetical case where DOH and PNNL results are identical. The blue dashed line is the best straight line fit to the data.

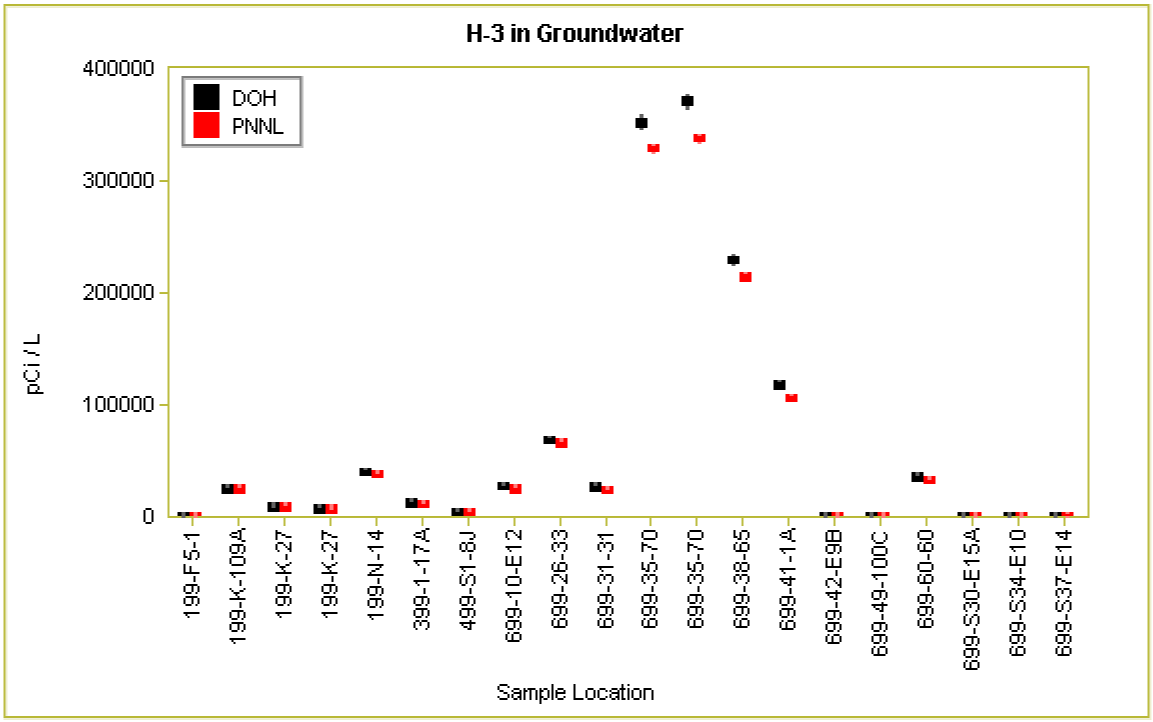

Figure 3.2.6 Tritium in Groundwater

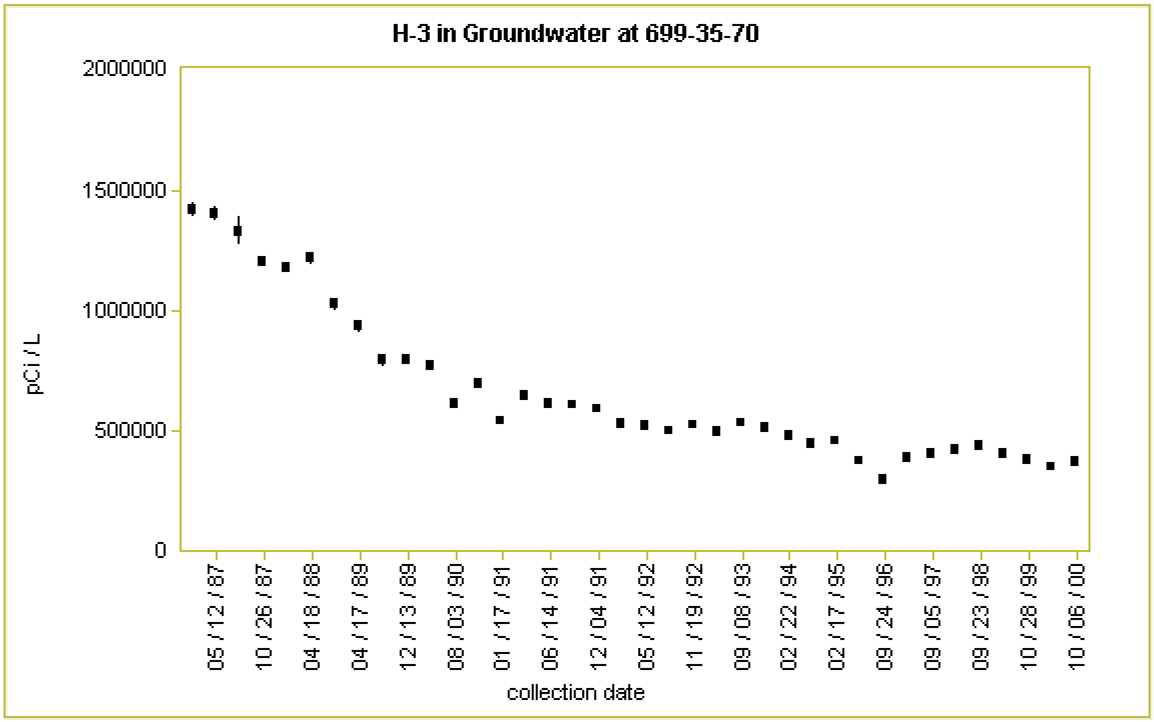

Figure 3.2.7 Tritium in Well 699-35-70

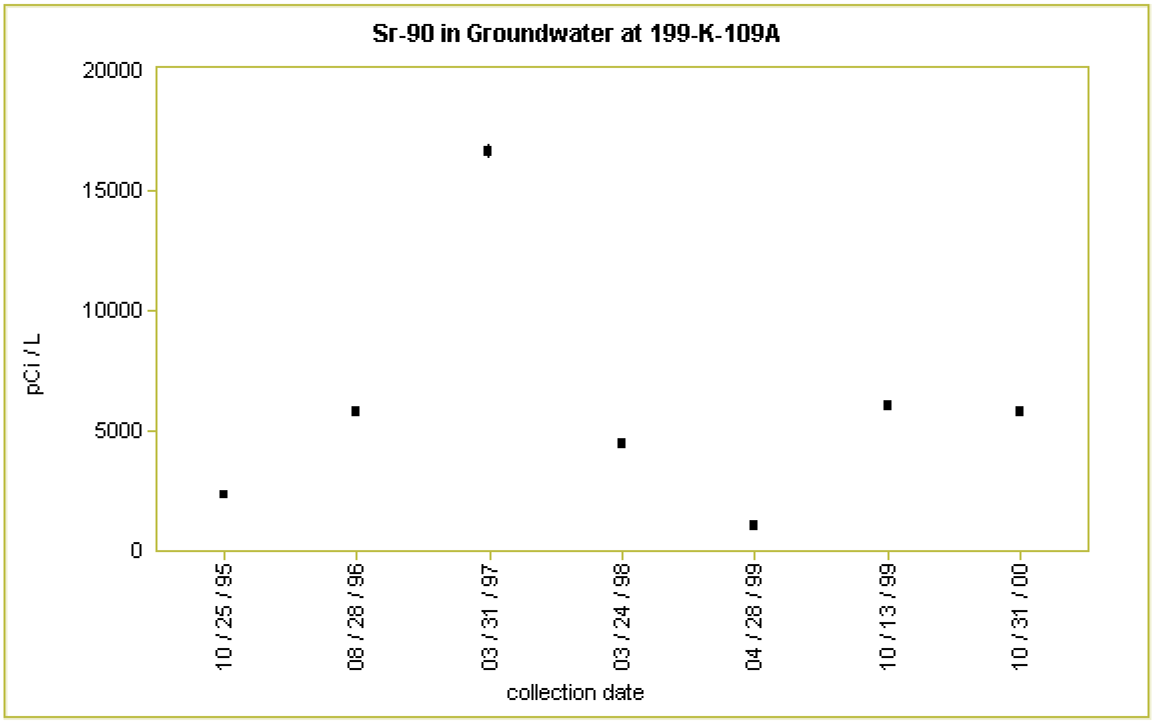

Figure 3.2.8 Sr-90 in Groundwater at 199-K-109A

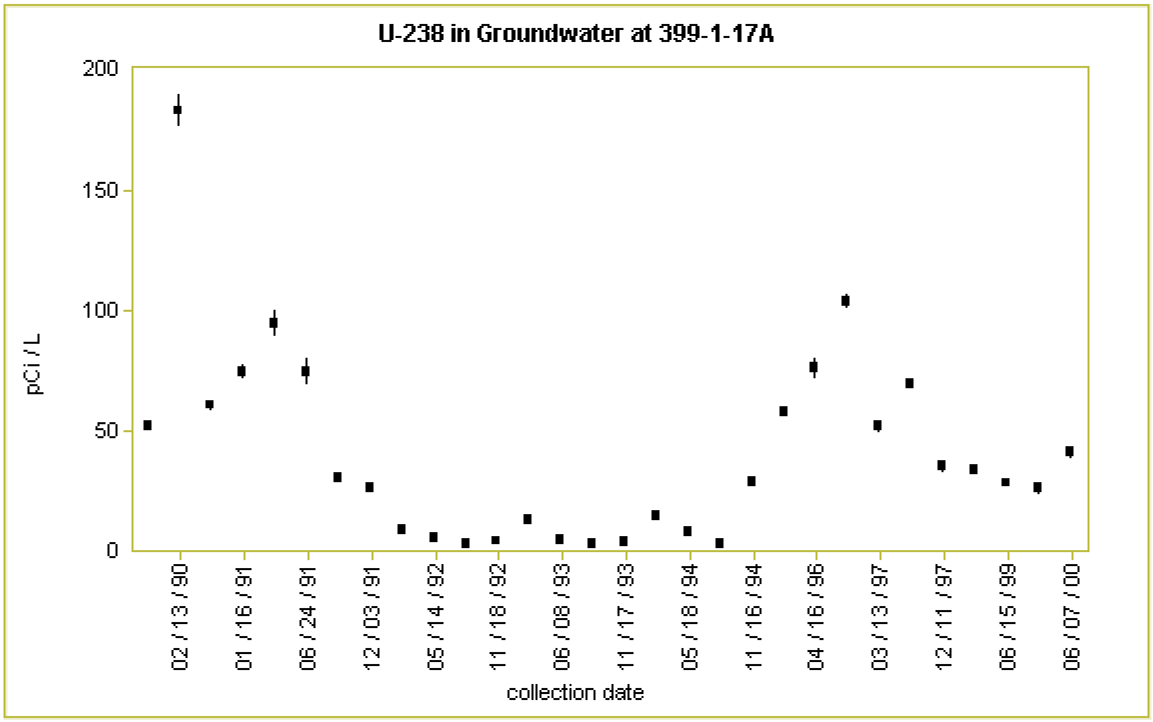

Figure 3.2.9 Uranium 238 in Groundwater at 399-1-17A

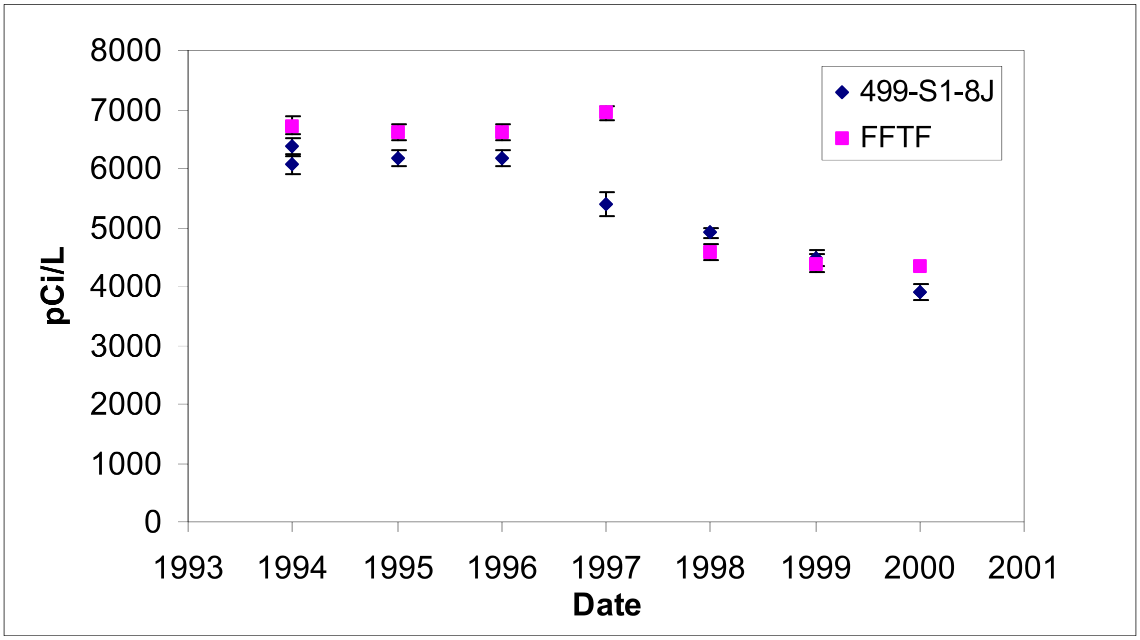

Figure 3.2.10 Tritium in 400 Area Drinking and Ground Water

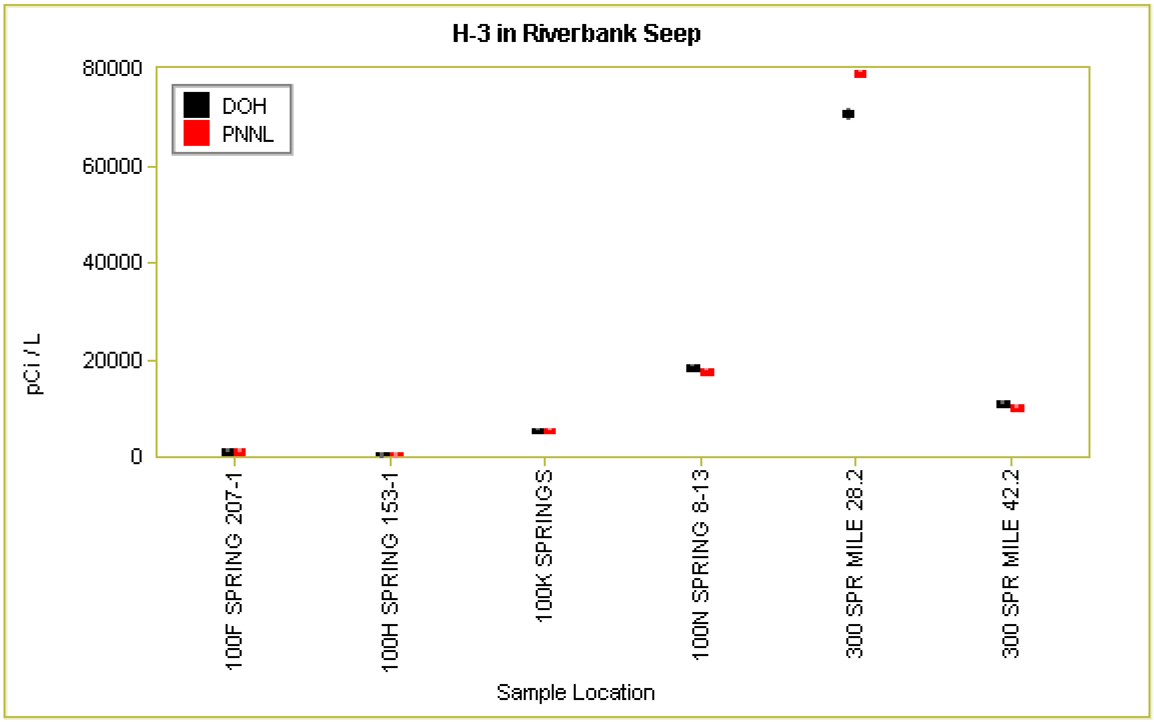

Figure 3.2.11 Tritium in Riverbank Seeps

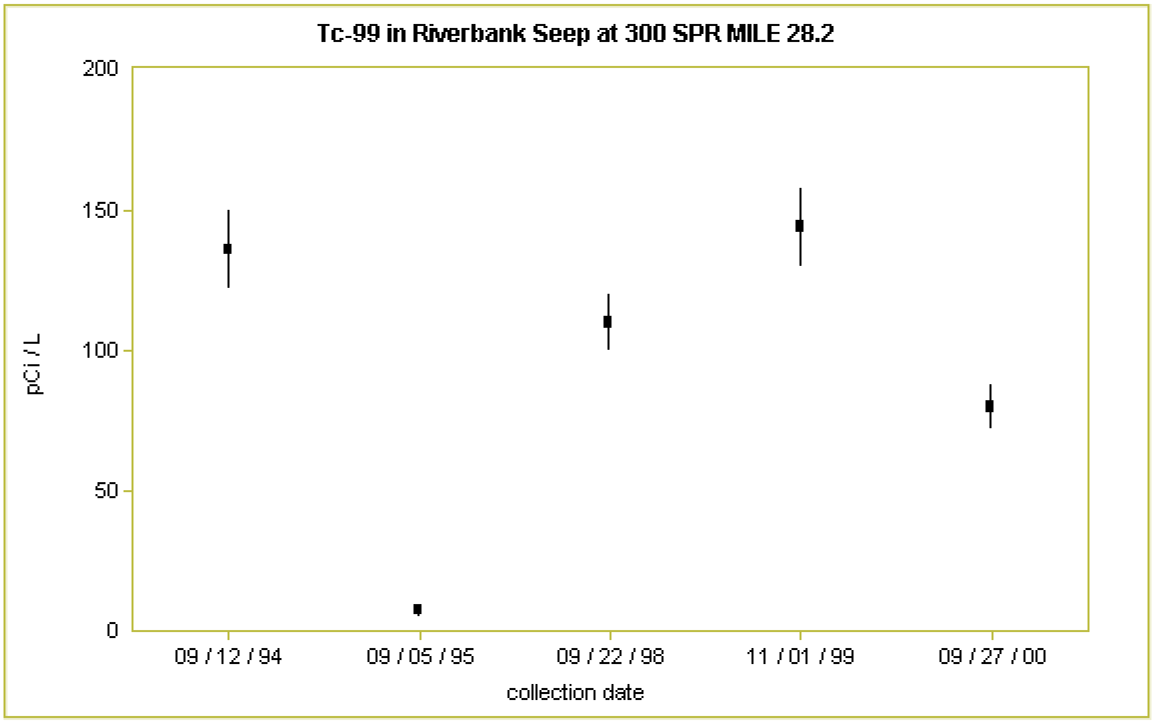

Figure 3.2.12 Tc-99 in Riverbank Seep at 300 SPR Mile 28.2

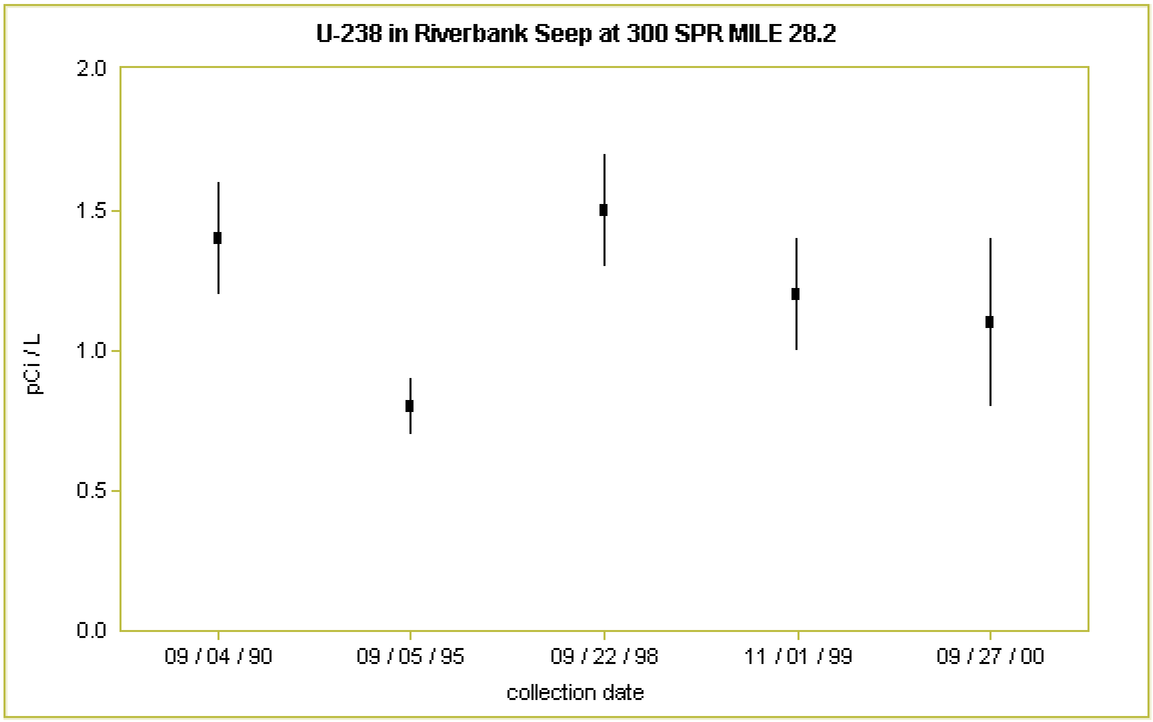

Figure 3.2.13 U-238 in Riverbank Seep at SPR Mile 42.2

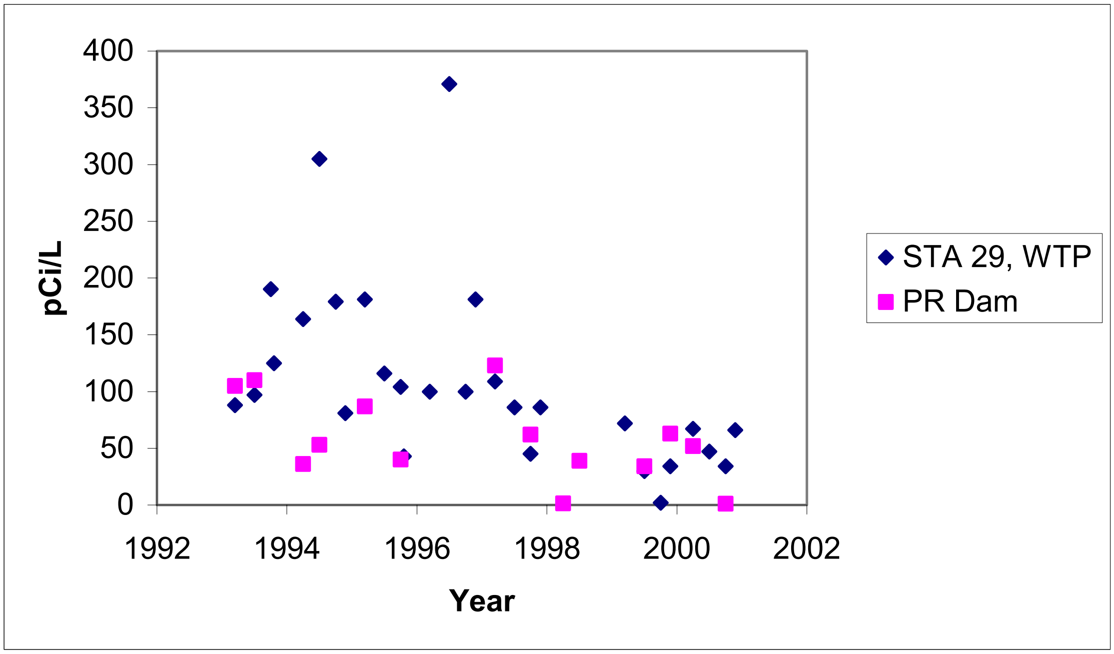

Figure 3.2.14 Tritium in Columbia River Water upstream of Hanford at the Priest Rapids Dam and downstream at the Richland Water Treatment Plant

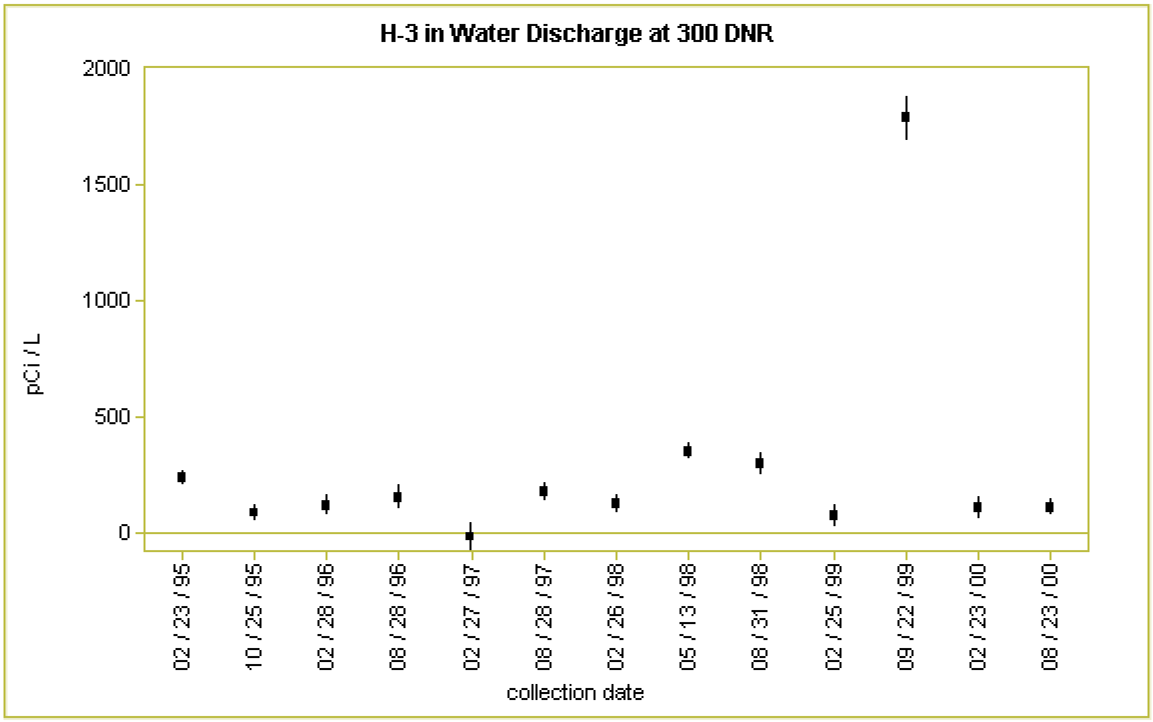

Figure 3.2.15 Tritium in Discharge Water at the 310 Treated Effluent Disposal Facility

3.3 External Gamma Radiation Monitoring

Major Findings:

- The DOH and DOE contractor results are in excellent agreement.
- Most radiation levels are consistent with background radiation levels.
- One site near known surface contamination in the 100 N Area has radiation exposure rates twice that of natural background, but below regulatory limits.

3.3.1 Purpose and General Discussion

The Department of Health and DOE contractors monitor external gamma radiation levels with Thermoluminescent Dosimeters (TLDs). TLDs measure the time-integrated exposure to gamma radiation at their location. Sources of background gamma radiation include natural cosmic and terrestrial radiation as well as fallout from atmospheric testing of nuclear weapons. Contamination from the Hanford Site contributes to man-made sources of gamma radiation. The primary purpose of the DOH TLD program is to provide oversight of the DOE monitoring program. In addition, DOH compares it's onsite and offsite TLD results to determine if Hanford is impacting workers or the public.

3.3.2 Monitoring Locations

In 2000, DOH operated 20 ambient gamma radiation monitoring sites under the Hanford Environmental Oversight Program, 6 of which are co-located with Duratek, and 14 of which are co-located with PNNL. The site locations are shown in Figure 3.3.1. All sites are located near Hanford operational or contaminated facilities, except for Yakima Barricade which is an unimpacted location at the Hanford Site perimeter; and Othello, Toppenish, and Yakima Airport which are distant from the Hanford Site. Many of the TLD sites are co-located with air monitoring sites.

3.3.3 Monitoring Procedures

TLDs are deployed on a quarterly basis. The TLDs are retrieved at the end of each calendar quarter and sent to the State Public Health Laboratory where the time-integrated gamma radiation exposure is determined for the three month period. The results are then converted to an average daily radiation exposure rate and reported in units of milli-Roentgen per day (mR/day). At the same time the TLDs are retrieved, a new TLD is placed at each site.

3.3.4 Comparison of DOH and Contractor Data

The DOH and Duratek TLD results for the 6 co-located sites are shown in Figure 3.3.2, and the DOH and PNNL TLD results for the 14 co-located sites are shown in Figure 3.3.3. Each of these figures show the four quarterly results for each site. As can be seen, there is excellent agreement between the two programs.

DOH vs. Duratek TLD scatterplot results for the combined co-located sites are shown in Figure 3.3.4. The x-coordinate of each point represents the DOH result, while the y-coordinate represents the contractor result. Ideally, if the DOH and contractor results were identical, all the points would fall on the straight line with slope equal to unity and y-intercept equal to zero (shown as the solid black line in the figure). Regression analysis was used to fit a straight line to the data (blue dashed line), and the resulting slope (0.96) and y-intercept (0.01) indicate excellent agreement between DOH and Duratek results.

DOH vs. PNNL TLD scatterplot results for the combined co-located sites are shown in Figure 3.3.5. The correlation coefficient for this data set is weak because the range of results is small. Therefore, it is not meaningful to carry out regression analysis. However, a qualitative comparison indicates reasonably consistent results.

3.3.5 Discussion of Results

All of the onsite results, except for 100N-1 (Figure 3.3.6), are consistent with the average offsite perimeter (considered background) radiation exposure rate of 0.23 ± 0.03 mR/day. Most of the offsite perimeter results come from sampling sites operated by Energy Northwest and are not the subject of this report. However, Energy Northwest has a TLD site at Wye Barricade co-located with DOH and PNNL. Because their offsite perimeter results were used to determine background exposure rates for this report, their data at Wye Barricade are shown in Figure 3.3.7. As can be seen, the Energy Northwest results are in excellent agreement with those of DOH and PNNL, resulting in confident use of their results to determine offsite background.

The results at 100N-1, which average 0.42 mR/day, are approximately twice background, resulting in an annual exposure rate of 70 mR/yr above background. An exposure rate of 70 mR/year is well below radiation exposure limits for workers, and is also below the DOE limit of 100 mrem/yr to the public from DOE operations (assuming 1 mrem is approximately equal to 1 mR). There is no public access to this region of the Hanford Site.

Yakima Barricade is a Hanford Site perimeter location, while Othello, Toppenish, and Yakima Airport are distant offsite locations. The exposure rates at the distant locations (average of 0.20 ± 0.02 mrem/day) are slightly lower than the perimeter locations, most likely due to different concentrations of naturally occurring radioactivity at the distant locations.

3.3.6 Data Trends

Historical DOH TLD data were examined for all of the TLD sites to determine if any new trends are present. All sites, except 100N-1, show consistent exposure rates over time. The historical data for site 100N-1 is shown in Figure 3.3.6. Exposure rates at this site have decreased over time, in part due to the decay of Co-60 (half life = 5 years) surface contamination at 100 N Area.

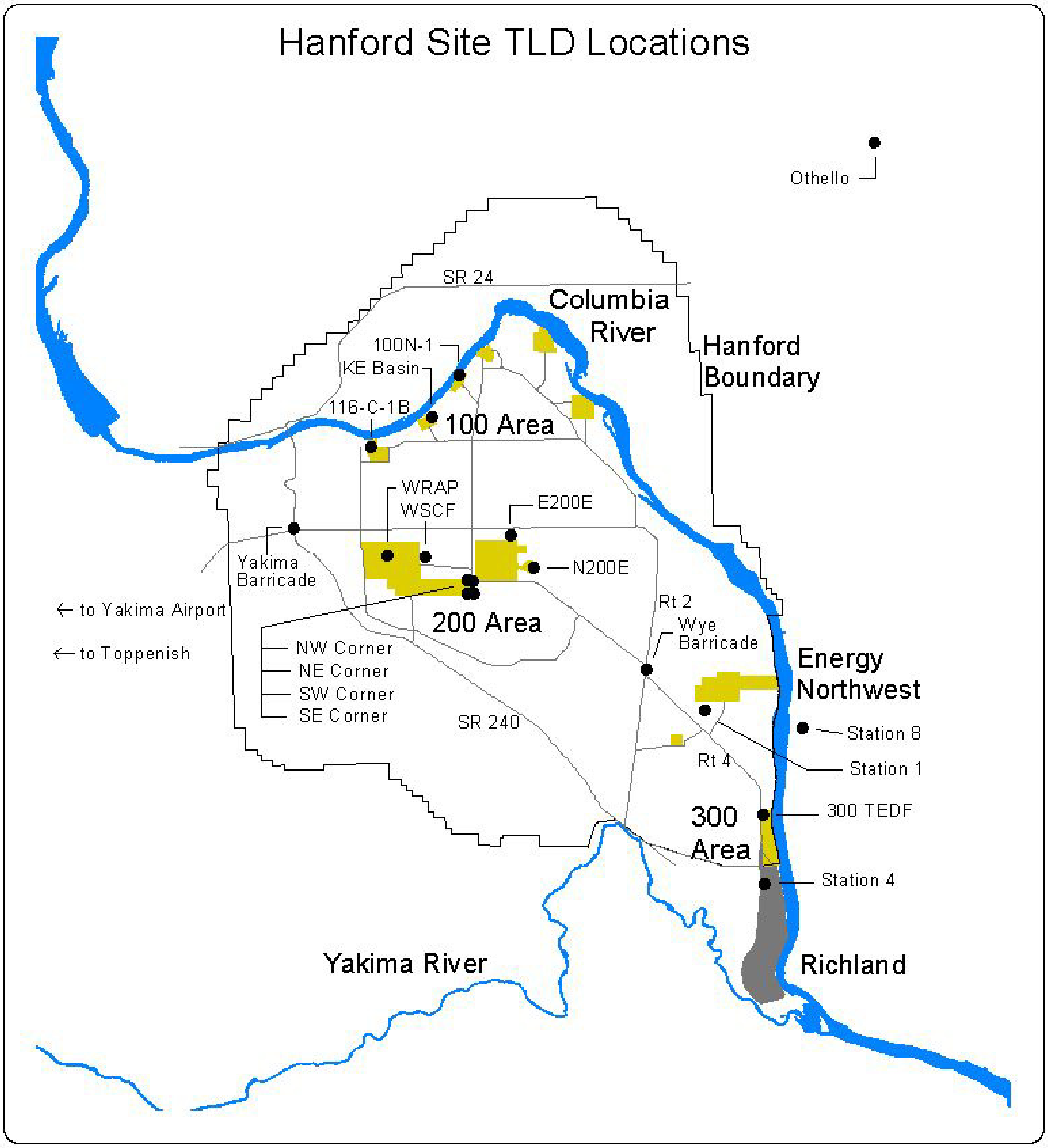

Figure 3.3.1 Hanford Oversight Program TLD Locations

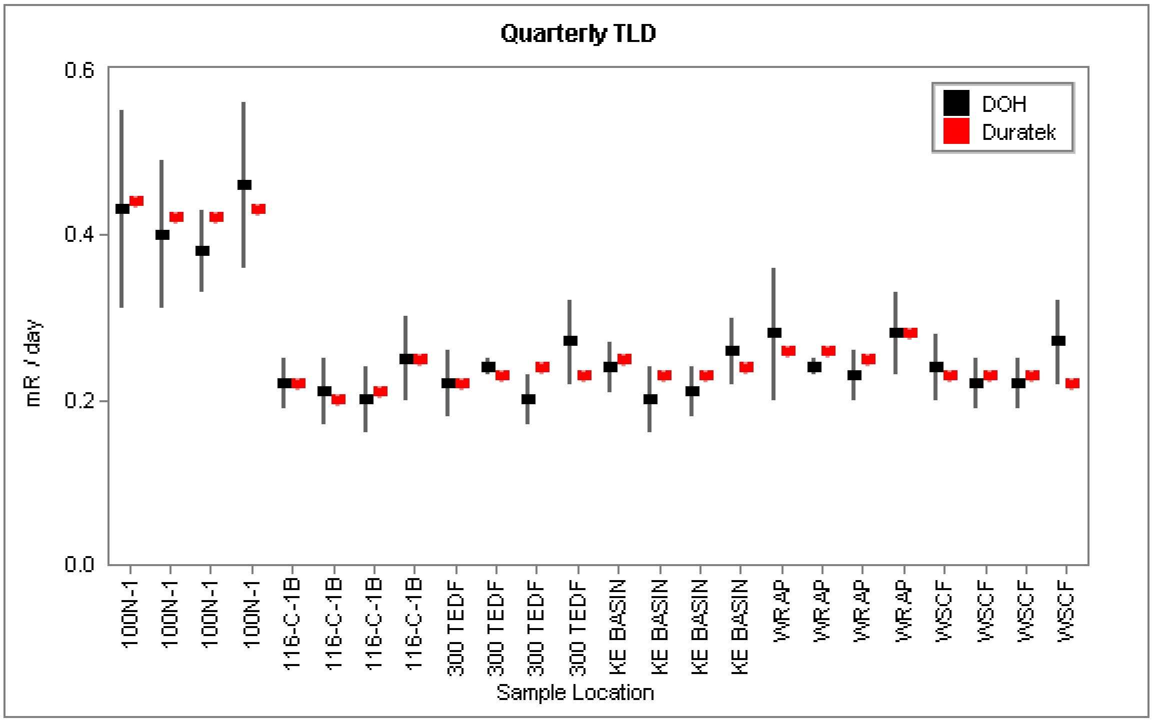

Figure 3.3.2 DOH and Duratek Quarterly TLD Results

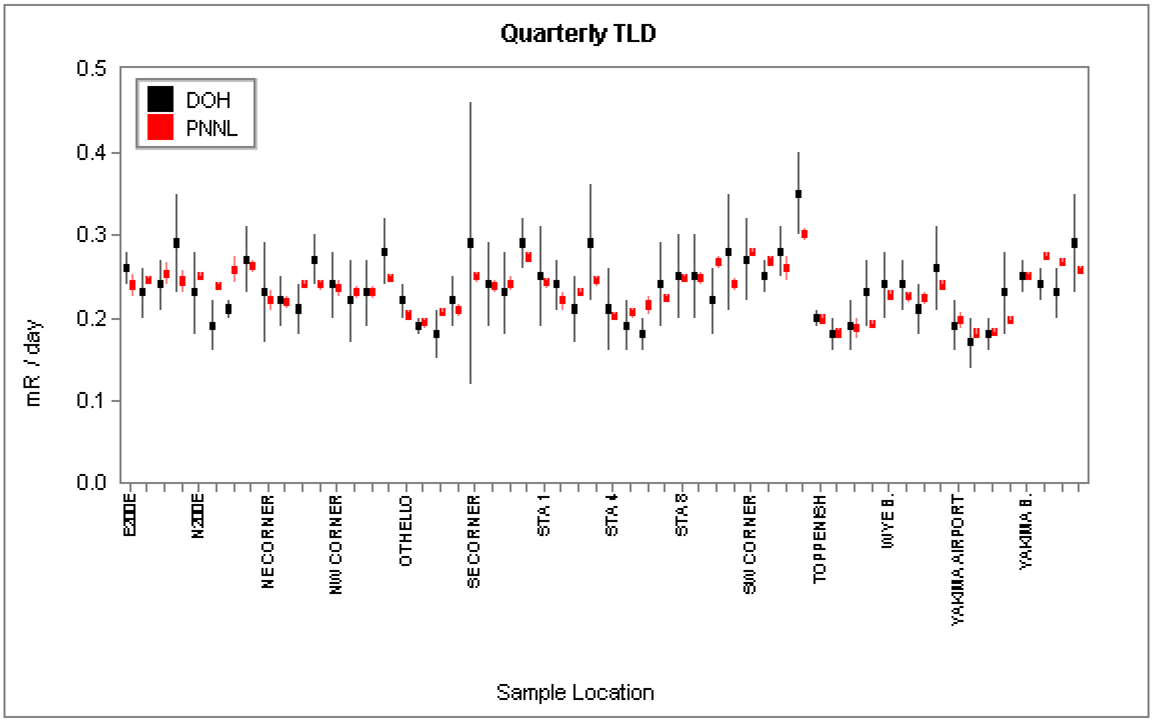

Figure 3.3.3 DOH and PNNL Quarterly TLD Results

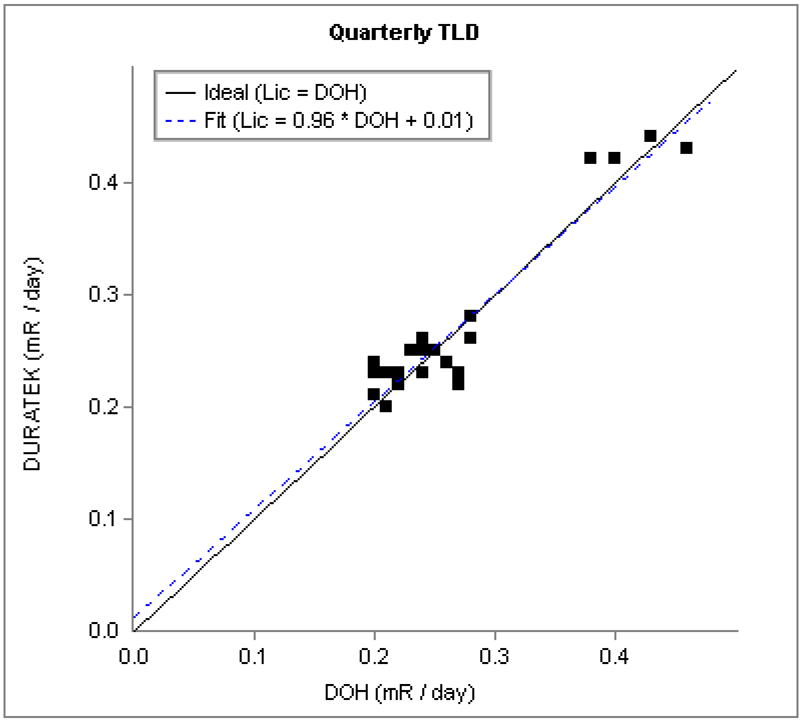

Figure 3.3.4 DOH vs. Duratek TLD Results
The solid black line represents the ideal hypothetical case where DOH and contractor results are identical. The blue dashed line is the best straight line fit to the data.

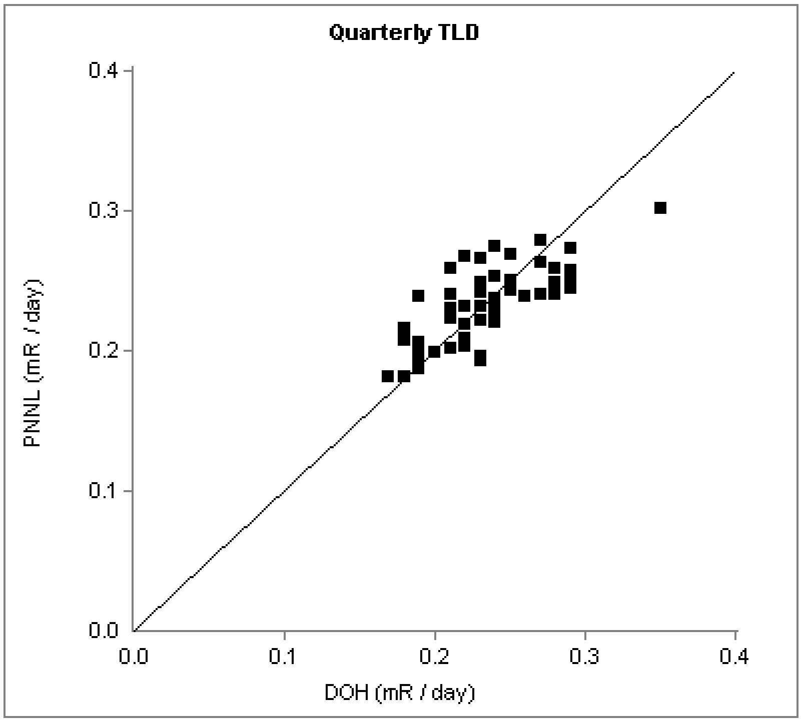

Figure 3.3.5 DOH vs. PNNL TLD Results
The solid black line represents the ideal hypothetical case where DOH and contractor results are identical.

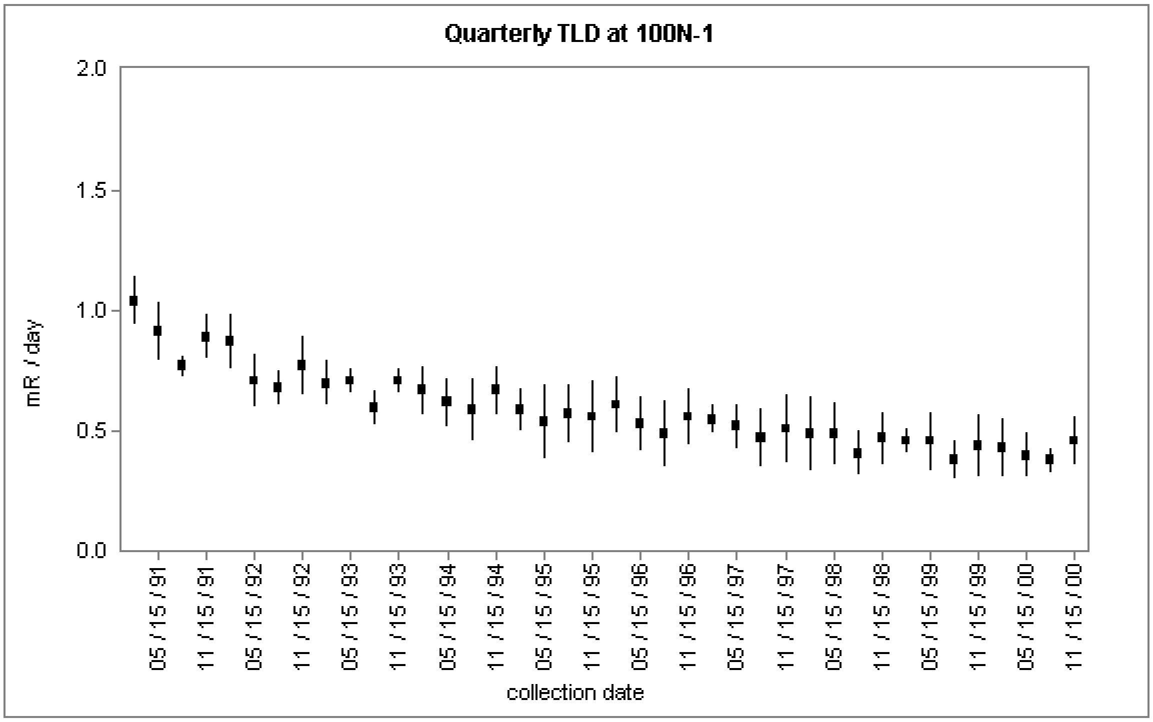

Figure 3.3.6 Historical DOH TLD Data at the 100 N Area

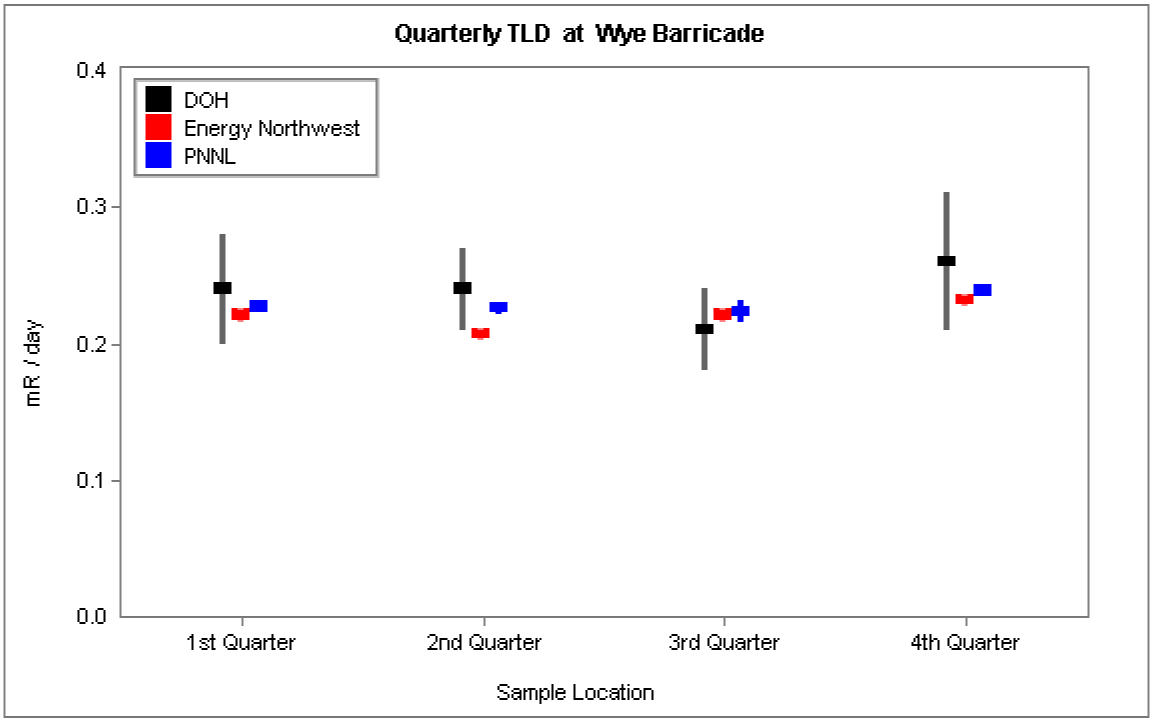

Figure 3.3.7 DOH, PNNL, and Energy Northwest Quarterly TLD Results at Wye Barricade

3.4 Soil and Sediment Monitoring

Major Findings:

- DOH and Duratek results in soil are in good agreement for Pu-239/240 in most of the samples; are in fair agreement, but consistently biased, for gamma emitting radionuclides; and are in poor agreement and consistently biased for Sr-90 and uranium isotopes.
- DOH and PNNL results in sediment are in good agreement for Pu-239/240, gamma emitting radionuclides, and Sr-90; and are in poor agreement and consistently biased for uranium isotopes.
- Concentrations of radionuclides detected in soil and sediment are either consistent with background or are in the range of activity that is typically observed at Hanford.

3.4.1 Purpose and General Discussion

Radionuclides in soils originate from many sources including natural terrestrial sources present since the earth's formation, atmospheric fallout from nuclear weapons tests, and from liquid and gaseous effluents. Radionuclides reach the sediments from erosion of contaminated soils, contaminated groundwater that flows into the river, atmospheric fallout, and natural sources.

Duratek, a DOE contractor, monitors surface soils throughout the Site to determine pre-operational baseline concentrations at new facilities and to verify that residual radioactivity at remediated sites meets clean-up criteria. PNNL monitors Columbia River sediments to evaluate Hanford's impact on the environment at the Site boundary. DOH splits soil and sediment samples with these contractors to provide oversight of the DOE monitoring programs.

Soil clean-up criteria are based on limiting radiation dose to people. Human exposure may result from direct contact with contaminated soil, ingestion of contaminated soil, inhalation of contaminants resuspended in air, or ingestion of food and farm products exposed to contaminated soil.

3.4.2 Monitoring Locations

Soil samples were collected from eight locations, all within the Hanford Site boundary. Six of the locations were near reactors along the Columbia River and two of the sites were in the central plateau near the 200 Area.

Sediment samples were collected from eight Columbia River locations: two from Priest Rapids Dam, four from shoreline locations along the Hanford Site, and two from McNary Dam. Priest Rapids Dam is upstream from the Hanford Site and samples from that area are considered unaffected by Hanford operations. This site serves as a background location for comparison to samples collected from Columbia River sediment along the Hanford Site boundary and downstream of the Hanford Site at McNary Dam. Because McNary Dam prevents sediment transport further downstream, this site is used to assess radionuclide accumulation. Sediment behind both Priest Rapids and McNary dams is collected annually. Sediment locations within the Hanford boundary change from year to year and are chosen to monitor areas where contaminants may be discharged into the river, areas where deposits could accumulate, or areas where the public may gain access to the shoreline. In 2000, shoreline sediments were collected from the 100F area, near the Old Hanford Townsite, and near the 300 Area.

3.4.3 Monitoring Procedures

Soil samples were collected within an estimated fifty-foot radius of the air sampling station that monitors a specific excavation operation. Four one-square foot areas were selected and excavated to a depth of one inch, composited, and split with Duratek. The samples were analyzed for radionuclides that are most likely present in the area sampled. This includes gamma-emitting radionuclides, Sr-90, isotopic uranium, and isotopic plutonium.

Sediment samples represent surface sediments and were collected with either a clam-shell style sediment dredge or in the case of shoreline sediments, a plastic spoon. All sediment samples were split with PNNL and dried prior to analysis. Samples were analyzed for gamma-emitting radionuclides, strontium 90, isotopic uranium, and isotopic plutonium

3.4.4 Comparison of DOH and Contractor Data

DOH and Duratek split soil results for isotopes of uranium and Sr-90 are in poor agreement, as they are systematically biased. Split soil results for Eu-152 and Cs-137 are in fair agreement, but systematically are slightly biased. A systematic bias indicates that results from one laboratory were consistently higher or lower than the other laboratory results for each of these radionuclides. Most of the Pu-239/240 results are in good agreement (Figure 3.4.4). Two of the eight Pu-239/240 results are in poor agreement. All DOH and Duratek Pu-238 results (not shown) were below detection limits.

DOH vs. Duratek scatter plots for Sr-90, U-238, and Cs-137 in soil are shown in Figures 3.4.1 through 3.4.3. The Eu-152 scatter plot (not shown) is similar to that of Cs-137. The x-coordinate of each point represents the DOH result, while the y-coordinate represents the contractor result. Ideally, if the DOH and contractor results were identical, all the points would fall on the black straight line with slope equal to unity and y-intercept equal to zero. These figures show the systematic bias between DOH and Duratek results.

The discrepancy in the uranium results is due to a difference in laboratory procedures wherein the DOH completely dissolves the soil prior to analyses and reports uranium present in the entire soil sample whereas the contractor laboratory reports only the uranium that can be leached from the surface of the soil granules. The discrepancies in the Cs-137, Eu-152, and Sr-90 results are not understood at this time. DOH is investigating these biases and will report on any findings in a future report.

DOH and PNNL split sediment results for Sr-90 are in good agreement, as shown in Figure 3.4.10. DOH and PNNL split sediment results for Cs-137 are in excellent agreement (Figure 3.4.9). A regression analysis on the Cs-137 data (not shown) also indicates excellent agreement between DOH and PNNL. The DOH and PNNL split sediment results for uranium are in poor agreement. A bias in these DOH/PNNL uranium results similar to that seen in the DOH/Duratek soil results was observed (Figure 3.4.11). The Pu-239/240 results (Figure 3.4.12) are in good agreement. All of the Pu-238 results in sediment (not shown) are below the detection limit.

3.4.5 Discussion of Results

Primary contaminants identified in soil were Cs-137 (Figure 3.4.5), Sr-90 (Figure 3.4.6), Pu-239/240 (Figure 3.4.4), and Eu-152 (Figure 3.4.7). In addition, all soil samples had detectable concentrations of uranium (U-238 shown in Figure 3.4.8). The concentrations of uranium isotopes found in soil samples are consistent with background concentrations. Cesium 137, Eu-152, Pu-239/240 and Sr-90 results were in the range of activity that is typically observed in Hanford soils from areas outside of operational areas.

The primary contaminants identified in sediments were Cs-137 (Figure 3.4.9), uranium isotopes (U-238 shown in Figure 3.4.11), Pu-239/240 (Figure 3.4.12), and Sr-90 (Figure 3.4.10). Cesium 137 and Pu-239/240 originate from worldwide fallout as well as from Hanford effluents. The levels observed in 2000 were consistent with levels historically observed by DOH. Uranium results at most sites are consistent with background. One sample at the 300 Area had isotopic uranium concentrations approximately twice background. Figure 3.4.13 shows historical U-238 results from sediment collected on the Washington shoreline behind McNary dam. These results are also consistent with background.

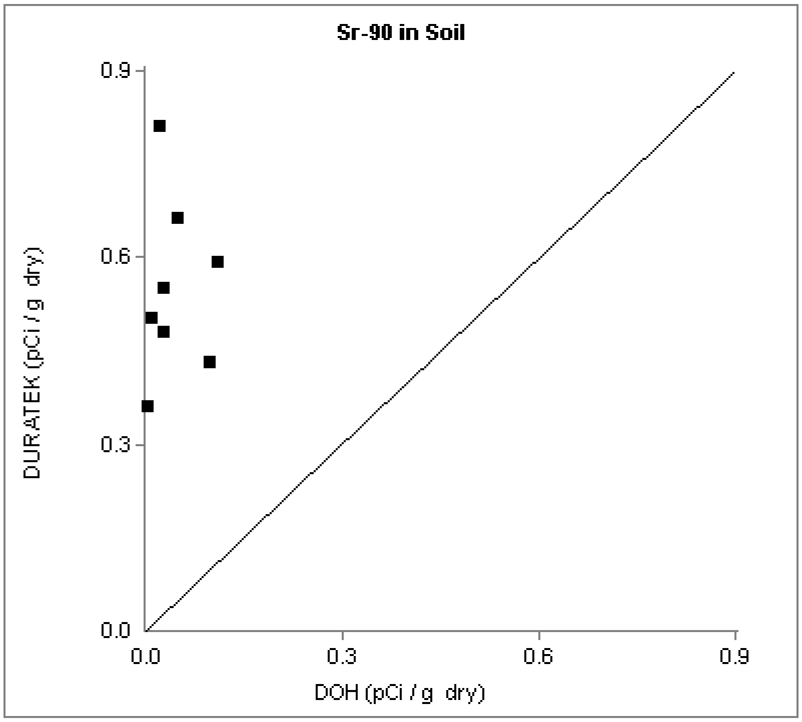

Figure 3.4.1 DOH vs Duratek Results for Sr-90 in Soil

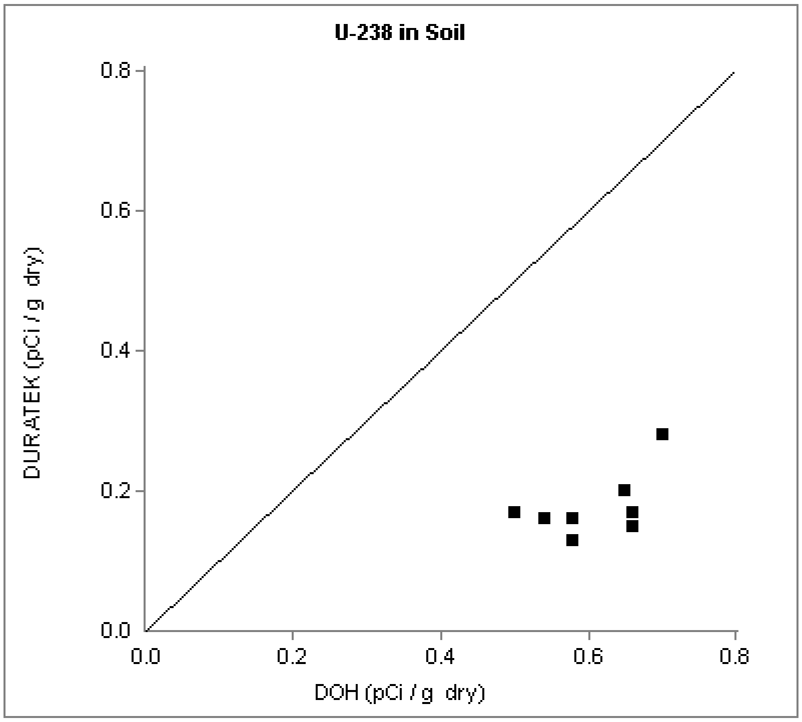

Figure 3.4.2 DOH vs Duratek Results for U-238 in Soil and Sediment

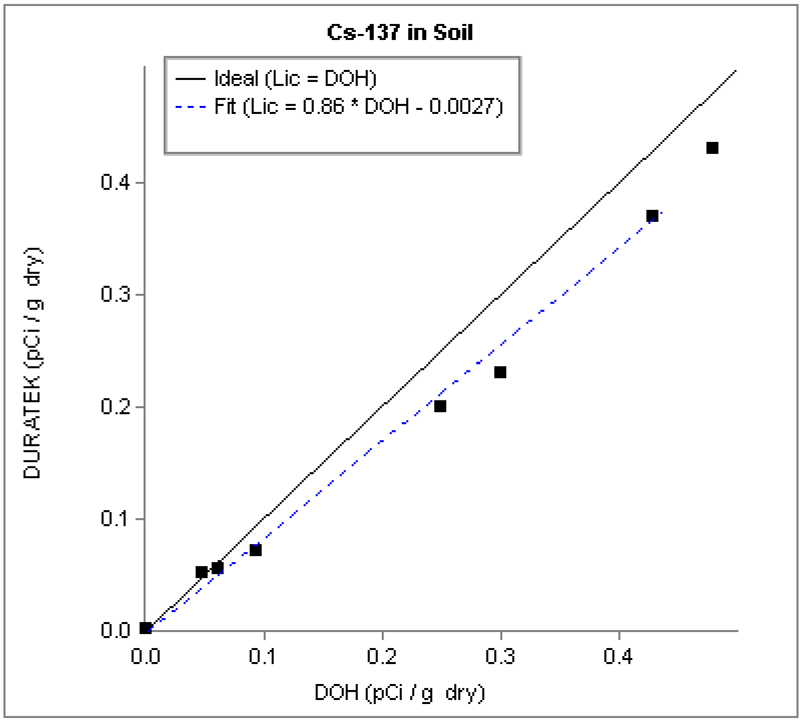

Figure 3.4.3 DOH vs Duratek Results for Cs-137 in Soil

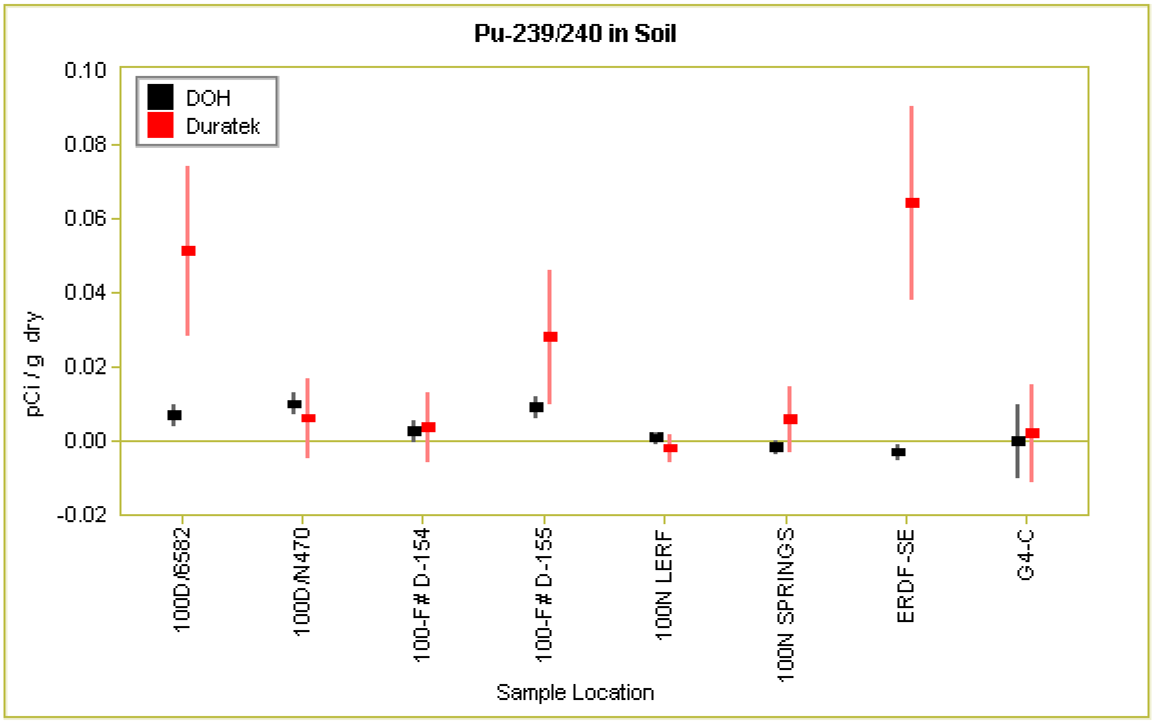

Figure 3.4.4 Pu-239/240 Results in Soil Samples Collected During CY 2000

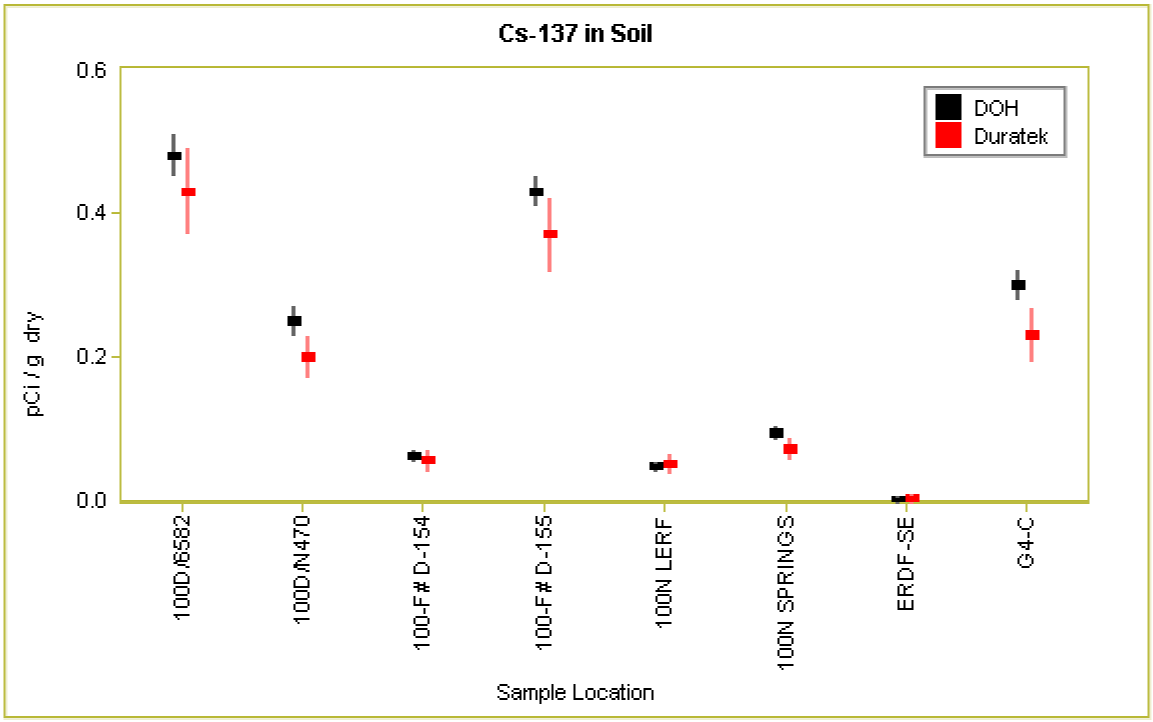

Figure 3.4.5 Cs-137 Results in Soil Samples Collected During CY 2000

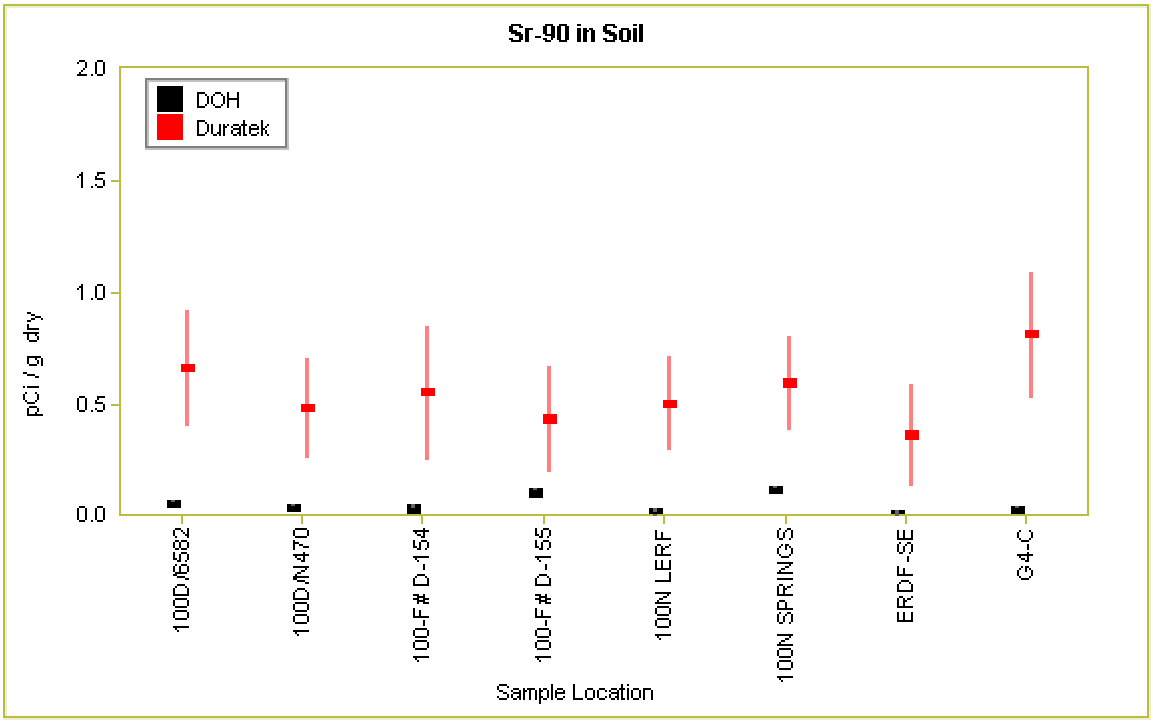

Figure 3.4.6 Sr-90 Results in Soil Samples Collected During CY 2000

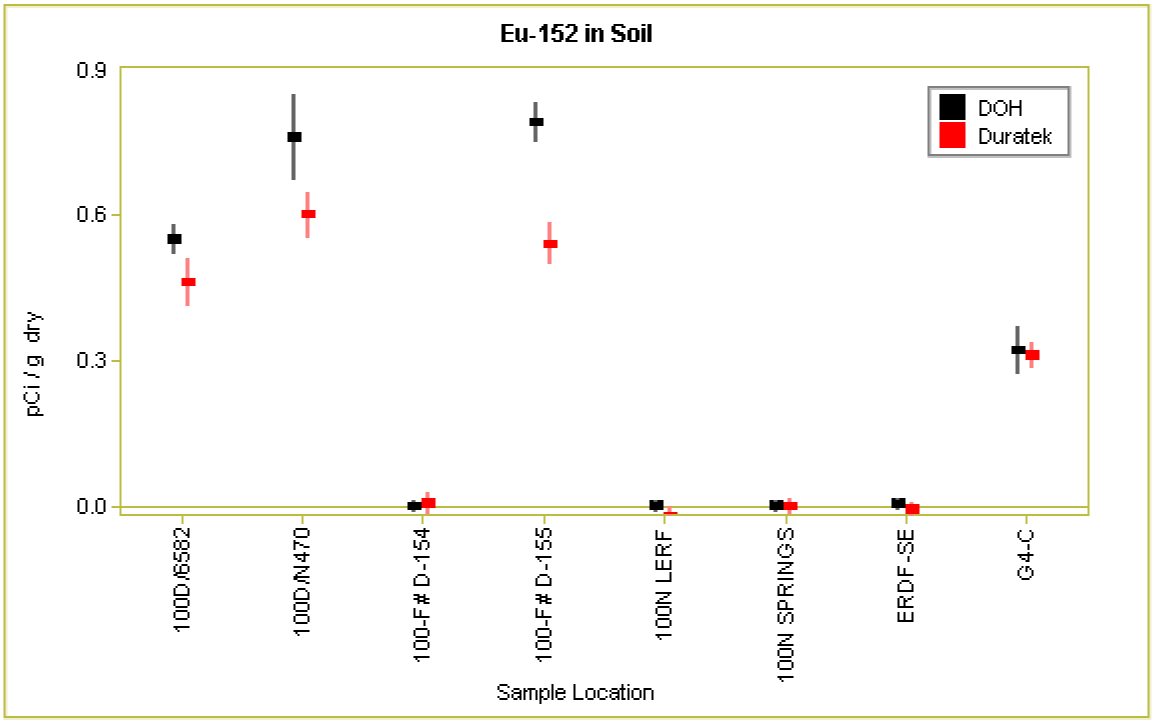

Figure 3.4.7 Eu-152 Results in Soil Samples Collected During CY 2000

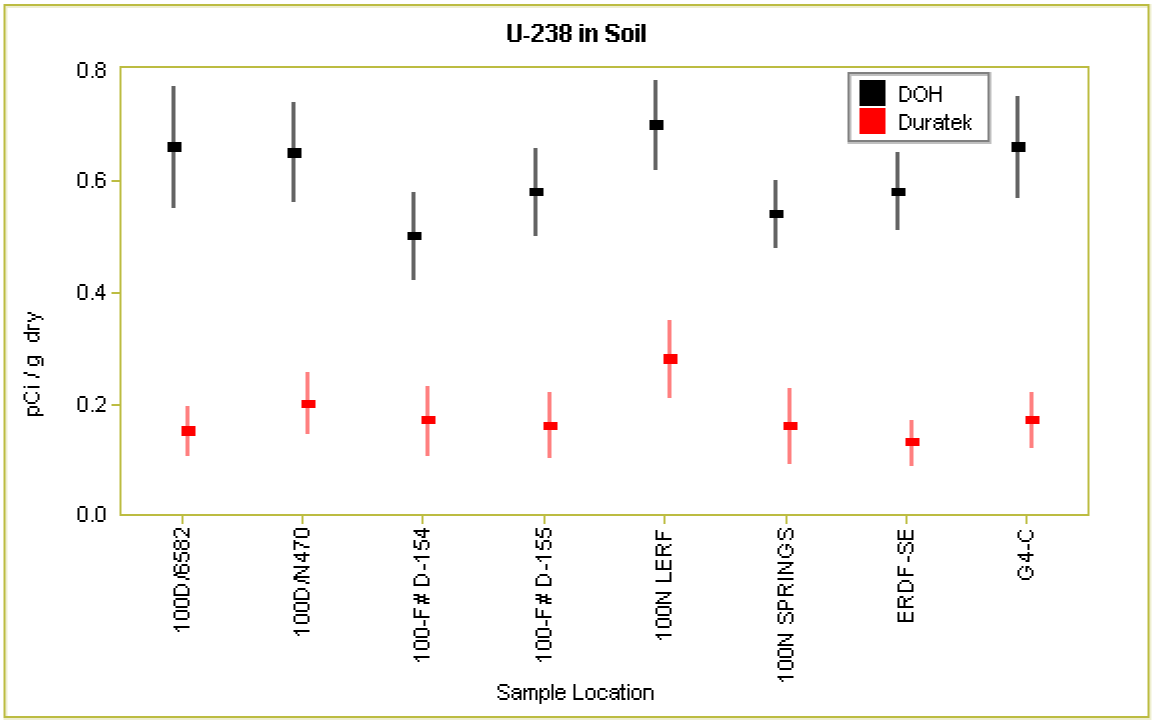

Figure 3.4.8 U-238 Results in Soil Samples Collected During CY 2000

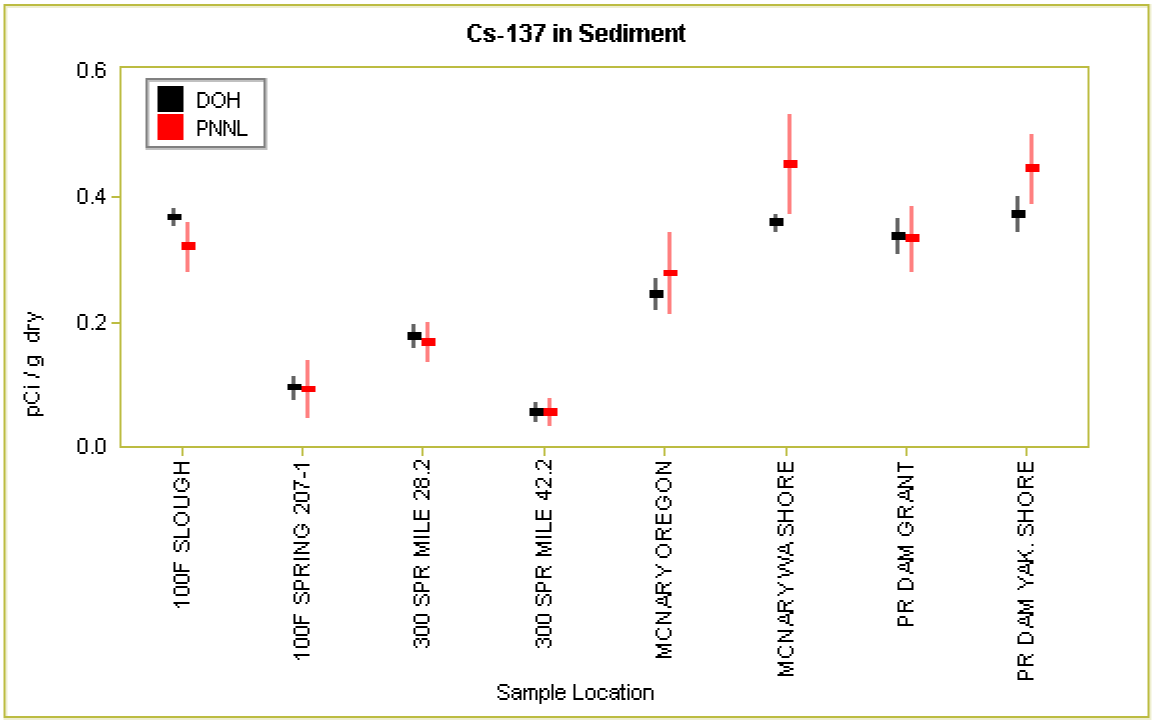

Figure 3.4.9 Cs-137 Results in Sediment Samples Collected During CY 2000

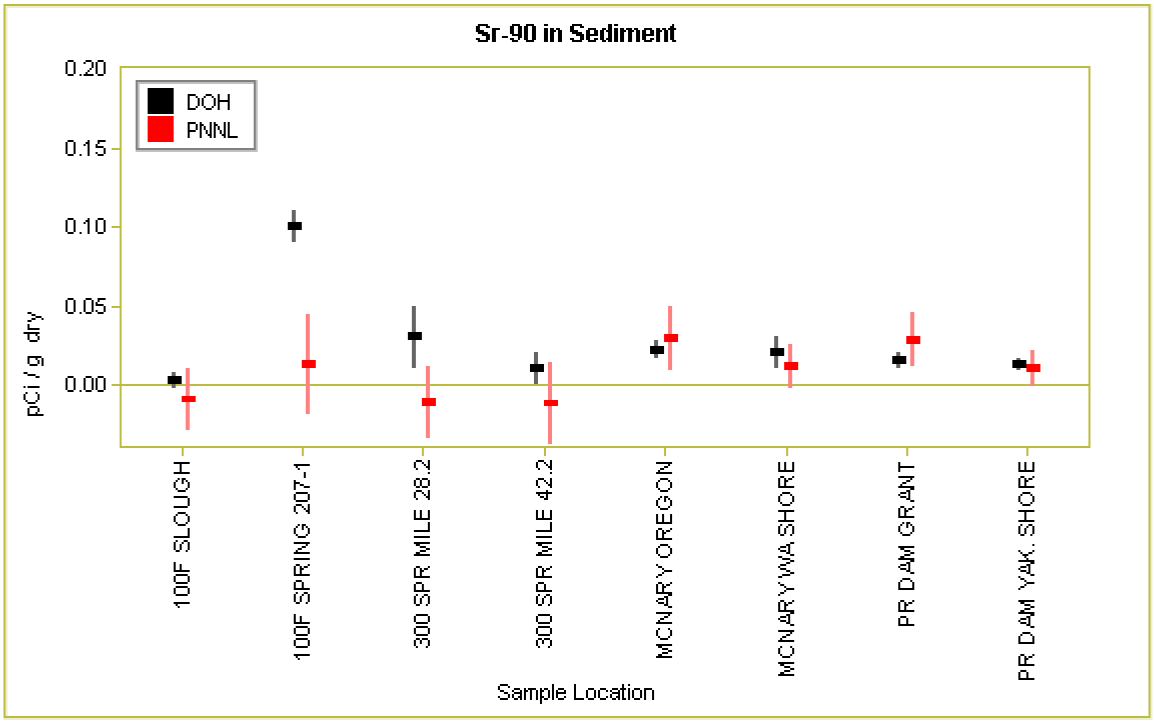

Figure 3.4.10 Sr-90 Results in Sediment Collected During CY 2000

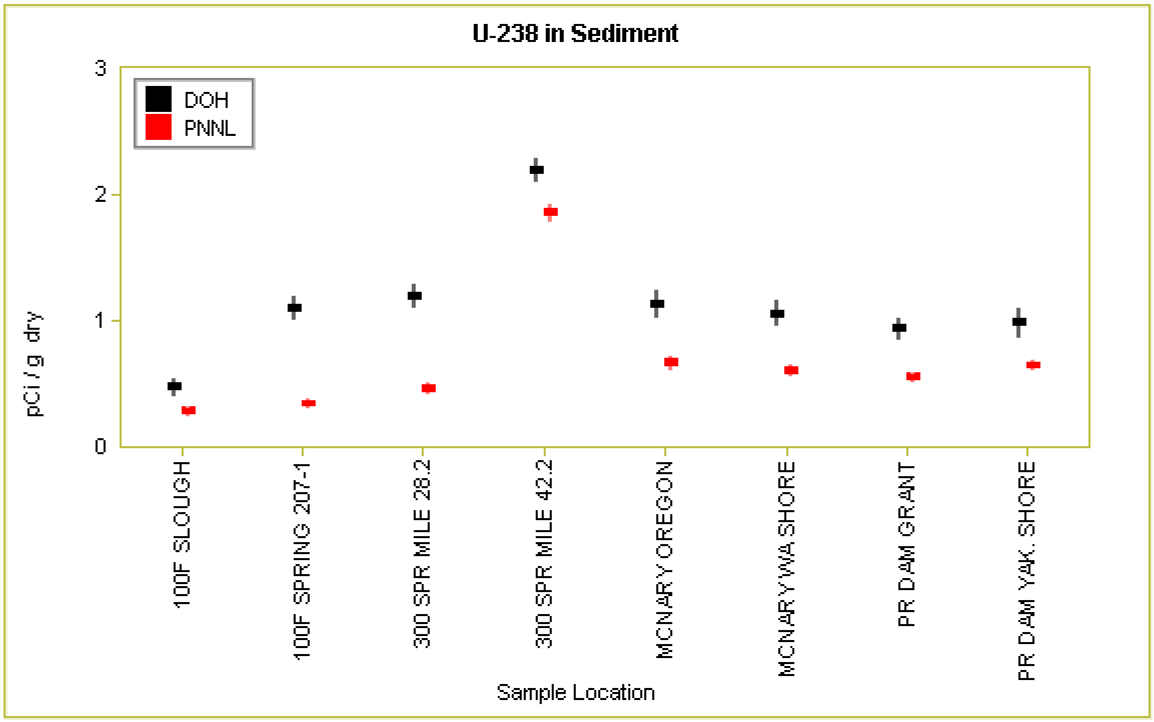

Figure 3.4.11 U-238 Results in Sediment Collected During CY 2000

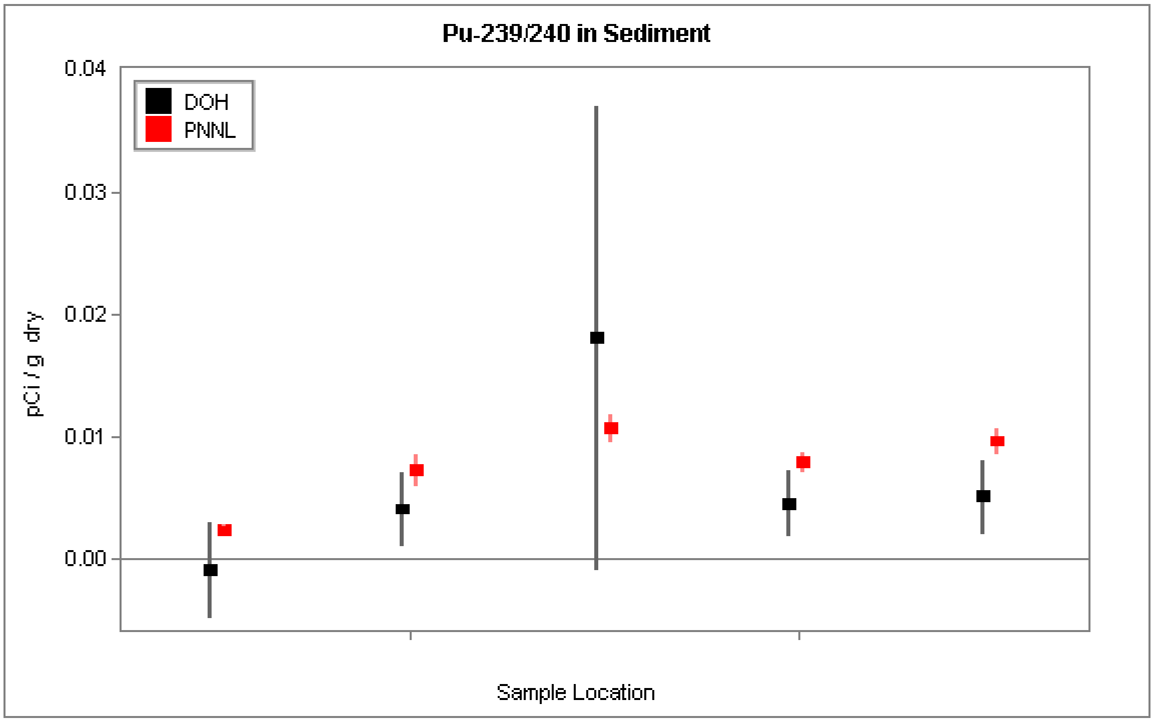

Figure 3.4.12 Pu-239/240 Results in Sediment Collected During CY 2000

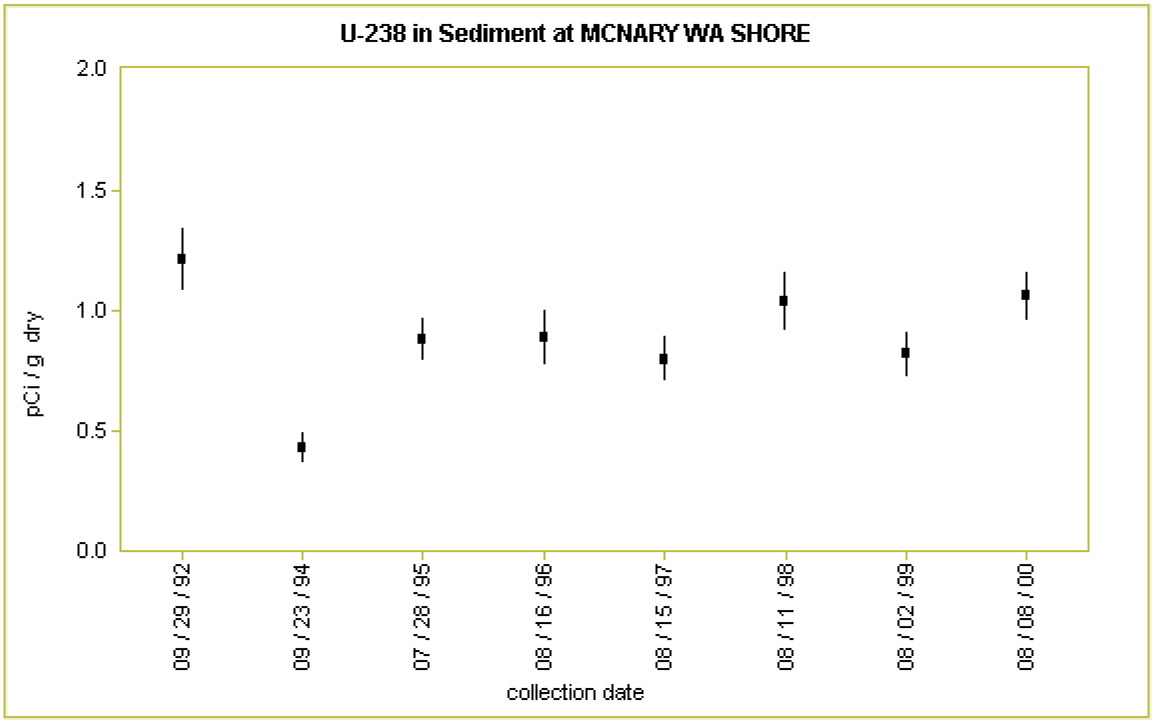

Figure 3.4.13 U-238 Concentration in Sediments Collected at the Washington Shoreline Behind McNary Dam

3.5 Food and Farm Products Monitoring

Major Findings:

- The DOH and DOE contractor results are in excellent agreement. Only 2 out of 28 results did not agree.
- Most radioactivity concentrations are below detection limits.
- Tritium, at 250 pCi/L, was found in a white wine sample. Although above the detection limit, this concentration is very small. Tritium concentrations above detection limits have previously been found in wine.

3.5.1 Purpose and General Discussion

The Department of Health and DOE contractors monitor food and farm products to determine if airborne contamination has deposited on plants that may be consumed by people. The primary purpose of the DOH program is to provide oversight of the PNNL monitoring program. In addition, Hanford impacts are evaluated by comparing radioactivity in food products collected upwind and downwind of the Hanford Site. The food products, monitored analytes, and number of samples are listed in Table 3.5.1.

Food Product	Analyte	Number of Samples
Apples	Cs-137, Sr-90	2
Beet Tops	Cs-137, Sr-90	1
Lettuce	Cs-137, Sr-90	1
Potato	Cs-137, Sr-90	3
Tomato	Co-60, Cs-137, Sr-90	1
Red Wine	Cs-137, H-3	2
White Wine	Cs-137, H-3	2
Hop Residue	Co-60, Cs-137, Sr-90	1

Table 3.5.1 Analytes Monitored in Food and Farm Products

3.5.2 Monitoring Locations

All of the food product sampling locations are offsite of the Hanford Site, with locations both upwind and downwind of the Site. Control locations are those upwind of the Site, while the locations most likely to be impacted from Hanford are those downwind of the Site.

3.5.3 Monitoring Procedures

Food product samples are collected and split with the DOE contractor, which in this case is PNNL. Samples are generally collected once a year in the fall when the products are being harvested. DOH and PNNL independently analyze the samples and then compare results. Results for wine are reported in pCi/L, while all other results, except for tritium (H-3), are reported in pCi/g. Water extracted from the plants is analyzed for tritium, and the results are reported in pCi/L.

3.5.4 Comparison of DOH and Contractor Data

The majority of DOH and PNNL results are in excellent agreement. As an example, Cs-137 results in potato samples are shown in Figure 3.5.1. Of all the food product results, only two results did not agree. DOH and PNNL results differed by a factor of 2 for a Sr-90 result in lettuce, and by a factor of 5 for a tritium result in white wine (see Figure 3.5.2). Since most of the results are below detection limits, a regression analysis is not meaningful, and therefore is not carried out for food product data.

3.5.5 Discussion of Results and Trends

Most of the radioactivity concentrations, both upwind and downwind of the Hanford Site, are below detection limits, and any results above detection limits are very small. The results for year 2000 are consistent with historical DOH results. Tritium was found in one white wine sample at 250 pCi/L. Consumption of a 750 ml bottle of this wine would result in a radiation dose of 0.00001 mrem, which is an extremely small dose. Tritium results above the detection limit (approximately 50 pCi/L) have been found in the past, as can be seen in Figure 3.5.3.

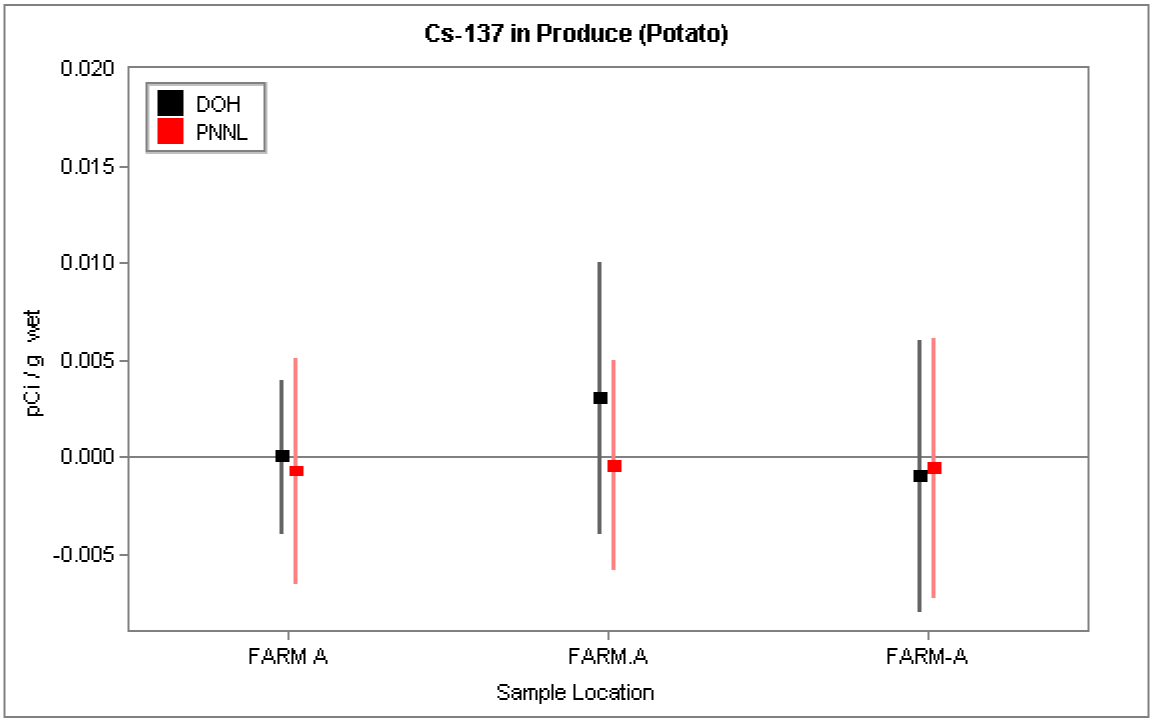

Figure 3.5.1 DOH and PNNL Cs-137 Results in Potatoes

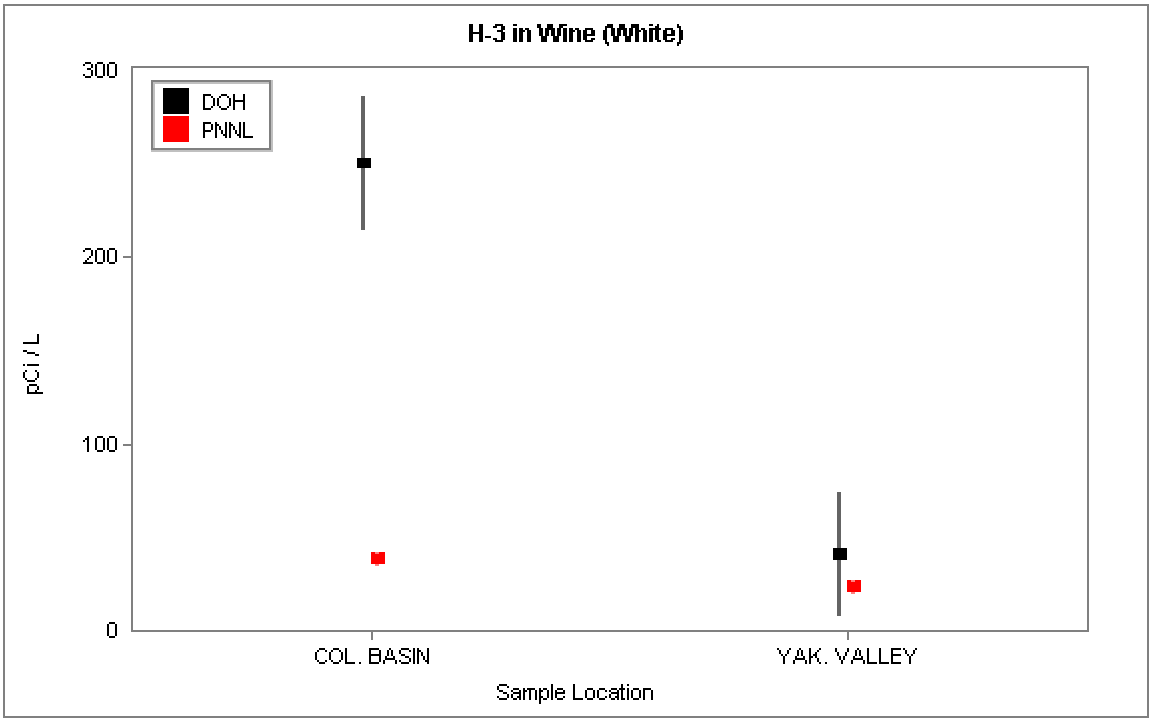

Figure 3.5.2 DOH and PNNL Tritium Results in White Wine

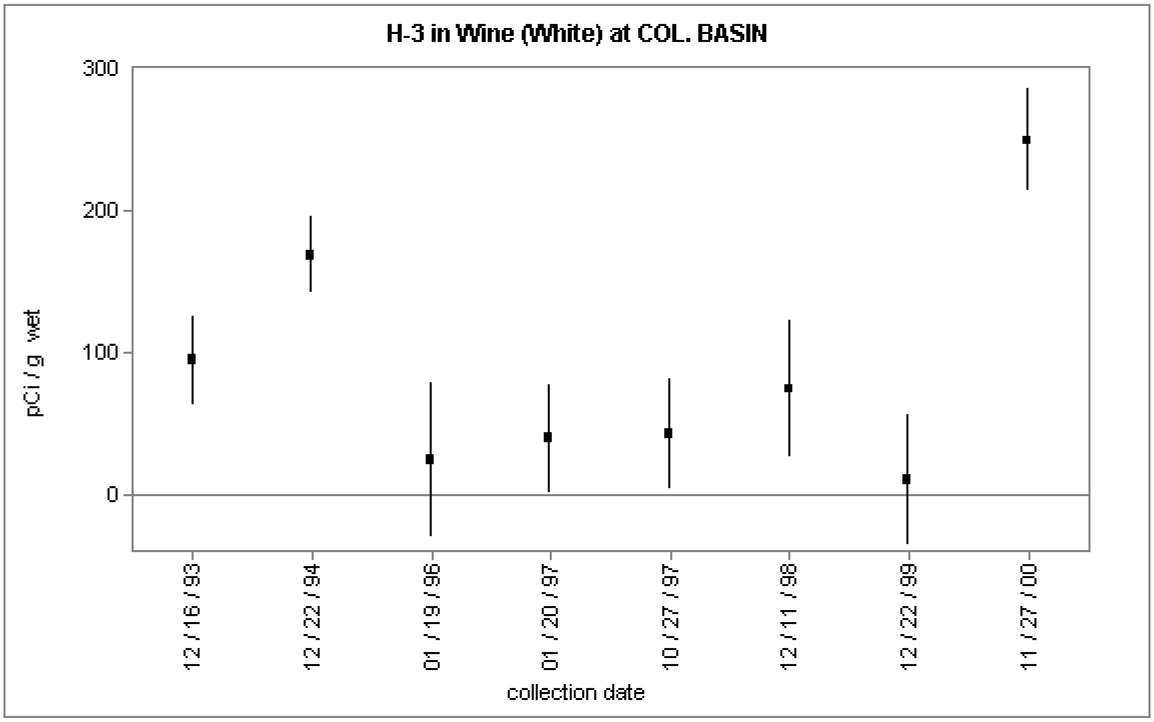

Figure 3.5.3 Tritium Concentrations in Wine from 1993 to 2000

3.6 Fish and Wildlife Monitoring

Major Findings:

- The DOH and DOE contractor results are in excellent agreement for Co-60 and Cs-137. Two of the four Sr-90 results differ by a factor of approximately five.
- The Co-60 and Cs-137 results are below detection limits. Sr-90 was detected at low levels in all fish and deer samples, including the deer collected at the background location.

3.6.1 Purpose and General Discussion

The Department of Health and DOE contractors monitor fish and wildlife to determine if contaminants have migrated into the food chain. Contaminants in fish arise from fish swimming in contaminated water and ingesting contaminated sediments. Contaminants in wildlife arise from ingestion of contaminated soil and vegetation. The primary purpose of the DOH program is to provide oversight of the PNNL monitoring program.

3.6.2 Monitoring Locations

Fish were collected from the Columbia River at the100N Area, the 300 Area, and a background location at Vantage. The deer were collected from the 100N Area and the 200 Area. No deer were collected from a background location in 2000. Deer from distant locations, both from western Washington near Olympia and from the northeast corner of the state, were collected in the past and serve as a basis for comparison.

3.6.3 Monitoring Procedures

Fish and Wildlife samples were collected by PNNL and given to DOH for analyses. For the fish, the carcass was analyzed for Sr-90 while the meat was analyzed for gamma emitting radionuclides, primarily Co-60 and Cs-137. For the deer, the bone was analyzed for Sr-90 and the meat was analyzed for gamma emitting radionuclides.

3.6.4 Comparison of DOH and Contractor Data

The DOH and DOE contractor results are in excellent agreement for Co-60 and Cs-137. Two of the four Sr-90 results differ by a factor of approximately five. The Sr-90 results for fish are shown in Figure 3.6.1 and for deer in Figure 3.6.2. The discrepancy in the Sr-90 results is not understood at this time, and will be discussed in a future report.

3.6.5 Discussion of Results and Trends

The Co-60 and Cs-137 results are below detection limits. Strontium 90, which originates from worldwide fallout as well as Hanford operations, was detected at low levels in all fish and deer. Figure 3.6.3 shows the levels of Sr-90 in deer bone collected in 2000 as compared to samples collected previously onsite and at distant locations.

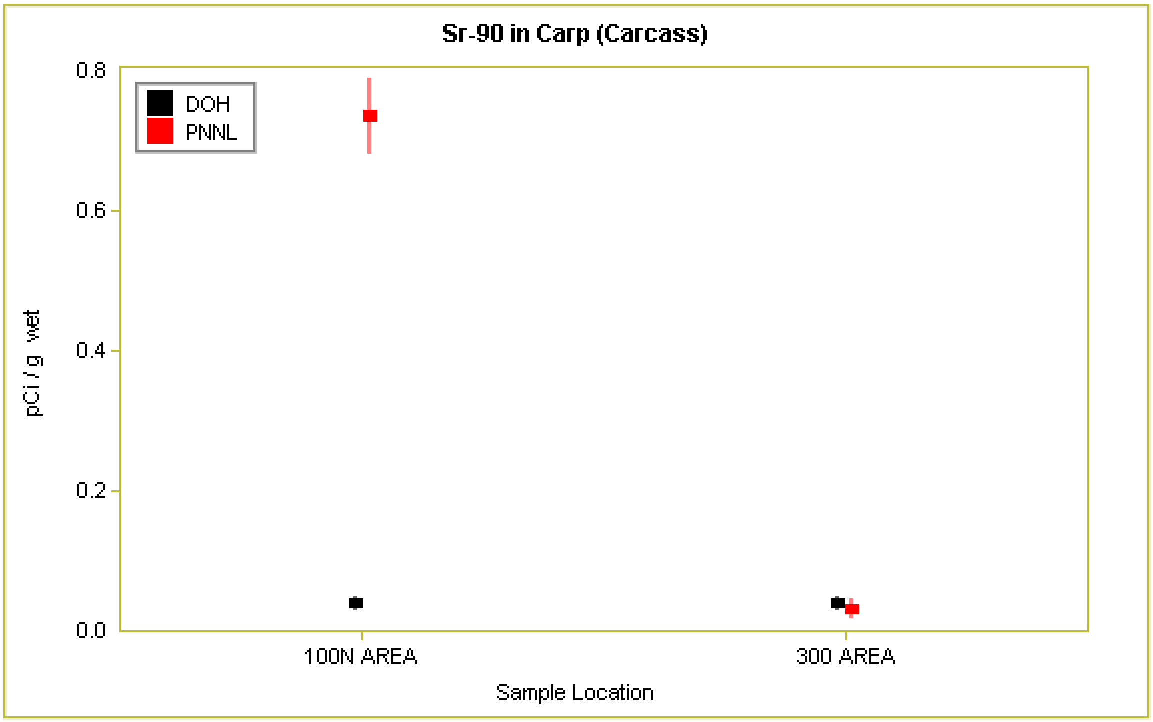

Figure 3.6.1 DOH and PNNL Results for Sr-90 in Carp Collected from the Columbia River Adjacent to the Hanford Site

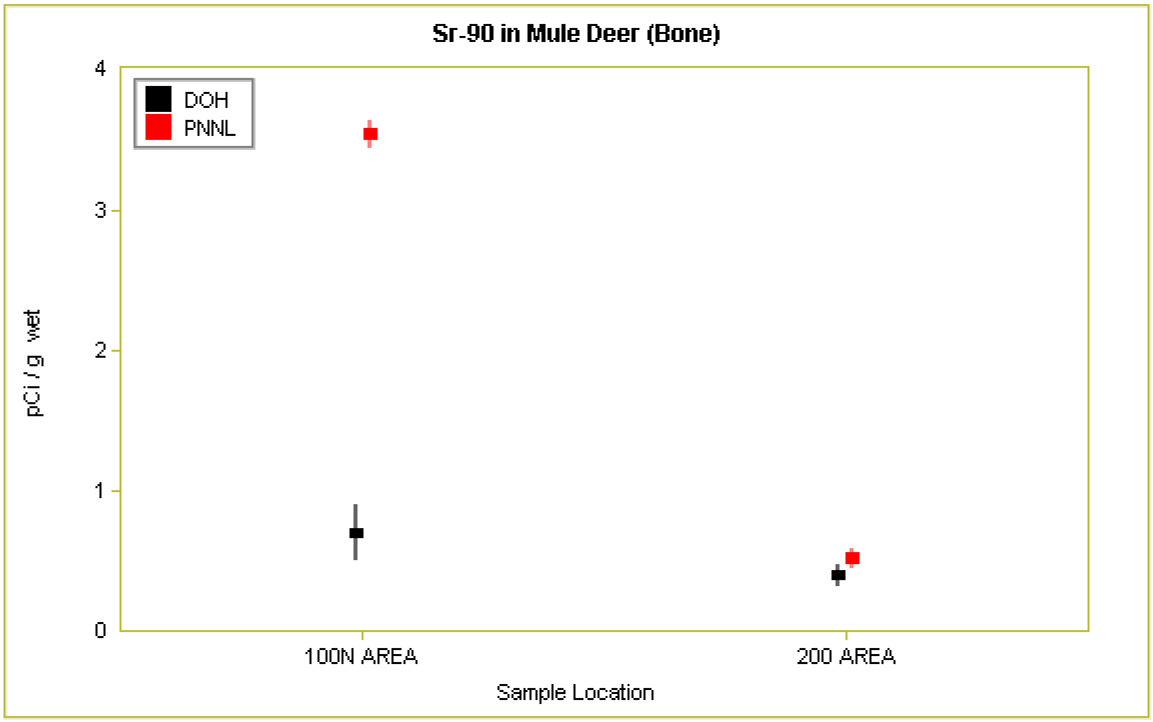

Figure 3.6.2 DOH and PNNL Results for Sr-90 in Mule Deer

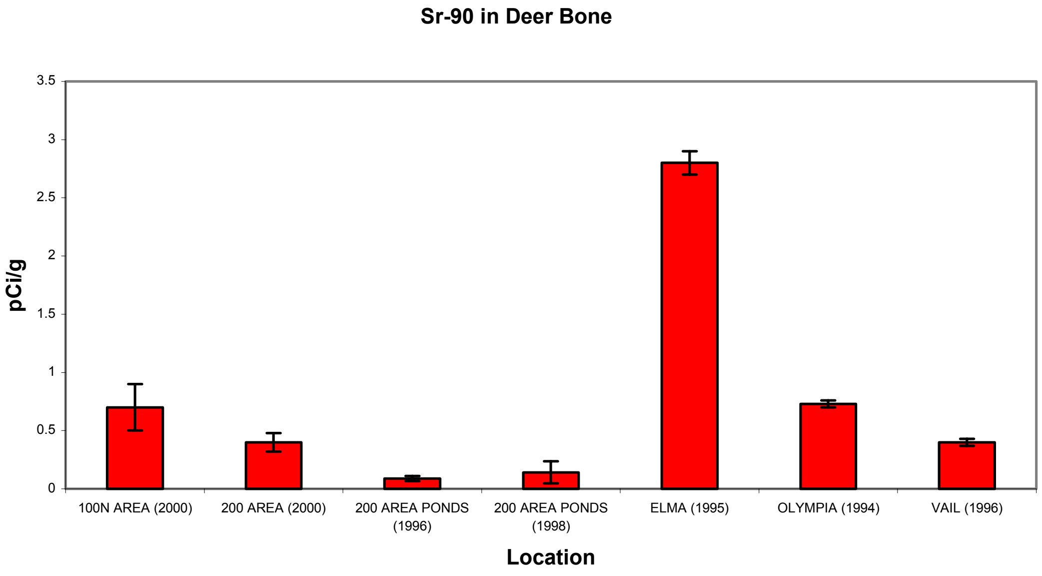

Figure 3.6.3 Sr-90 results in deer bone samples collected in 2000 as compared to historical samples collected onsite and at distant locations.

3.7 Vegetation Monitoring

Major Findings:

- The DOH and DOE contractor results are in excellent agreement.
- All radioactivity concentrations are below detection limits.

3.7.1 Purpose and General Discussion

The Department of Health and DOE contractors monitor vegetation to evaluate contaminants that are incorporated into plants that, in turn, may be consumed by animals and potentially reach the public. Contaminants in vegetation arise from airborne deposition and from soil to plant transfer via root uptake. The primary purpose of the DOH program is to provide oversight of the PNNL monitoring program. In 2000, DOH split a single vegetation sample, specifically hop residue.

3.7.2 Monitoring Locations

The vegetation sample was initially collected from a farm located downwind of the Hanford Site and then transported to a hop processor, where it was collected by PNNL.

3.7.3 Monitoring Procedures

The hop residue was collected in the fall of 2000 and split with PNNL. DOH and PNNL independently analyzed the sample for Co-60, Cs-137 and Sr-90, and then compared results. The results are reported in pCi/g.

3.7.4 Comparison of DOH and Contractor Data

The Co-60, Cs-137 and Sr-90 DOH and PNNL results are all in excellent agreement. The Sr-90 results are shown Figure 3.7.1.

3.7.5 Discussion of Results and Trends

The Co-60, Cs-137 and Sr-90 results are all below the detection limit.

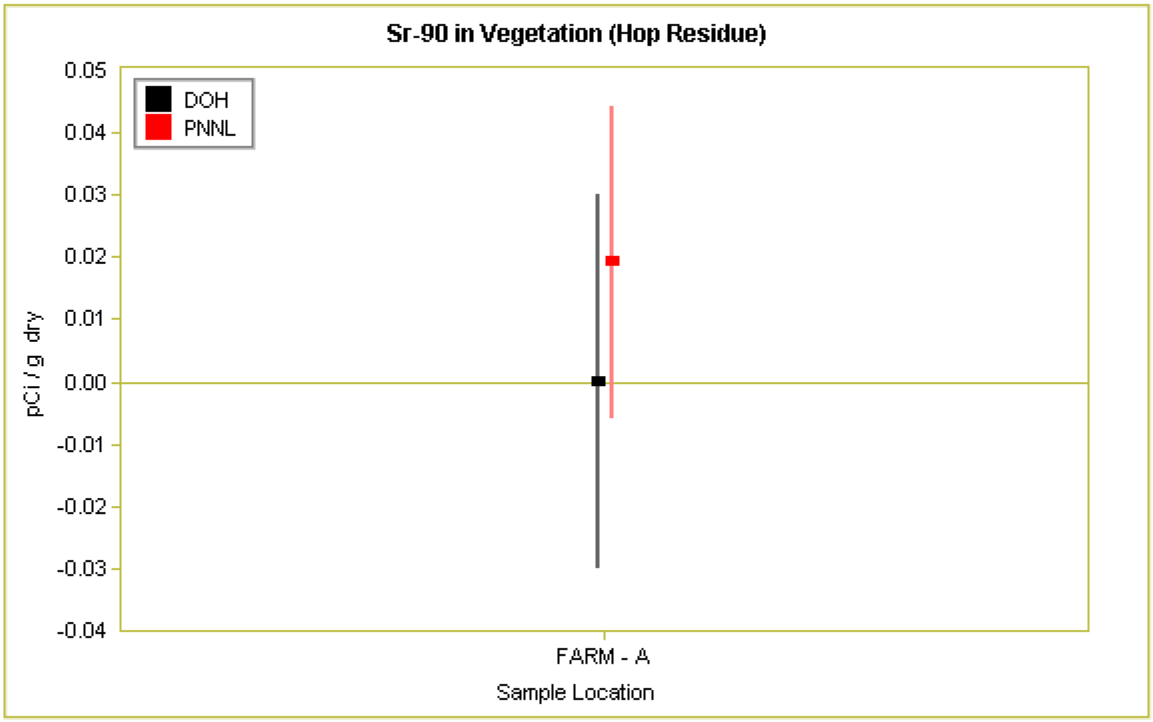

Figure 3.7.1 DOH and PNNL Sr-90 Results for Hop Residue

Appendix A - Radiation Tutorial

A.1 Radiation and Radioactivity

Radioactivity from natural sources is found throughout nature, including in air, water, soil, within the human body, and animals. Naturally occurring radioactivity originates from the decay of primordial terrestrial sources such as uranium and thorium. Other sources are continually produced in the upper atmosphere through interactions of atoms with cosmic rays. These naturally occurring sources of radiation produce the background levels of radiation to which humans are unavoidably exposed.

Radioactivity is the name given to the phenomena of matter emitting ionizing radiation. Radiation emitted from the nucleus of an atom is termed nuclear radiation. Atoms that emit radiation are termed radioactive. The three most common types of radiation are:

- Alpha – A particle consisting of two protons and two neutrons emitted from the nucleus of an atom. These charged particles lose their energy very rapidly in matter and are easily shielded by small amounts of material, such as a sheet of paper or the surface layer of skin. Alpha particles are only hazardous when they are internally deposited.

- Beta – An electron emitted from the nucleus of an atom. These charged particles lose their energy rapidly in matter, although less so than alpha radiation. Beta radiation is easily shielded by thin layers of metal or plastic. Beta particles are generally only hazardous when they are internally deposited.

- Gamma – Electromagnetic radiation, or photons, emitted from the nucleus of an atom. Gamma radiation is best shielded by thick layers of lead or steel. Gamma energy may cause an external or internal radiation hazard. (X-rays are similar to gamma radiation but originate from the outer shell of the atom instead of the nucleus).

In the past century, exposure of people to radiation has been influenced by the use and manufacture of radioactive materials. Such uses include the use of radioactive materials in the healing arts, uranium mining and milling operations, nuclear power generation, nuclear weapons manufacturing and testing, and storage and disposal of nuclear wastes. Radiation levels were most altered by residual fallout from nuclear weapons testing. The United States ceased atmospheric testing following adoption of the 1963 Nuclear Test Ban Treaty and exposure has been decreasing since then.

Radioisotope and radionuclide are interchangeable terms used to refer to radioactive isotopes of an element. Elements are delineated by their chemical names followed by their atomic number, which is the sum of its number of protons and neutrons. For example, carbon-12, which is the most naturally abundant form of carbon, consists of six protons and six neutrons for a total of twelve. Carbon-13 and carbon-14, which consist of six protons and seven and eight neutrons respectively, are also found in nature. These forms of carbon are called isotopes of carbon. If an isotope is radioactive it is called a radioisotope. In the example given, carbon-12 and carbon-13 are non-radioactive isotopes of carbon. Carbon-14 is radioactive, and therefore a radioisotope of carbon.

All radioisotopes will eventually decay, by emitting radiation, to non-radioactive isotopes. For example, carbon-14 decays to nitrogen-14. An important property of any radioisotope is the half-life. Half-life is the amount of time it takes for a quantity of any radioisotope to decay to one-half of its original quantity.

In the example above carbon-14 has a half-life of 5,730 years. Thus, one gram of pure carbon-14 would transform into 1/2 gram of carbon-14 and 1/2 gram of nitrogen-14 after 5,730 years. After another 5,730 years, for a total of 11,460 years, 1/4 gram of carbon-14 and 3/4 grams of nitrogen-14 would remain. This decay process would continue indefinitely until all of the carbon-14 had decayed to nitrogen-14.

Heavier radioisotopes often decay to another radioisotope, which decays to another radioisotope, and so on until this decay process culminates in a non-radioactive isotope. This sequence of decays is called a decay chain. Each of the isotopes produced by these decays is called a decay product. For example, uranium-238 decays to thorium-234, which decays to protactinium-234 and so on until the decay chain ends with non-radioactive lead-206.

A.2 Radiological Units and Measurement

From the perspective of human health, exposure to radiation is quantified in terms of radiation dose. Radiation dose measures the amount of energy deposited in biological tissues. Commonly, units of the roentgen, rad, and rem are used interchangeably to quantify the radiation energy absorbed by the body. The international scientific units (SI) for rad and rem are gray and sievert, respectively. There is no SI unit for roentgen.

The roentgen is a measure of radiation exposure in air, rad is a measure of energy absorbed per mass of material, and rem is a unit that relates radiation exposure to biological effects in humans. See the glossary (Appendix D) for more complete definitions of these terms.

The quantity of radioactivity in material is measured in curies. A curie (Ci) is a quantity of any radionuclide that undergoes an average transformation rate of 37 billion transformations per second. One curie is the approximate activity of 1 gram of radium. The SI unit for activity is becquerel equal to one disintegration per second.

Human radiation doses are expressed in units of rems or seiverts. Since radiation doses are often small, units of millirem (mrem) or milliseivert (mSv) are commonly used. A mrem is one-thousandth of a rem. Table A.1 below shows the average annual dose for the United States from both natural and artificial sources. Natural sources account for 82% of the annual dose to the U.S. population, with radon being the dominant natural dose contributor at 55%.

Source		Dose (mrem/yr)	Dose (mSv/yr)	Percent of Total
Natural	Radon	200	2.0	55
	Cosmic	27	0.27	8
	Terrestrial	28	0.28	8
	Internal	39	0.39	11
	Total Natural	**300**	**3**	**82%**
Artificial	Medical X-Ray	39	0.39	11
	Nuclear Medicine	14	0.14	4
	Consumer Products	10	0.1	3
	Total Artificial	**63**	**0.63**	**18%**
Other	Occupational	0.9	< 0.01	< 0.3
	Nuclear Fuel Cycle	< 1	< 0.01	< 0.03
	Fallout	< 1	< 0.01	< 0.03
	Miscellaneous	< 1	< 0.01	< 0.03
	Grand Total	**363**	**3.63**	**100%**

Table A.1 Annual Effective Dose Equivalent (NCRP 93)

It is well established that very high radiation doses, in the neighborhood of 300,000 to 500,000 mrem, are fatal. At lower, but still high doses (above approximately 20,000 mrem), the primary biological impact is an increased risk of cancer.

The health effects of radiation are substantially better known than those of most other carcinogens because, in addition to animal data, there is a wealth of human data. However, virtually all the evidence on the harmful effects of radiation comes from observations at high doses or high dose rates. The primary source of information on the health effects of radiation comes from studies of the survivors of the Japanese atomic bombings. Other sources include radiation accidents, occupational exposures, and medical exposures.

Most exposures to radiation workers and the general public, however, involve low doses, i.e. lifetime doses of less than approximately 20,000 mrem above natural background. The health effects of exposure to low doses of radiation are too small to unambiguously measure. In the absence of direct evidence on the harmful effects of radiation at low doses, estimates of health effects are made by extrapolation from observations at high doses. There is much controversy and disagreement about the procedure for such an extrapolation. The conventional procedure traditionally has hypothesized a linear extrapolation of the high dose, high dose rate health effects data all the way down to a point of zero dose, zero risk.

Typically, radiation doses associated with exposure to environmental contamination are very small, and the health effects from these exposures are not known with a reasonable degree of certainty.

Appendix B - Minimum Detection Limits

Air Cartridge

	Nuclide	Volume (m^3)	Method***	Standard 100 minutes (pCi/m^3)	Priority 10 mintues (pCi/m^3)
Gamma	I-131*	450	INGE	1.00E-02	3.00E-02

Air Filter

	Nuclide	Volume (m^3)	Method***	Standard 1000 minutes (pCi/m^3)	Priority 10 mintues (pCi/m^3)
Gamma	Be-7	450	INGE	3.00E-02	2.00E-01
	Co-60	450	INGE	4.00E-03	3.00E-02
	Ru-106	450	INGE	3.00E-02	2.00E-01
	Cs-134	450	INGE	4.00E-03	2.00E-02
	Cs-137	450	INGE	3.00E-03	2.00E-02
	Ce-144	450	INGE	2.00E-02	1.00E-01
	Mo-99	450	INGE	8.00E-04	8.00E-03
	Tc-99M	450	INGE		

	Nuclide	Volume	Method***	100 minutes (pCi/m^3)	20 minutes (pCi/m^3)
Beta	Gross	450 m^3	αβ Cntr	1.00E-03	2.00E-03
	Sr-90	1 filter	αβ Cntr	1.00E-00******	

* LLD calculated for a decay time of 3 days

*** INGE = intrinsic germanium detector; IX = ion exchange resin method;
LS = liquid scintillation

αβ Cntr = alpha,beta counter; alpha spec = alpha spectrometer; oxid = oxidation

****** Units - pCi/filter

Composite Air Filter

	Nuclide	Volume (m^3)	Method***	Standard 100 minutes (pCi/m^3)	Priority 20 minutes (pCi/m^3)
Gamma	Be-7	5200	INGE	8.00E-02	3.60E-02
	Cs-134	5200	INGE	2.00E-03	8.90E-04
	Cs-137	5200	INGE	1.00E-03	4.50E-04
	Co-60	5200	INGE	1.00E-03	4.50E-04

Food

	Nuclide	Mass (g)	Method***	Standard 1000 minutes (pCi/g)	Priority 10 minutes (pCi/g)
Gamma	I-131*	400	INGE	2.00E-02	2.00E-01
	Cs-134	400	INGE	2.00E-02	2.00E-01
	Cs-137	400	INGE	2.00E-02	2.00E-01
	Co-60	400	INGE	1.00E-02	1.00E-01
	Mo-99**	400	INGE	8.00E-03	8.00E-02
	Tc-99M**	400	INGE	1.00E-01	1.00E+00
	Ra-226 (DA)	400	INGE	2.50E-01	2.50E 00
	Am-241(GA)	400	INGE	2.00E-02	2.00E-01

	Nuclide	Mass (g)	Method***	Standard 100 minutes (pCi/l) ◊
Beta	H-3	20	LS	2.00E+02

Nuclide	Mass (g)	Method***	Standard 100 minutes (pCi/g)
Sr-89	150	αβ Cntr	4.00E-02*
Sr-90	150	αβ Cntr	4.00E-02*
Tc-99	20	IX/LS	1.00E-01

* LLD calculated for a decay time of 3 days

** LLD calculated for a decay time of 1 day

*** INGE = intrinsic germanium detector; IX = ion exchange resin method;
LS = liquid scintillation

αβ Cntr = alpha,beta counter; alpha spec = alpha spectrometer; oxid = oxidation

◊ The tritium LLD changed in 1993 to 60 pCi/liter

Food (Continued)

	Nuclide	Volume (g)	Method***	Standard 1000 minutes (pCi/g)
Alpha	Nat-U	20	Alpha Spec	5.00E-03
	Ra-226	20	IX/ αβ Cntr	6.00E-04
	Th-230	20	Alpha Spec	5.00E-03
	Th-232	20	Alpha Spec	1.00E-03
	U-234	20	Alpha Spec	3.00E-03
	U-238	20	Alpha Spec	3.00E-03
	Pu-238	20	Alpha Spec	4.00E-03
	Pu-239	20	Alpha Spec	4.00E-03
	Am-241	20	Alpha Spec	4.00E-03

Milk

	Nuclide	Volume (l)	Method***	Standard 400 minutes (pCi/l)	Priority 10 minutes (pCi/l)
Gamma	K-40	3	INGE	3.00E+01	3.00E+02
	I-131*	3	INGE	2.00E+00	2.00E+01
	Cs-134	3	INGE	2.00E+00	2.00E+01
	Cs-137	3	INGE	2.00E+00	2.00E+01
	Ba-140	3	INGE	1.20E+00	6.00E+01

Nuclide	Volume (l)	Method***	Standard 1000 minutes (pCi/l)
I-131*	4	IX/INGE	7.00E-01

	Nuclide	Volume (l)	Method***	Standard 100 minutes (pCi/l)
Beta	Sr-89	1	Nitric Acid/ αβ Cntr	7.00E-01
	Sr-90	1	Nitric Acid/ αβ Cntr	7.00E-01

* LLD calculated for a decay time of 3 days

*** INGE = intrinsic germanium detector; IX = ion exchange resin method; LS = liquid scintillation

αβ Cntr = alpha,beta counter; alpha spec = alpha spectrometer; oxid = oxidation

Meat

	Nuclide	Volume (g)	Method	Standard 1000 minutes (pCi/g wet)	Standard 10 minutes (pCi/g wet)
Gamma	K-40	400	INGE	1.40E-01	1.40E 00
	Mn-54	400	INGE	7.00E-03	8.00E-02
	Co-58	400	INGE	7.00E-03	7.00E-02
	Co-60	400	INGE	8.00E-03	8.00E-02
	Cs-137	400	INGE	6.00E-03	6.00E-02
	I-131*	400	INGE	2.00E-02	2.00E-01
	Mo-99**	400	INGE	8.00E-03	8.00E-02
	Tc-99M**	400	INGE	1.00E-01	1.00E+00
	Ra-226(DA)	400	INGE	2.50E-01	2.500E 00
	Am-41(GA)	400	INGE	2.00 E-02	2.00E-01
Alpha	Total U	10	Alpha Spec	9.00E-03	
	U-234	10	Alpha Spec	6.00E-03	
	U-238	10	Alpha Spec	5.00E-03	
	Ra-226	10	Alpha Spec	1.20E-03	
	Pu-238	10	Alpha Spec	2.00E-03	
	Pu-239	10	Alpha Spec	2.00E-03	
	Am-241	10	Alpha Spec	2.00E-03	

Shellfish

	Nuclide	Mass (g)	Method***	Standard 400 minutes (pCi/g)	Priority 10 minutes (pCi/g)
Gamma	Zn-65	400	INGE	3.00E-02	2.00E-01
	Zr-95	400	INGE	3.00E-02	2.00E-01
	Ru-106	400	INGE	1.00E-01	8.00E-01

* LLD calculated for a decay time of 3 days

** LLd calculated for a decay time of 1 day

*** INGE = intrinsic germanium detector; IX = ion exchange resin method; LS = liquid scintillation

Soil / Sediment

	Nuclide	Mass (g)	Method***	Standard 1000 minutes (pCi/g)	Priority 10 minutes (pCi/g)
Alpha	Nat-U	1	Alpha Spec	1.00E-01	
	U-234	1	Alpha Spec	7.00E-02	
	U-238	1	Alpha Spec	7.00E-02	
	Nat-U (da)	600	INGE	1.00E-01	1.00E+00
	Ra-226	1	αβ Cntr	1.00E-01**	
	Ra-226 (da)	600	INGE	2.00E-02	2.00E-01
	Total-Th	1	Alpha Spec	1.00E-01	
	Th-230	1	Alpha Spec	1.00E-01	
	Pu-238	10	Alpha Spec	4.00E-03	
	Pu239/240	10	Alpha Spec	3.00E-03	
	Am-241	10	Alpha Spec	5.00E-03	

	Nuclide	Mass (g)	Method***	Standard 1000 minutes (pCi/g)	Priority 10 minutes (pCi/g)
Gamma	K-40	600	INGE	1.50E-01	1.50E-00
	Mn-54	600	INGE	1.00E-02	1.00E-01
	Co-60	600	INGE	1.00E-02	1.00E-01
	Zn-65	600	INGE	1.50E-02	1.50E-01
	Zr-95	600	INGE	1.00E-02	1.00E-01
	Ru-103	600	INGE	1.00E-02	1.00E-01
	Ru-106	600	INGE	1.00E-01	1.00E-00
	Sb-125	600	INGE	2.00E-02	2.00E-01
	Cs-134	600	INGE	1.00E-02	1.00E-01
	Cs-137	600	INGE	1.00E-02	1.00E-01
	Ce-144	600	INGE	4.00E-02	4.00E-01
	Eu-152	600	INGE	2.00E-02	2.00E-01
	Eu-154	600	INGE	2.00E-02	2.00E-01
	Eu-155	600	INGE	2.00E-02	2.00E-01
	Ra-226(DA)	600	INGE	3.50E-01	3.50E 00

** Standard counting time - 100 minute

*** INGE = intrinsic germanium detector; IX = ion exchange resin method; LS = liquid scintillation

αβ Cntr = alpha,beta counter; alpha spec = alpha spectrometer; oxid = oxidation

Soil/Sediment (Continued)

	Nuclide	Mass (g)	Method***	Standard 1000 minutes (pCi/g)	Priority 10 minutes (pCi/g)
Gamma	Am-241(GA)	600	INGE	3.00E-02	3.00E-01
	Mo-99	600	INGE	7.00E-03	7.00E-02
	Tc-99M	600	INGE	8.50E-02	8.50E-01

	Nuclide	Mass (g)	Method***	Standard 100 minutes (pCi/g)	Priority 20 minutes (pCi/g)
Beta	Sr-89	250	NitricAcid/ αβ Cntr	3.00E-03	
	Sr-90	250	Nitric Acid/ αβ Cntr	3.00E-03	
	Tc-99	10	IX /LS	2.00E-01	
Gross	Beta	0.4	αβ Cntr	1.50E+00	3.00E+00
	Alpha	0.1	αβ Cntr	4.00E+00	9.00E+00

*** INGE = intrinsic germanium detector; IX = ion exchange resin method; LS = liquid scintillation

αβ Cntr = alpha,beta counter; alpha spec = alpha spectrometer; oxid = oxidation

Vegetation

	Nuclide	Mass (g)	Method***	Standard 1000 minutes (pCi/g)*****	Priority 10 minutes (pCi/g)*****
Alpha	Pu-238	10	Alpha Spec	8.00E-03	
	Pu-239/240	10	Alpha Spec	5.00E-03	
	Am-241	10	Alpha Spec	4.00E-03	
	U-Tot	10	Alpha Spec	9.00E-03	
	U-234	10	Alpha Spec	6.00E-03	
	U-238	10	Alpha Spec	5.00E-03	

	Nuclide	Mass (g)	Method***	Standard 1000 minutes (pCi/g)*****	Priority 10 minutes (pCi/g)*****
Gamma	K-40	100	INGE	3.00E-01	3.00E+00
	Mn-54	100	INGE	4.00E-02	4.00E-01
	Co-60	100	INGE	4.00E-02	4.00E-01
	Zn-65	100	INGE	7.00E-02	7.00E-01
	Zr-95	100	INGE	7.00E-02	7.00E-01
	Ru-106	100	INGE	3.00E-01	3.00E+00
	Cs-137	100	INGE	4.00E-02	4.00E-01
	I-131*	100	INGE	4.00E-02	4.00E-01
	Mo-99**	100	INGE	2.50E-02	2.50E+00
	Tc-99M**	100	INGE	3.10E-01	3.10E+00

	Nuclide	Mass (g)	Method***	Standard 100 minutes (pCi/g)	Priority 20 minutes (pCi/g)
Beta	Gross	0.4	αβ Cntr	1.50E+00	3.00E+00
	Sr-90	20	Nitric Acid/ αβ Cntr	5.00E-02	
	Tc-99	5	IX/LS	1.50E+00	

Nuclide	Volume (l)	Method***	Standard 100 minutes (pCi/l)
C-14	0.0002	Oxid/LS	4.00E+00
H-3	0.002	LS	5.00E+02

* LLD calculated for a decay time of 3 days

** LLD calculated for a decay time of 1 day

*** INGE = intrinsic germanium detector; IX = ion exchange resin method;
LS = liquid scintillation;
αβ Cntr = alpha,beta counter; alpha spec = alpha spectrometer; oxid = oxidation

***** Dry weight for all except uranium mill samples which are reported in terms of wet weight.

Water

	Nuclide	Volume (l)	Method***	Standard 1000 minutes (pCi/l)
Alpha	Nat-U	0.5	Alpha Spec	1.30E-01
	U-234	0.5	Alpha Spec	1.00E-01
	U-238	0.5	Alpha Spec	1.00E-01
	Ra-226	0.5	αβ Cntr	2.00E-01**
	Total-Th	0.5	Alpha Spec	1.30E-01
	Th-230	0.5	Alpha Spec	1.00E-01
	Pu-238	0.5	Alpha Spec	8.00E-02
	Pu-239/240	0.5	Alpha Spec	6.00E-02
	Am-241	0.5	Alpha Spec	8.00E-02

	Nuclide	Volume (l)	Method***	Standard 1000 minutes (pCi/l)	Priority 10 minutes (pCi/l)
Gamma	Am-241	3	INGE	6.00E+00	6.00E+01
	Ba-140	3	INGE	1.20E+01	1.20E+02
	Ce-144	3	INGE	1.30E+01	1.30E+02
	Co-58	3	INGE	1.50E+00	1.50E+01
	Co-60	3	INGE	2.00E+00	2.50E+01
	Cr-51	3	INGE	1.80E+01	1.80E+02
	Cs-134	3	INGE	2.00E+00	2.00E+01
	Cs-137	3	INGE	2.00E+00	2.60E+01
	Eu-152	3	INGE	4.00E+00	4.00E+01
	Eu-154	3	INGE	4.00E+00	4.00E+01
	Eu-155	3	INGE	1.00E+01	1.00E+02
	Fe-59	3	INGE	4.00E+00	4.00E+01
	I-131*	3	INGE	2.00E+00	2.00E+01
	K-40	3	INGE	3.00E+01	3.00E+02
	Mn-54	3	INGE	1.50E+00	1.50E+01
	Nb-95	3	INGE	2.00E+00	2.00E+01
	Ru-103	3	INGE	2.00E+00	2.00E+01
	Ru-106	3	INGE	1.50E+01	1.50E+02
	Sb-125	3	INGE	5.00E+00	5.00E+01
	Sn-113	3	INGE	2.00E+00	2.00E+01
	Zn-65	3	INGE	3.00E+00	3.00E+01
	Zr-95	3	INGE	3.00E+00	3.00E+01
	Mo-99**	3	INGE	2.15E+00	2.15E+01
	Tc-99M**	3	INGE	2.58E+01	2.58E+02

** Standard counting time - 100 minute.

*** INGE = intrinsic germanium detector; IX = ion exchange resin method;
LS = liquid scintillation;

αβ Cntr = alpha,beta counter; alpha spec = alpha spectrometer; oxid = oxidation

Water (Continued)

	Nuclide	Volume (l)	Method***	Standard 200 minutes (pCi/l) ◊	Standard 100 minutes pCi/l)	Priority 20 minutes (pCi/l)
Beta	H-3	0.005	LS	2.00E+02		1.10E+03
	Sr-89	1	Nitric Acid/ αβ Cntr		7.00E-01	
	Sr-90	1	Nitric Acid/ αβ Cntr		7.00E-01	
	Tc-99	0.5	IX/LS		4.00E+00	
Gross	Beta	0.5	αβ Cntr		1.00E-00	2.00E+00
	Alpha	0.1	αβ Cntr		4.00E+00	9.00E+00

*** INGE = intrinsic germanium detector; IX = ion exchange resin method; LS = liquid scintillation

αβ Cntr = alpha,beta counter; alpha spec = alpha spectrometer; oxid = oxidation

◊ The tritium LLD changed in 1993 to 60 pCi/liter

Formulas

A. Random Uncertainty

$RU = 1.96((\text{gross sample cpm}/T_1) + (BKGCPM/T_2))^{1/2}/((E)(2.22)(V)(Y)(D))$

B. Uncertainty (standard error) of the sample mean (U)

$U = s/(n)^{1/2}$

C. Lower Limit of Detection (LLD)

$LLD = 4.66S/((2.22)(E)(V)(Y)(D))$

D. Definitions

2.22 = conversion factor from dpm to picocuries

BKGCPM = background counts per minute

D = decay factor = $e^{-(\ln2/T1/2)(t)}$

E = counting efficiency: counts per disintegration

LLD = the a priori determination of the smallest concentration of radioactive material sampled that has a 95 percent probability of being detected, with only five percent probability that a blank sample will yield a response interpreted to mean that radioactivity is present above the system background.

n = number of samples analyzed (number of data points).

RU = random uncertainty at the 95 percent confidence level (sometimes referred to as counting error)

s = sample standard deviation

S = one standard deviation of the background count rate (which equals $(BKG/T_2)^{1/2}$)

sample cpm = counts per minute of sample

t = elapsed time between sample collection and counting

T_1 = sample count time

T_2 = background count time

$T_{1/2}$ = half-life of radionuclide counted

U = uncertainty (standard error) of the sample mean

V = volume in liters (or mass in grams) of sample

Y = fractional radiochemical yield (when applicable)

Appendix C- Glossary of Terms

Alpha Particle	A heavy particle emitted from the nucleus of an atom. It consists of two protons and two neutrons, which is identical to the nucleus of a helium atom without orbital electrons. These heavy charged particles lose their energy very rapidly in matter. Thus, they are easily shielded by paper or the surface layer of skin. Alpha particles are only hazardous when they are internally deposited.
Analyte	The specific component measured in a radiochemical analysis. For example, tritium, Sr-90, and U-238 are analytes.
Background (Background Radiation)	Radiation that occurs naturally in the environment. Background radiation consists of cosmic radiation from outer space, radiation from the radioactive elements in rocks and soil, and radiation from radon and its decay products in the air we breathe.
Baseline Samples	Environmental samples taken in areas unlikely to be affected by any facilities handling radioactive materials.
Becquerel	A unit, in the International System of Units (SI), of measurement of radioactivity equal to one transformation per second.
Beta Particle	A high-speed particle emitted from the nucleus, which is identical to an electron. They can have a –1 or +1 charge and are effectively shielded by thin layers of metal or plastic. Beta particles are generally only hazardous when they are internally deposited.
CFR	Code of Federal Regulations

Curie	The basic unit of activity. A quantity of any radionuclide that undergoes an average transformation rate of 37 billion transformations per second. One curie is the approximate activity of 1 gram of radium. Named for Marie and Pierre Curie, who discovered radium in 1898.
Decay, Radioactive	The decrease in the amount of any radioactive material with the passage of time, due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, often accompanied by gamma radiation.
Detection Level	The minimum amount of a substance that can be measured with a 95% confidence that the analytical result is greater than zero.
DOH or WDOH	Department of Health or Washington State Department of Health
Dose	A generic term that means absorbed dose, equivalent dose, effective dose, committed equivalent dose, committed effective dose, or total effective dose.
DWS	Drinking Water Standard
Fallout	Radioactive materials that are released into the earth’s atmosphere following a nuclear explosion or atmospheric release and eventually fall to earth.
Gamma Ray	Electromagnetic waves or photons emitted from the nucleus of an atom. They have no charge and are best shielded by thick layers of lead or steel. Gamma energy may cause an external or internal radiation hazard. (X-rays are similar to gamma radiation but originate from the outer shell of the atom instead of the nucleus).

Half-life	The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years. Also called physical half-life.
ICRP	International Commission on Radiation Protection
Ionizing radiation	Any radiation capable of displacing electrons from atoms or molecules, thereby producing ions. Examples: alpha, beta, gamma, x-rays and neutrons.
Isotope	One of two or more atoms with the same number of protons, but different numbers of neutrons, in the nuclei.
Lower limit of detection (LLD)	The smallest amount or concentration of a radioactive element that can be reliably detected in a sample.
NCRP	National Council for Radiation Protection
PHL	Public Health Laboratory
pCi (picocurie)	10^{-12} curies (one trillionth of a curie)
PNNL	Pacific Northwest National Laboratory
QATF	Quality Assurance Task Force
Quality assurance	All those planned and systematic actions necessary to provide adequate confidence that a facility, structure, system or component will perform satisfactorily and safely in service.
Quality control	A component of Quality Assurance; comprises all those actions necessary to control and verify that a material, process or product meets specified requirements.

Quality Factor (Q)	A numerical factor assigned to describe the average effectiveness of a particular kind (and sometimes energy) of radiation in producing biological effects in the human.
Rad	The special unit of absorbed dose. It is a measure of the energy absorbed per mass of material. One rad is equal to an absorbed dose of 0.01 J kg^{-1} (1 rad = 0.01 gray).
Radioactivity	The process of undergoing spontaneous transformation of the nucleus, generally with the emission of alpha or beta particles, often accompanied by gamma rays. The term is also used to designate radioactive materials.
Radioisotope	A radioactive isotope; i.e. an unstable isotope that undergoes spontaneous transformation, emitting radiation. Approximately 2500 natural and artificial radioisotopes have been identified.
Radionuclide	A radioactive nuclide.
Rem	The special unit of dose equivalent. The dose equivalent in rem in equal to the absorbed dose in rad multiplied by a quality factor that accounts for the biological effect of the radiation. (1 rem = 0.01 sievert).
Replicate Sample	Two or more samples from one location that is analyzed by the same laboratory.
Roentgen	A unit of exposure to ionizing radiation. It is that amount of gamma or x-rays required to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions. Named after Wilhelm Roentgen, German scientist who discovered x-rays in 1895.
Split Sample	A sample from one location that is divided into 2 samples and analyzed by different laboratories.

TLD	Thermoluminescent Dosimeters
U.S. DOE	United States Department of Energy
WAC	Washington Administrative Code
X ray	Electromagnetic waves or photons emitted from the outer shell of the atom instead of the nucleus. They have no charge and are best shielded by thick layers of lead or steel. X ray energy may cause an external or internal radiation hazard.

Appendix D - List of Analytes

Am-241	Americium-241
Be-7	Beryllium-7
C-14	Carbon-14
Cm-244	Curium-244
Co-60	Cobalt 60
Cs-137	Cesium-137
Eu-152	Europium-152
Eu-154	Europium-154
Eu-155	Europium-155
H-3	Hydrogen-3
I-129	Iodine-129
K-40	Potassium
NO2+NO3	Nitrite + Nitrate
Pu-238	Plutonium-238
Pu-239/240	Plutonium-239/240
Ru-106	Ruthenium
Sb-125	Antimony
Sr-90	Strontium-90
Tc-99	Technetium-99
Total U	Total Uranium
U-234	Uranium-234
U-235	Uranium-235
U-236	Uranium-236
U-238	Uranium-238