DOH 320-043

Environmental Radiation Monitoring and Assessment Program

Hanford Environmental Oversight Program 2005 Data Summary Report

February 2007

Washington State Department of Health

Division of Environmental Health

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Contents

Figures

Tables

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
WAC	Washington Administrative Code

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, 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 2005.

The Oversight Program's objectives are met through collection and analysis of environmental samples and interpretation of results. DOH samples are either split or colocated with samples collected by DOE contractors, and the results are compared to verify the quality of the DOE monitoring programs at Hanford. In 2005, samples of air, groundwater, surface water, riverbank seep water, drinking water, discharge water, sediment, soil, food and farm products, fish and wildlife, and vegetation were collected. In addition, ambient external radiation levels were measured using radiation dosimeters.

This report uses the categories of 'good', 'fair', and 'poor' to describe the agreement between DOH and DOE contractor results. Generally there is good agreement between data split between DOH and DOE contractors. The good agreement between this limited split data gives confidence that the remainder of the DOE environmental radiation data are valid.

The DOH and DOE contractor data are not expected to be in exact agreement for every sample because of the statistical nature of radioactive decay and the fact that samples collected from the field are not homogenous. In addition to a few samples where the concentrations are similar but do not exactly match, there are a few categories of samples that display a systematic disagreement, and are categorized as fair or poor agreement.

The agreement between DOH and DOE contractor results for samples collected in 2005 is fair for gross beta and uranium activity in air samples, fair for gross alpha, gross beta, and tritium activity in water samples, and fair for uranium activity in sediment and soil samples. In the case of uranium, the discrepancy is due to a difference in laboratory analytical methods. For the case of gross beta in air, the difference in sampling intervals and sampling equipment may contribute to the discrepancy. For the other cases, the discrepancy indicates a probable difference in laboratory procedures.

Most environmental samples analyzed by DOH have radioactivity concentrations either below detection limits or consistent with background. A few samples have

concentrations elevated above background; however, in most cases the concentrations are very small and are consistent with historical trends.

For example, H-3 (tritium), Sr-90, Tc-99, and isotopes of uranium were detected above background levels in some Hanford Site and Hanford boundary water samples. A variety of radionuclides, including Cs-137, Eu-152, Pu-239/240, Sr-90, and isotopes of uranium, were found above background levels in some Hanford Site soil samples and in some sediment samples from behind Columbia River dams that are downriver of the Hanford Site. Strontium 90 was found in small concentrations in some fish, wildlife, and vegetation samples. All elevated concentrations found in 2005 are consistent with historical trends.

Tritium concentrations in 100K Area groundwater wells have displayed large fluctuations over the last several years, and this trend continued in 2005. DOH will continue to monitor these wells in the future due to their proximity to the Columbia River.

While Hanford operations have resulted in radionuclides entering the environment, the data from the DOH Oversight Program indicate that public exposure to radioactivity from Hanford is far below regulatory limits.

1. Introduction

Chapter 70.98 of the Revised Code of Washington designates the Washington State 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, DOH conducts radiological monitoring throughout the state, placing 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 radioactive waste originating from the plutonium production era. DOE has extensive monitoring programs to characterize and track this contamination as it moves through the environment. 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 monitoring programs at the Hanford Site by conducting split, colocated, and independent sampling at locations having 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 by comparing radionuclide concentrations in samples potentially impacted by Hanford with concentrations in background samples. 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.

- 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 2005.

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 lower limits of detection are listed in Appendix B. Appendix C lists a glossary of radiation terms. Appendix D is a list of analytes (i.e., the radionuclides that are detected and measured by laboratory analysis).

2. The Hanford Environmental Oversight Program Description

The objectives of the Oversight Program (see Section 1. Introduction) are met through collection and analysis of environmental samples and interpretation of results. DOH samples are either split or colocated with samples collected by the DOE contractors. In 2003, samples were split with the Pacific Northwest National Laboratory (PNNL), Duratek, and Waste Management Federal Services (WMFS).

Split samples are prepared by dividing a sample into two parts. Colocated 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 related 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/$m^{3)}$; 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 milliroentgens per day (mR/day). Radiation exposure is discussed in Appendix A, and the units used to quantify radioactivity and exposure are defined in Appendix C.

2.2.1 Uncertainty in Radioactivity Measurements

All radioactivity measurements (i.e., counting the number of decays per unit time) 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 there is 95% confidence 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 colocated 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 colocated or split data are sorted by sample type and radionuclide. Then, for each sample type and radionuclide, 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 and Scatter Plots

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 colocated DOH and DOE results for a given sample type and radionuclide 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 radionuclide 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 colocated sample 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, and discharge water (Section 3.2); dosimeters measuring external gamma radiation (Section 3.3); 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.

3.1 Air Monitoring

Major Findings:

- The DOH and DOE contractor colocated biweekly gross beta results are in fair agreement. The data follow the same trends, but there is a small systematic discrepancy between the data sets. Different sampling frequencies and differences in sampling equipment between DOH and DOE contractors likely contribute to differences in results.
- The DOH and DOE contractor colocated quarterly and semiannual composite air sample results are in good agreement for all radionuclides, except for isotopes of uranium. The discrepancy in uranium concentrations originates from a difference in DOH and DOE contractor laboratory analytical methods.
- The gross beta results are consistent with background air concentrations.
- The DOH quarterly and semiannual composite air concentrations are below detection limits for most radionuclides. However, uranium was detected in composite air samples at concentrations consistent with historical results. Plutonium-239/240 was detected in a few samples, at concentrations 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. DOH and DOE contractors monitor radioactivity in air to determine if the Hanford Site is contributing to airborne contamination. DOH collects air samples that are colocated with PNNL and Duratek. In addition to oversight of the DOE monitoring program, DOH evaluates Hanford impacts by comparing radioactivity in air at locations upwind and downwind of Hanford facilities and contaminated areas.

Sources of Hanford airborne emissions include resuspension of contaminated soil (caused by wind or cleanup activities, for example) and escape of radioactive particulates and gasses from facilities and operations. Sources of natural airborne radioactivity include natural radon gas and its decay products, resuspension of soil containing natural radionuclides such as uranium-234, 238 and potassium-40, and radioactive atoms such as beryllium-7 and tritium that are generated in the atmosphere by interactions with cosmic radiation.

3.1.2 Monitoring Locations

DOH collected air samples colocated with PNNL at five locations. These locations include Wye Barricade, Prosser Barricade, Battelle Complex, and Station 8 that are located in the prevailing downwind direction of most Hanford Site facilities and contaminated areas; and Yakima Barricade that is in the prevailing upwind direction of potential sources of airborne radioactivity.

DOH also collected air samples colocated with Duratek at four locations, three of which are near 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-SE), and the K Area fuel storage basins (KE Basin). The fourth colocated site is at the Wye Barricade. All the DOH colocated 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 colocated filters every other week (biweekly). 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 biweekly) filter samples for a three or six-month period are dissolved and combined into quarterly or semiannual composite samples. The composite samples are analyzed for gamma emitting radionuclides and isotopes of uranium and plutonium. A summary of the 2005 colocated 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

Weekly/Biweekly Results

The DOH and PNNL gross beta concentrations in biweekly colocated air samples are in fair agreement, as the data follow the same trend at each of the monitoring locations. As an example, the DOH and PNNL data at Station 8, which is located in the predominant downwind direction from Hanford on the opposite side of the Columbia River, are shown in Figure 3.1.2.

The scatter plots for 2005 and historical DOH and PNNL gross beta concentrations are shown in Figures 3.1.3 and 3.1.4. These plots show the data from all sites that are colocated with PNNL. The DOH and PNNL data follow the same general trend. However, there is significant scatter about the theoretical line where the DOH and PNNL results are identical, with differences up to a factor of two being common. In addition, there is a small systematic bias between the DOH and PNNL results. The regression analysis of historical data indicates that PNNL on average reports slightly higher concentrations at the lower range of results, while DOH on average reports slightly higher concentrations at the upper range.

The DOH and Duratek gross beta concentrations in biweekly colocated air samples are in fair agreement, as the data follow the same trend at each of the monitoring locations. As an example, DOH and Duratek data at C Farm are shown in Figure 3.1.5.

The scatter plots for 2005 and historical DOH and Duratek gross beta concentrations are shown in Figures 3.1.6 and 3.1.7. These plots show the data from all sites that are colocated with Duratek. The DOH and Duratek data follow the same general trend. However, there is significant scatter about the theoretical line where the DOH and Duratek results are identical, with differences up to a factor of two being common. In addition, there is a small systematic bias between the DOH and Duratek results. The regression analysis of historical data indicates that Duratek on average reports slightly higher concentrations at the lower range of results, while DOH on average reports slightly higher concentrations at the upper range.

In general, the DOH and DOE contractor data sets are not expected to match identically because the sampling frequencies and equipment are different, and therefore the results correspond to an averaging of the air concentration over different time periods.

Quarterly Composite Results

DOH and PNNL analyzed colocated quarterly composite air samples for Co-60, Cs-134, and Cs-137 at Battelle Complex, Prosser Barricade, Station 8, Wye Barricade, and Yakima Barricade. In addition, samples were analyzed for isotopes of uranium at Station 8, Wye Barricade, and Yakima Barricade.

The DOH and PNNL Co-60, Cs-134, and Cs-137 quarterly composite concentrations are in good agreement, with all results below the detection limits listed in Appendix B. The agreement is only fair for isotopes of uranium due to a systematic discrepancy between the two data sets. The U-238 concentrations for each quarter at all three sample locations are shown in Figure 3.1.8. The PNNL uranium concentrations are systematically less than those reported by DOH. The results for U-234 are similar. The agreement is good for U-235; however, all concentrations are below detection limits.

The discrepancy between DOH and PNNL uranium concentrations in air exists historically, and originates from different laboratory procedures. DOH completely dissolves samples prior to analysis and reports uranium present in the entire sample, whereas the contractor laboratory reports only the uranium that can be leached from the sample surface.

The historical DOH and PNNL quarterly composite U-238 concentrations for the years 1999 through 2005 are shown in the scatter plot of Figure 3.1.9. The discrepancy appears for samples in which DOH measures U-238 concentrations greater than the detection limit of 2.5E-5 pCi/m^3. In these cases, the corresponding PNNL data do not confirm the elevated DOH results. The scatter plot clearly shows that DOH consistently reports higher concentrations than PNNL.

Semi-Annual Composite Results

DOH and Duratek analyzed colocated semiannual composite air samples at C Farm, ERDF-SE, and KE Basin. The DOH and Duratek airborne concentrations are in good agreement for Co-60, Cs-134, Cs-137, Pu-238, and U-235, with most results below detection limits. As an example, the Cs-137 results are shown in Figure 3.1.10.

Most of the DOH and Duratek Pu-239/240 airborne concentrations are in good agreement, as shown in Figure 3.1.11. There is one exception, where Duratek reports a concentration several times higher than DOH. This discrepancy appears occasionally in historical results, as can be seen in the scatter plot of Figure 3.1.12. This plot, for samples collected from 1999 to 2005, shows several instances where Duratek reports Pu-239/240 concentrations significantly higher than DOH.

The U-234 and U-238 concentrations are only in fair agreement, as the Duratek concentrations are systematically less than those reported by DOH. As with the DOH and PNNL composite data, the bias originates from a known difference in laboratory procedures. The DOH and Duratek U-238 data for 2005 are shown in Figure 3.1.13, and the historical data are shown in the scatter plot of Figure 3.1.14. The U-234 data are similar.

3.1.5 Discussion of DOH 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 decay 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 3.1.15, which shows gross beta activity at Wye Barricade over the last decade from 1995 through 2005.

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, Prosser Barricade, Battelle Complex, and Station 8 are downwind locations where the public may potentially be exposed. The annual average concentrations for these sites are shown in Table 3.1.2, along with the statistics for locations on the Hanford Site (C Farm, ERDF-SE, and KE Basin).

The average air concentrations at upwind sites and downwind sites are not significantly different, indicating that Hanford is not impacting air quality at locations where the public may be exposed. In addition, the average air concentration at the locations near operating facilities is also not significantly different from the upwind site.

Site	**Average DOH Gross Beta Concentration (pCi/m^3)**
Battelle Complex	0.022
C Farm	0.024
ERDF-SE	0.020
KE Basin	0.021
Prosser B.	0.022
Station 8	0.016
Wye B.	0.022
Yakima B.	0.020

Table 3.1.2 Summary Statistics for Gross Beta Concentrations in Air

Most of the DOH results for Co-60, Cs-134, Cs-137, Pu-238, and U-235 concentrations in composite air samples are below laboratory detection limits (see Appendix B). The single exception is a semi-annual composite Cs-137 concentration of 0.0013 pCi/m^3 at C Farm (see Figure 3.1.10). Historical Cs-137 air concentrations at C Farm are shown in Figure 3.1.16. The concentration of 0.0013 pCi/m^3 is four times higher than the ten-year average concentration of 0.003 pCi/m^3. As can be seen, concentrations at this level have been measured occasionally in the past decade.

Uranium-234 and U-238 were detected in most air samples, with concentrations ranging from 0.00002 pCi/m^3 to 0.00015 pCi/m^3. These uranium concentrations are consistent with historical results, and most likely originate from natural uranium in the soil.

Plutonium-239/240 was detected at concentrations slightly above the detection limit in several samples. Historical Pu-239/240 concentrations at KE Basin are shown in Figure 3.1.17. The two results for 2005, with a maximum concentration of 0.000012 pCi/m^3, are three times greater than the detection limit. The figure indicates an increase in plutonium concentrations over the last two years.

These uranium and plutonium concentrations are very small, and are only at most a few times greater than the detection limits. Continuous breathing of air with a Pu-239/240 concentration of 0.000012 pCi/m^3 would result in an annual radiation dose of approximately 0.05 mrem/yr. Both the U.S. Environmental Protection Agency (40 CFR Part 61) and Washington State (Chapter 246-247 WAC) limit radiation dose to the public from air emissions to 10 mrem/year. The maximum radionuclide concentrations detected in DOH composite air samples are all several orders of magnitude less than EPA Concentration Levels for Environmental Compliance (as listed in 40 CFR Part 61, Appendix E, Table 2).

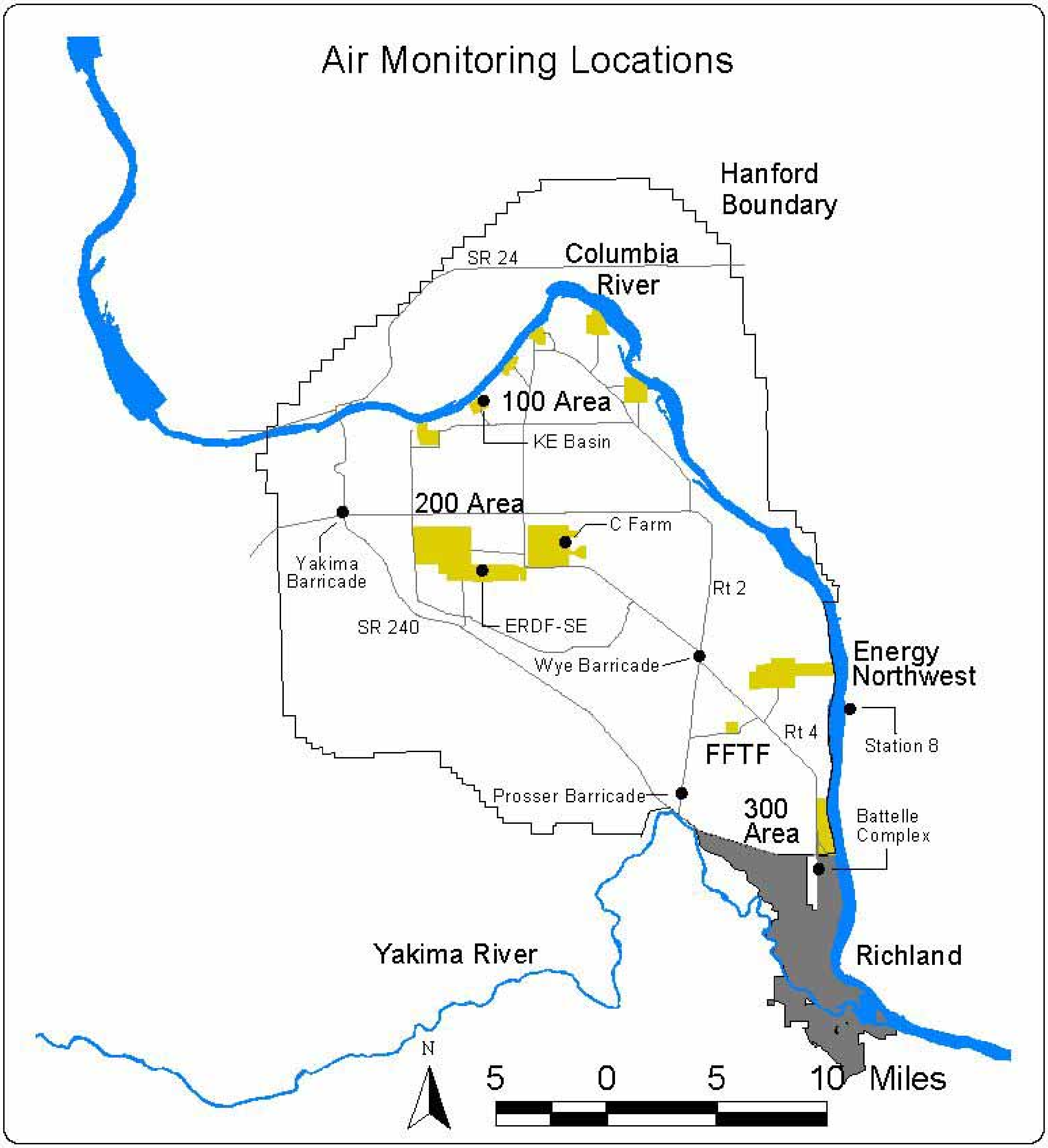

Figure 3.1.1 Air Monitoring Locations

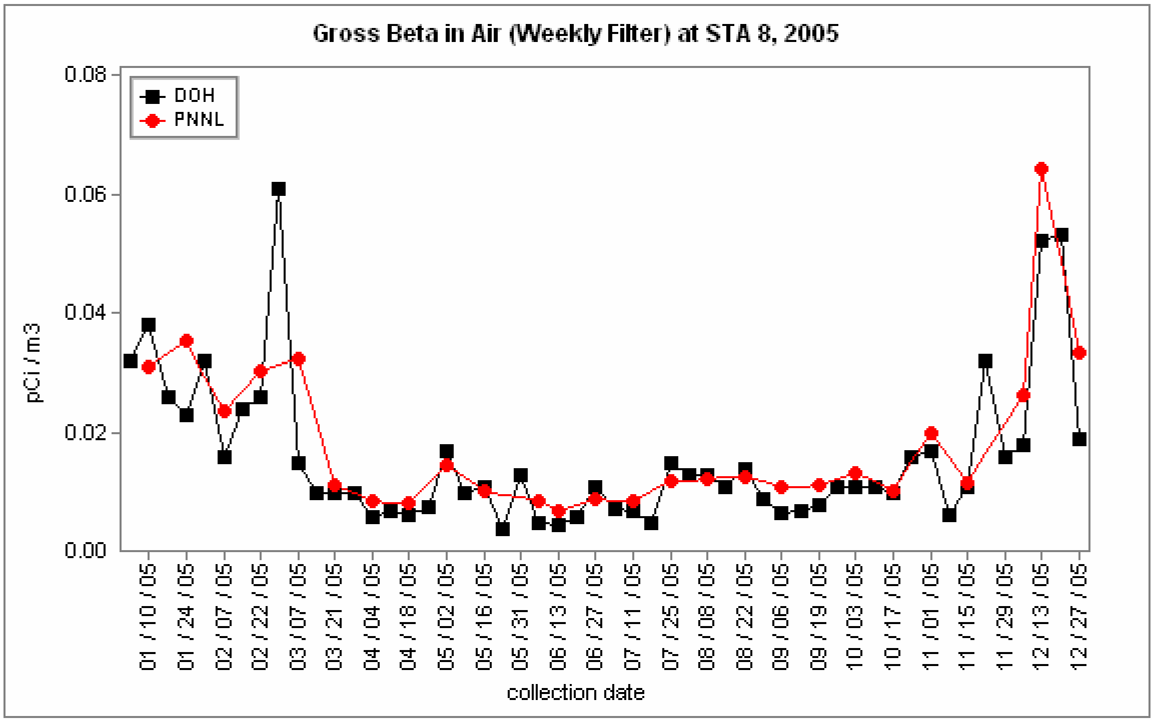

Figure 3.1.2 DOH and PNNL Gross Beta Concentrations in Air at Station 8

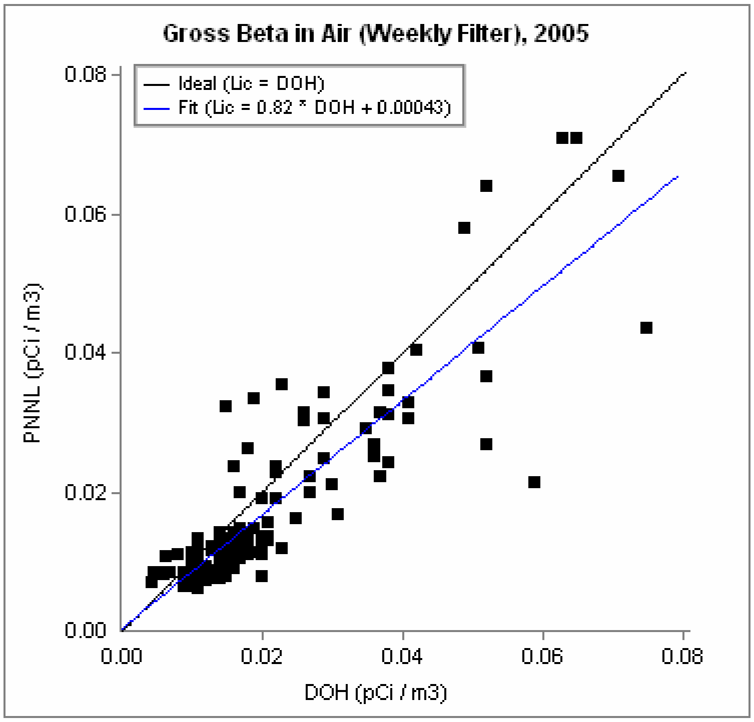

Figure 3.1.3 DOH and PNNL Scatter Plot for Gross Beta Concentrations in Air (2005)

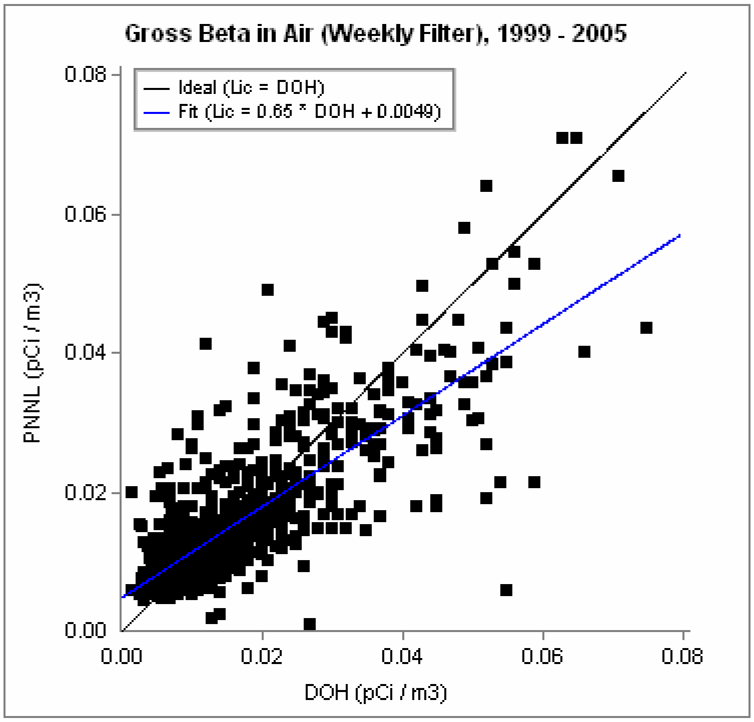

Figure 3.1.4 DOH and PNNL Scatter Plot for Historical Gross Beta Concentrations in Air

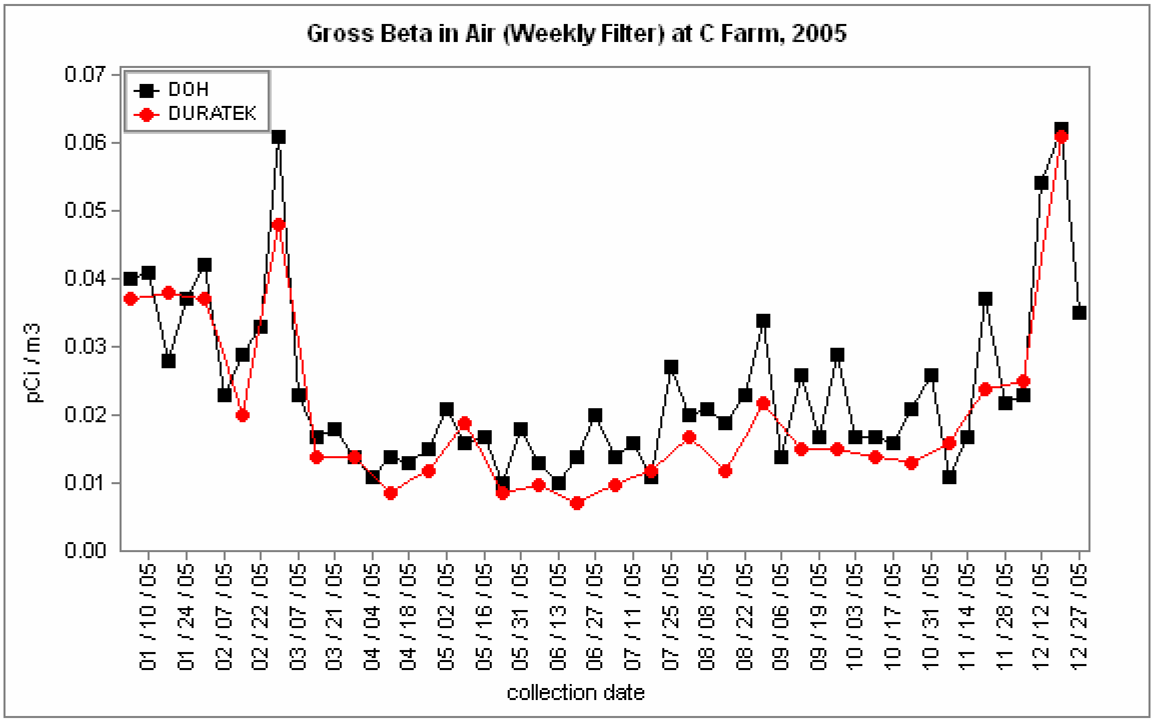

Figure 3.1.5 DOH and Duratek Gross Beta Concentrations in Air at C Farm

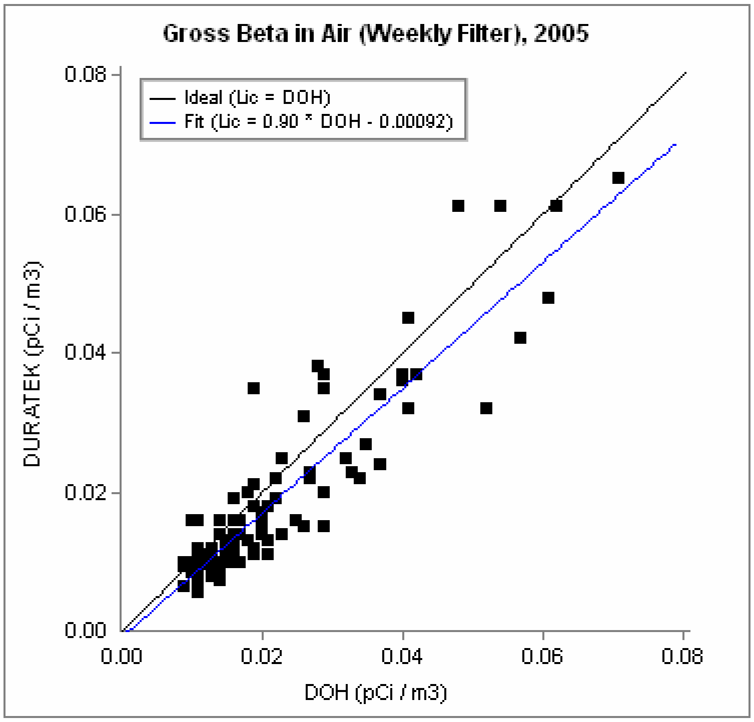

Figure 3.1.6 DOH and Duratek Scatter Plot for Gross Beta Concentrations in Air (2005)

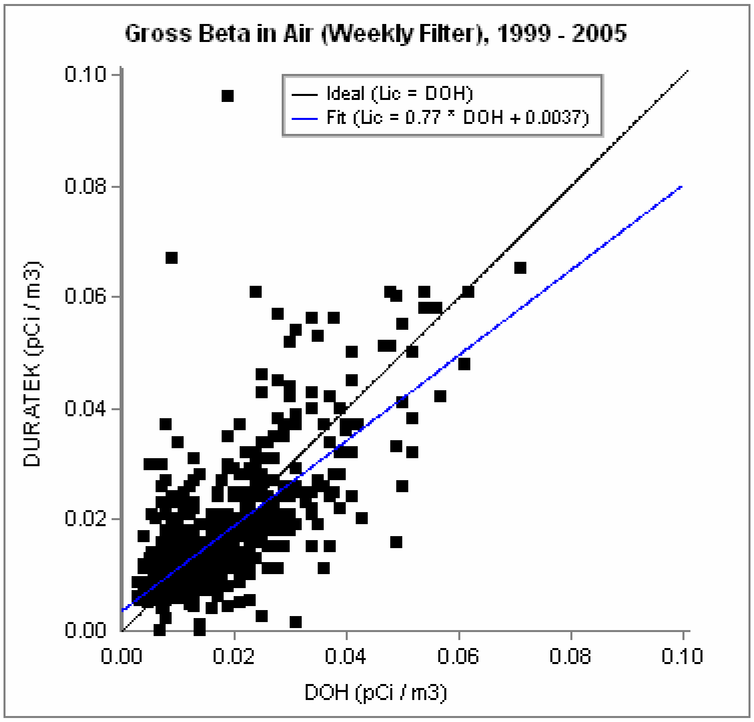

Figure 3.1.7 DOH and Duratek Scatter Plot for Historical Gross Beta Concentrations in Air

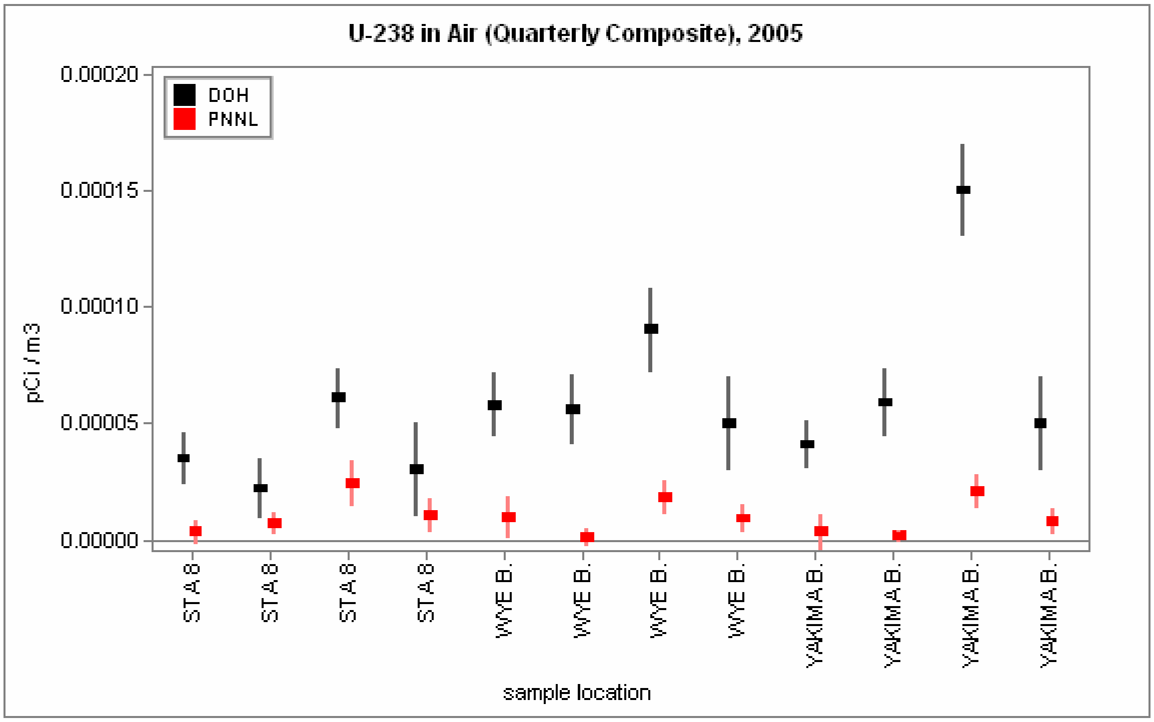

Figure 3.1.8 DOH and PNNL U-238 Concentrations in Air

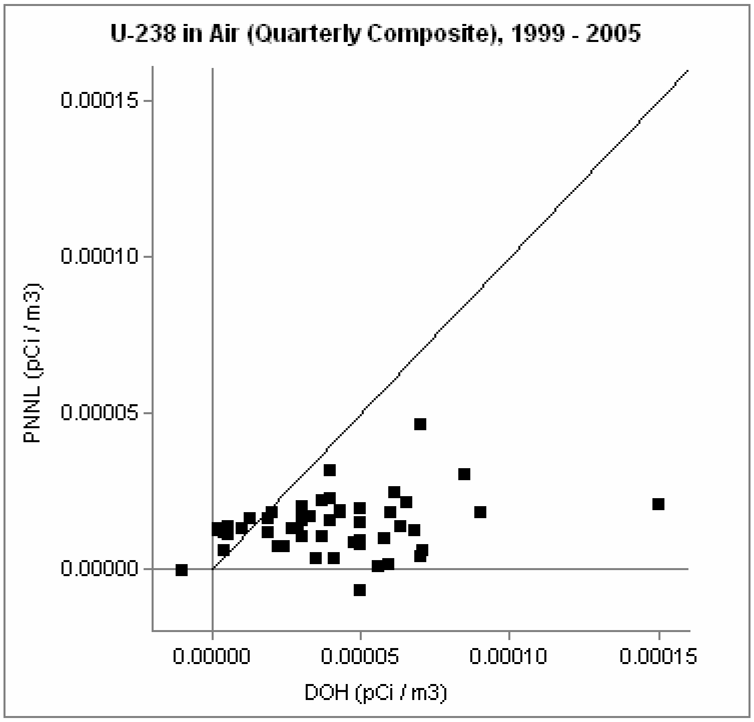

Figure 3.1.9 DOH and PNNL Scatter Plot for Historical U-238 Concentrations in Air

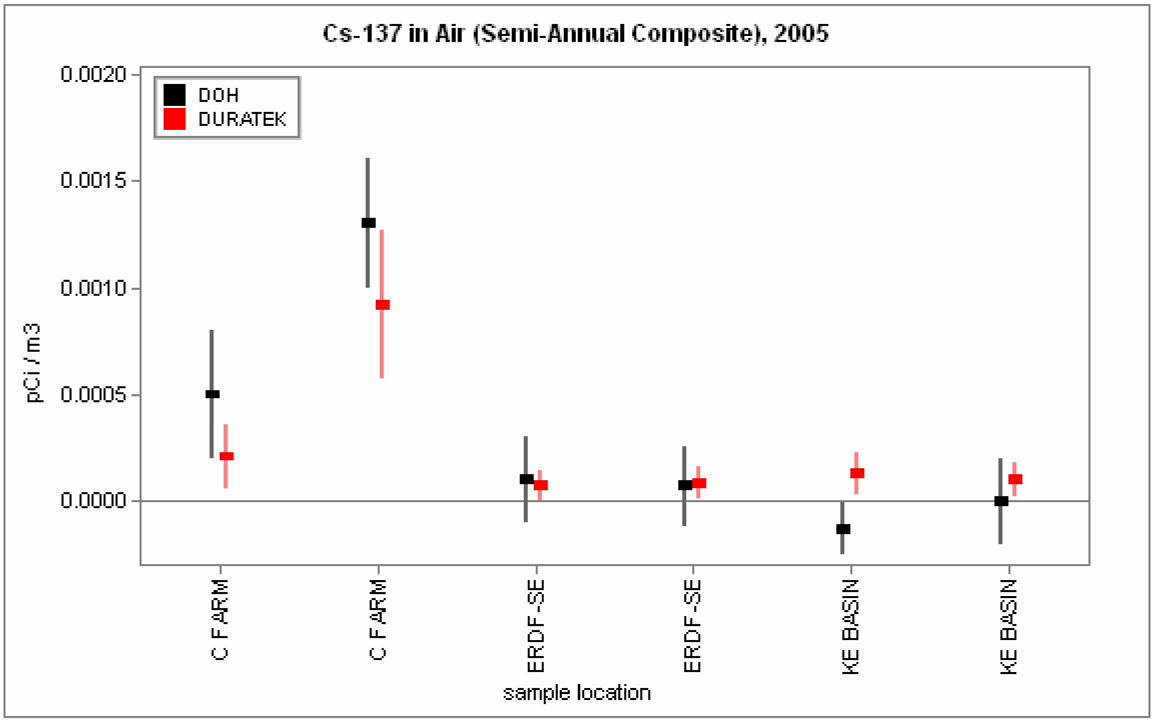

Figure 3.1.10 DOH and Duratek Cs-137 Concentrations in Air

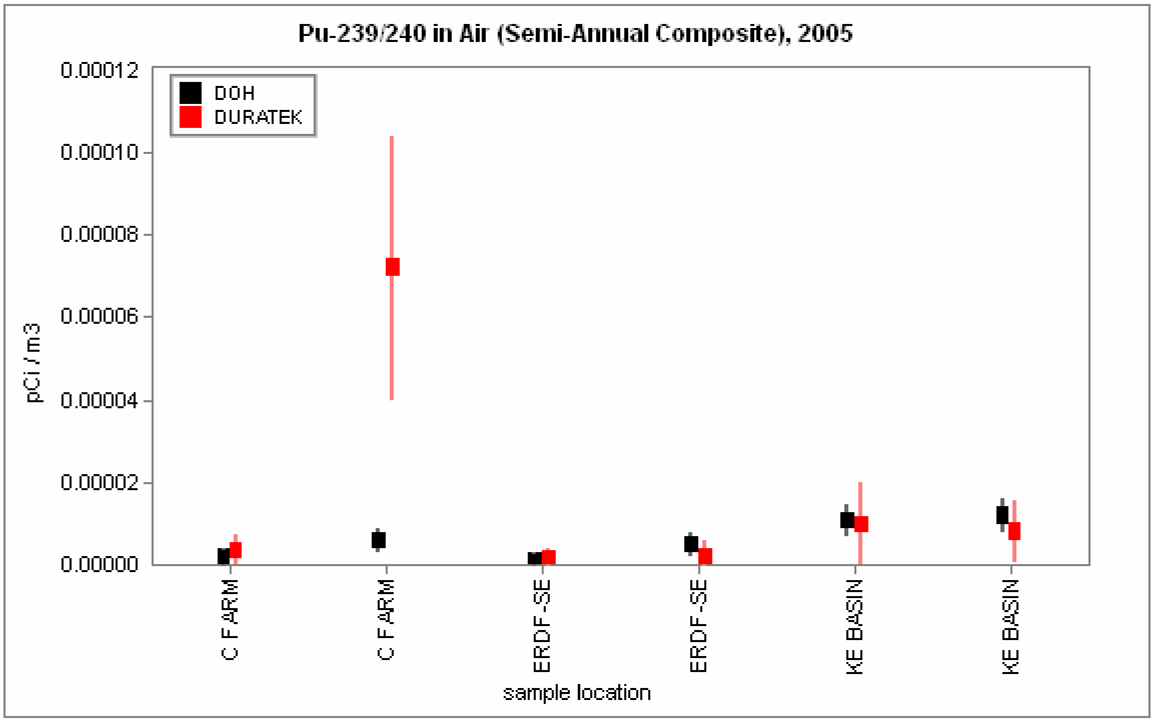

Figure 3.1.11 DOH and Duratek Pu-239/240 Concentrations in Air

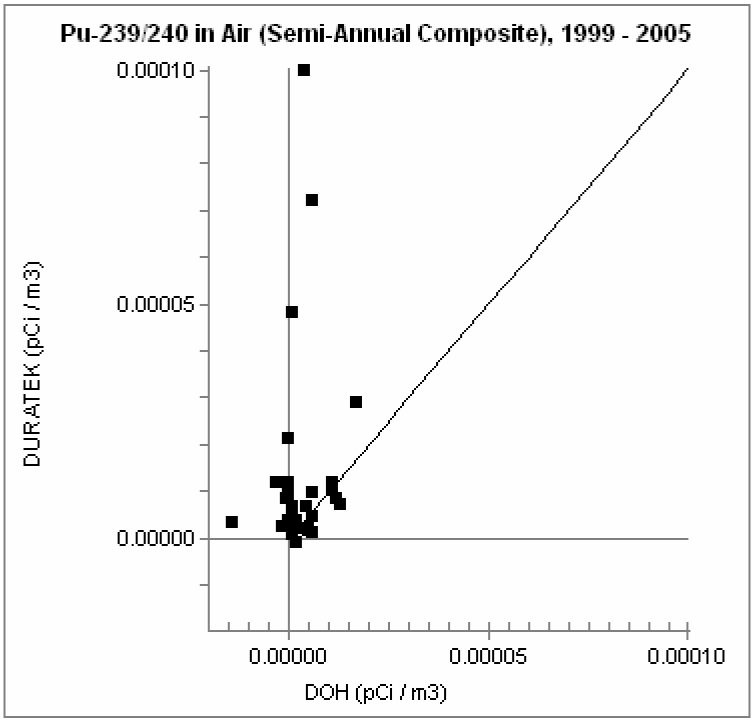

Figure 3.1.12 DOH and PNNL Scatter Plot for Historical Pu-239/240 Concentrations in Air

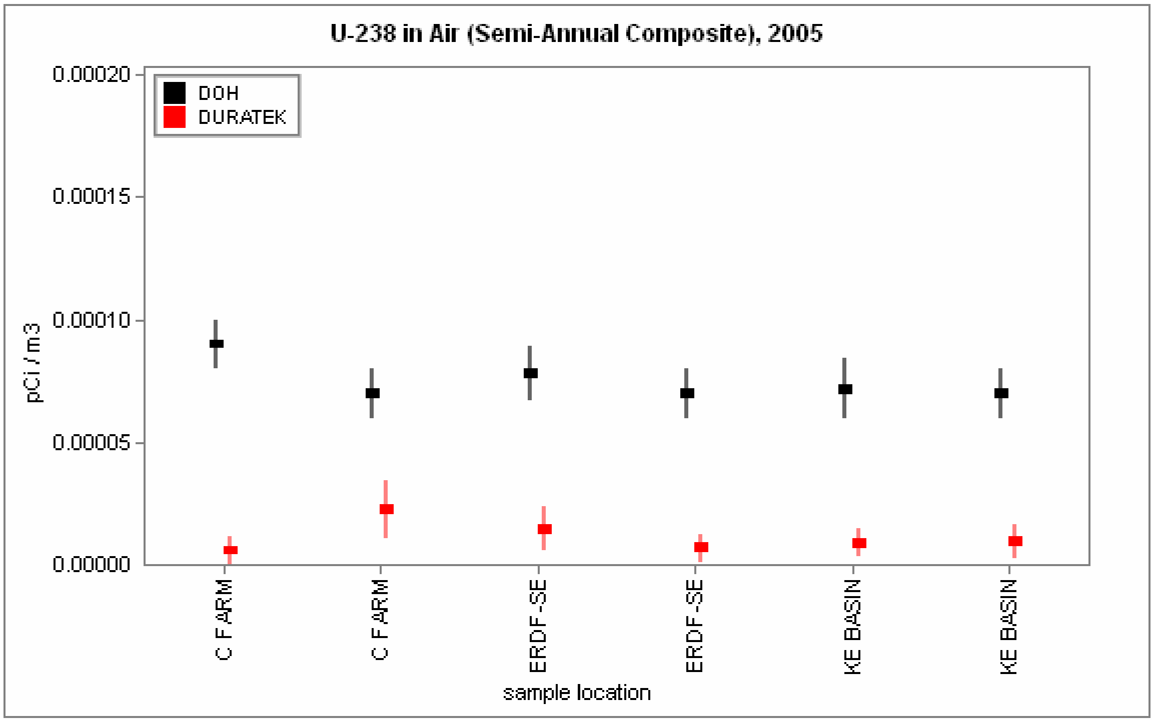

Figure 3.1.13 DOH and Duratek U-238 Concentrations in Air

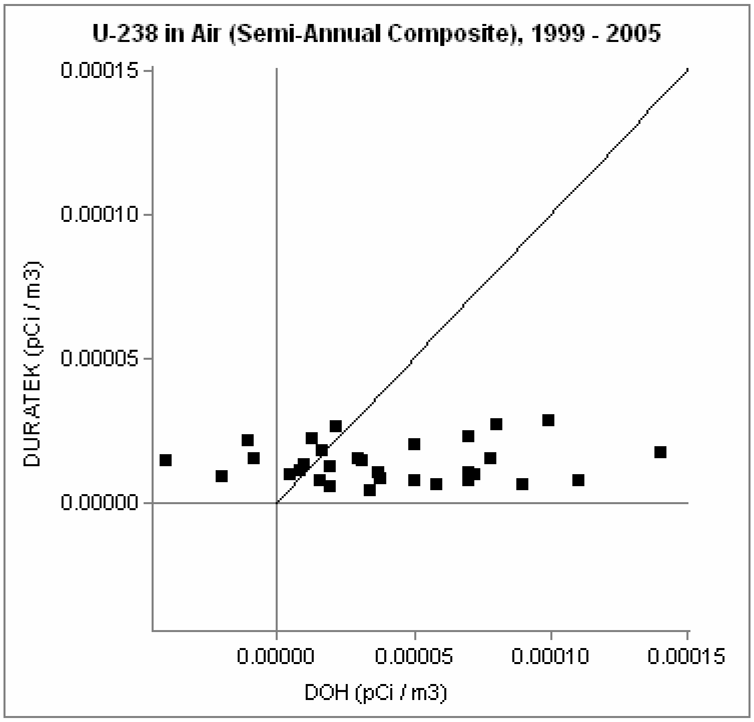

Figure 3.1.14 DOH and Duratek Scatter Plot for Historical U-238 Concentrations in Air

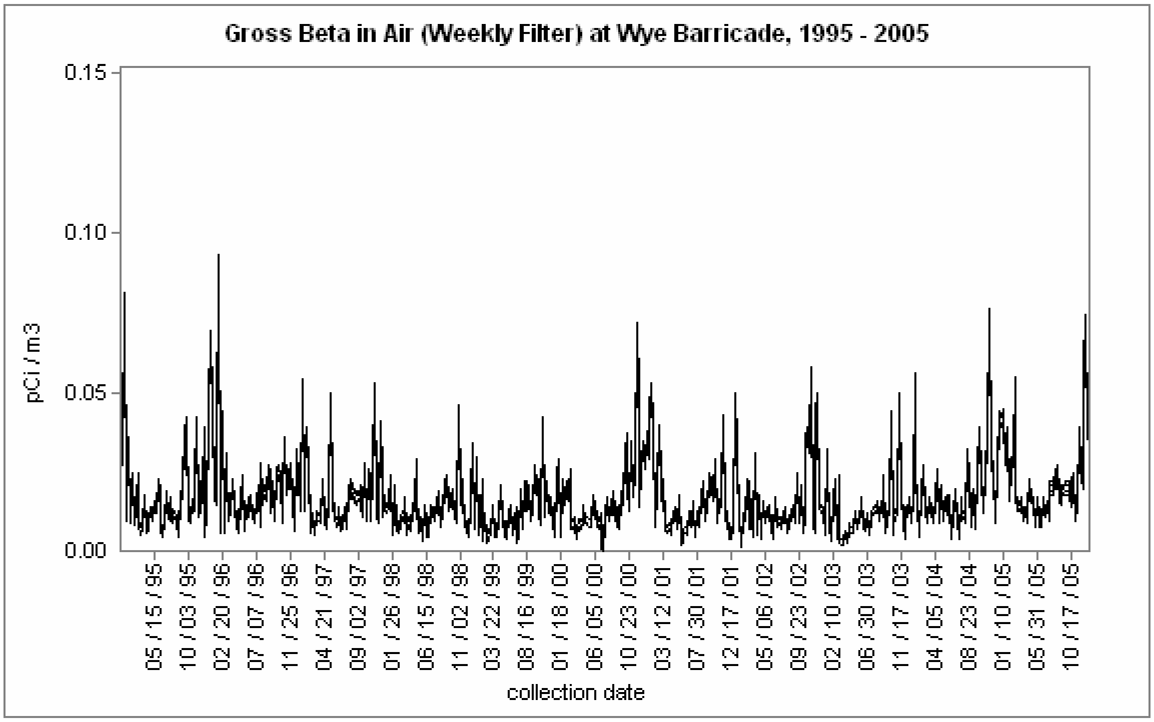

Figure 3.1.15 DOH Historical Gross Beta Concentrations in Air at Wye Barricade

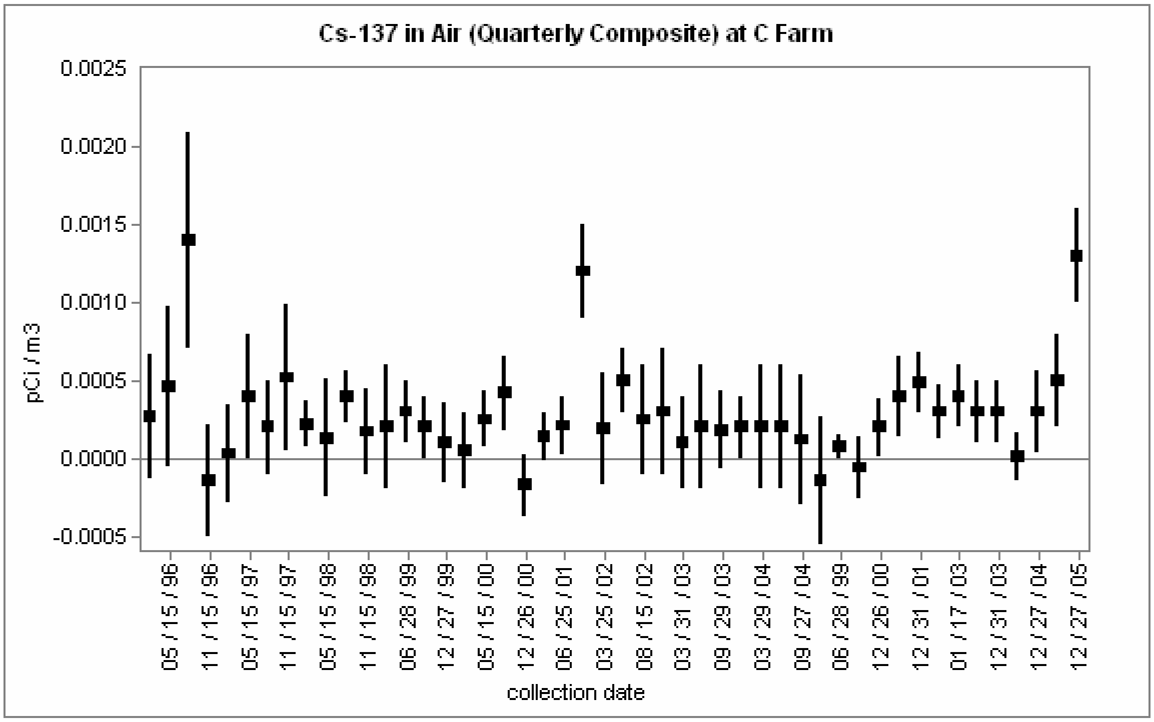

Figure 3.1.16 DOH Historical Cs-137 Concentrations in Air at C Farm

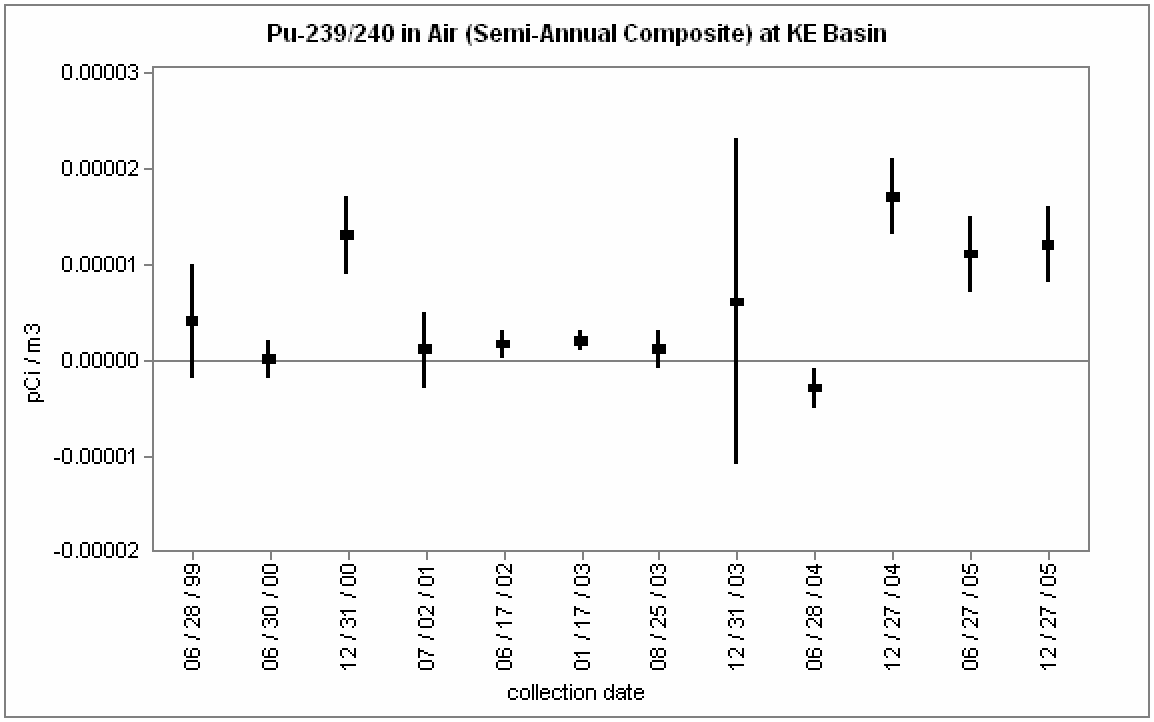

Figure 3.1.17 DOH Historical Pu-239/240 Concentrations in Air at KE Basin

3.2 Groundwater, Riverbank Seep, and Surface Water Monitoring

Major Findings:

- The DOH and PNNL split water results are in good agreement for most radionuclides analyzed in water samples. Historically, the agreement for I-129 is poor; however, detectable concentrations were not found in any of the 2005 split samples. A small systematic bias exists in the gross alpha and gross beta results. The DOH and DOE split TEDF discharge water results are in good agreement. There were no split drinking water samples in 2005.
- Radionuclides were detected in groundwater in the vicinity of known groundwater plumes, and in riverbank seep water and Columbia River surface water in the vicinity of plumes known to be entering the Columbia River.
- DOH detected H-3, Sr-90, Tc-99, and isotopes of uranium in some Hanford groundwater, seep water, and surface water samples. Most concentrations in 2005 samples are consistent with historical trends. I-129 concentrations are fluctuating in groundwater well 699-35-70, and H-3 concentrations are fluctuating in 100K Area groundwater wells.
- Radionuclide concentrations in drinking water samples analyzed by DOH are all below federal standards. These samples were not split with DOE contractors.
- Radionuclide concentrations in TEDF discharge water samples are all below Washington State standards.

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 enters the Columbia River through 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.

DOH typically splits groundwater, surface water, riverbank seep water, and drinking water samples with PNNL. In 2005, there were no split drinking water samples. PNNL monitors radioactivity in water to track contaminant plumes in groundwater, and to evaluate impacts to the public and environment. While the DOH program does not sample enough groundwater wells to track groundwater plumes, the riverbank seep and Columbia River data are adequate to assess impacts to the public. In addition, DOH and DOE contractors split discharge water samples from an effluent treatment facility.

3.2.2 Monitoring Locations

Groundwater

DOH and PNNL split 22 groundwater samples from 18 groundwater wells in 2005. Most cosampled well locations are on the Hanford Site, either within contaminated plumes, near waste sites, or along the Columbia River shoreline. A few of the cosampled 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.

Groundwater sampling is conducted in the 100, 200, 300, 400, and 600 Areas of the Hanford Site. The 100 Area consists of nine retired reactors and support facilities located along the Columbia River. Tritium (H-3) and Sr-90 are contaminants commonly found in groundwater beneath the reactor facilities. A primary objective of the groundwater collection in the 100 Area is to monitor contaminants that may enter the Columbia River. At the 100K Area, groundwater is sampled to evaluate potential changes in radioactivity as spent nuclear fuel, shield water, and sludge are removed from the 100 KE Fuel Storage Basin. Eight samples were split from this area in 2005.

The 200 Area consists of retired reactor fuel processing facilities located in the center of the Hanford Site on the central plateau. Common groundwater contaminants include H-3, I-129, Tc-99, uranium, and Sr-90. A primary objective of groundwater collection in the 200 Area is to track radioactive plume movement and monitor potential leaks from waste storage tanks. No samples were split from this area in 2005.

The 300 Area consists of retired reactor fuel fabrication facilities located adjacent to the Columbia River. Groundwater contains tritium originating from the 200 Area and uranium originating from past 300 Area fuel fabrication activities. A primary objective of the groundwater collection in the 300 Area is to monitor contaminants at the southern boundary of the Hanford Site, which is close to the City of Richland’s drinking water wells. Two samples were split from this area in 2005.

The 400 Area is the location of the Fast Flux Test Facility, a liquid sodium cooled test reactor that ceased operation in 1993 and is currently being deactivated. Tritium originating from the 200 Area is a common contaminant found in 400 Area groundwater. The primary objective of groundwater monitoring in this area is to assess impacts to the primary drinking water source for this area. One sample was split from this area in 2005.

The 600 Area includes all the land outside the operational areas of the Hanford Site. Tritium originating from the 200 Area is a common contaminant found in 600 Area groundwater. The major objective of sampling 600 Area groundwater is to assess the nature and extent of radioactive plumes originating in the 200 Area that may be moving off-site. Eleven samples were split from this area in 2005.

Riverbank Seeps

Groundwater enters the Columbia River through riverbank seeps. Historically, the predominant areas for discharge of riverbank seep water to the Columbia River were located at the reactors in the 100 Area, the Old Hanford Town Site, and the 300 Area. DOH and PNNL split three Columbia River riverbank seep samples in 2005. Sample locations included the 100K Area, the Old Hanford Town Site (Spring 28.2), and the 300 Area.

Surface Water

DOH and PNNL split 13 surface water samples in 2005. Eleven of the samples were collected from the Columbia River - two from near Priest Rapids Dam located upstream of Hanford, four from the 100N Area, one from the 100F Area, one from the Old Hanford Town Site, two from the 300 Area, and one from near the Richland drinking water pumphouse. Two of the samples were collected from irrigation canals, one located across the Columbia River at Riverview, and the other at the southern boundary of the Hanford Site at the Horn Rapids irrigation pumping station.

The Priest Rapids Dam location is upstream of the Hanford Site, while the remaining surface water sites are downstream of areas that may be impacted by Hanford. A comparison of contaminant concentrations at these sites gives an indication of Hanford's impact on the Columbia River.

Discharge Water

DOH conducts discharge 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 provide oversight of the discharge effluent monitoring program by splitting approximately 15% of the samples.

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 since that time. DOH and DOE contractors split two discharge samples in 2005. One sample was split with Waste Management Federal Services (WMFS), and the other with Duratek.

Drinking Water

Drinking water is supplied to DOE facilities on the Hanford Site by numerous water systems, most of which use water from the Columbia River. One of these systems, in the 400 Area (the Fast Flux Test Facility [FFTF]), uses groundwater from the unconfined aquifer beneath the site. Typically, DOH and PNNL split one or more drinking water samples each year. There were no split drinking water samples in 2005. However, DOH collected drinking water samples from the Laser Interferometer Gravitational-Wave Observatory (LIGO) Facility and the FFTF on the Hanford Site, and from the Edwin Markham elementary school in Pasco.

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 those 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 C-14, I-129, Sr-90, Tc-99, and isotopes of uranium were added where appropriate.

Riverbank Seeps

Columbia River seep samples were collected in the fall when the river flow is typically the lowest. This ensures 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. All samples were analyzed for gross alpha, gross beta, gamma emitting radionuclides, and H-3. Specific analyses for Sr-90, Tc-99, and isotopes of uranium were added where appropriate.

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 samples are also collected from near the Hanford shoreline at locations where known groundwater plumes are near the river. In addition, Columbia River water is collected at Richland. Finally, surface water samples are collected from irrigation pumping stations located at Horn Rapids and Riverview.

Samples were split in the field and analyzed unfiltered. All samples were analyzed for isotopes of uranium and H-3. Analyses for gross alpha, gross beta, gamma emitting radionuclides, Sr-90, and Tc-99 were added where appropriate. Discharge samples from the 310 Treated Effluent Disposal Facility were analyzed for gross alpha, gross beta, gamma emitting radionuclides, and H-3.

Drinking Water

Drinking water is monitored by sampling tap water. The samples were analyzed for gross alpha, gross beta, gamma emitting radionuclides, and H-3. There were no split drinking water samples in 2005. However, DOH collected three drinking water samples.

Summary

A summary of the split water samples is presented in Table 3.2.1.

Water Matrix	Analytes	Number of Sample Sites	Number of Samples
Groundwater	Co-60; Cs-134, 137; Eu-152, 154, 155; gross alpha; gross beta; H-3; I-129; Ru-106; Sb-125; Sr-90; Tc-99; U-234, 235, and 238	18	22
Riverbank Seep	Co-60; Cs-134, 137; Eu-152, 154, 155; gross alpha; gross beta; H-3; I-129; Ru-106; Sb-125; Sr-90; Tc-99; U-234, 235, and 238	3	3
Surface Water	Co-60; Cs-134, 137; Eu-152, 154, 155; gross alpha; gross beta; H-3; Ru-106; Sb-125; Sr-90; Tc-99; U-234, 235, and 238	12	13
Discharge Water	Co-60, Cs-137, gross alpha, gross beta, H-3	1	2

Table 3.2.1 Summary of Split Water Samples

3.2.4 Comparison of DOH and Contractor Data

In 2005, DOH split groundwater, surface water, and riverbank seep water samples with PNNL. In addition, DOH split discharge water samples with Waste Management Federal Services (WMFS) and Duratek. The analysis of the split water sample results is discussed below. See section 2.2.4.2 for a discussion of scatter plots and regression analyses that are used to assess these data.

Gamma Emitting Radionuclides

Gamma emitting radionuclides also emit beta particles, and in some cases (for example, I-129), the beta particle is more important from the standpoint of health impacts. In this report, the term *gamma emitting radionuclide* refers to the fact that radioactivity concentrations were obtained by measuring gamma ray activity using gamma spectroscopy.

With the exception of a DOH measurement of I-129 in a groundwater well, the DOH and PNNL concentrations of gamma emitting radionuclides in water samples were all below detection limits, including concentrations of Co-60, Cs-134, Cs-137, Eu-152, Eu-154, Eu-155, Ru-106, and Sb-125.

Historically, DOH and PNNL split water results are in good agreement for all gamma emitting radionuclides except I-129. However, in 2005, DOH and PNNL did not split groundwater samples from any wells that typically have detectable concentrations of I-129. See section 4 of this report for a further discussion of I-129.

Gross Alpha and Gross Beta

The DOH and PNNL gross alpha concentrations in water samples are in fair agreement. The split gross alpha results in all water samples are shown in Figure 3.2.2, where it can be seen that the DOH and PNNL data generally agree. However, a systematic bias is revealed upon close inspection of the data.

Figure 3.2.3 shows a scatter plot for historical DOH and PNNL gross alpha concentrations in water samples. This scatter plot, and all others in this section, show data for all water samples, which include groundwater, surface water, and riverbank seep water. The figure shows that DOH disproportionately reports higher concentrations than PNNL, as indicated by the data points to the right of the solid black line.

The DOH and PNNL gross beta concentrations in water samples are in fair agreement. The split gross beta results in all water samples are shown in Figure 3.2.4, where it can be seen that the DOH and PNNL data generally agree. However, a systematic bias is revealed upon close inspection of the data.

Figure 3.2.5 shows a scatter plot for historical DOH and PNNL gross beta data, specifically for data with concentrations below 125 pCi/L. The figure indicates that when gross beta concentrations are below 125 pCi/L, there is a systematic bias in the results in which DOH disproportionately reports higher concentrations than PNNL, as indicated by the data points to the right of the solid black line. For concentrations above 125 pCi/L, the DOH and PNNL concentrations generally agree.

H-3, Sr-90, and Tc-99

The DOH and PNNL tritium (H-3) concentrations in water samples are in fair agreement. Figure 3.2.6 shows H-3 results in split water samples for cases where concentrations are greater than 100 pCi/L (results for lower concentrations are left out to make the graph easier to read). As can be seen, the DOH and PNNL reported concentrations are similar; however, DOH generally reports slightly higher concentrations than PNNL. This phenomenon has been observed historically, as seen in Figure 3.2.7, which shows the scatter plot of historical H-3 water sample results. The regression analysis indicates that PNNL results are typically 8% less than those reported by DOH.

The DOH and PNNL concentrations for Sr-90 and Tc-99 in water samples are in good agreement. As an example, Figure 3.2.8 shows the split Sr-90 concentrations in water samples in which the concentrations are above the DOH detection limit of 0.7 pCi/L. Historically, the DOH and PNNL split results for Sr-90 and Tc-99 in water are in good agreement.

Uranium Isotopes

The DOH and PNNL isotopic uranium concentrations for U-234, 235, and 238 in water samples collected in 2005 are in good agreement. Historically, the DOH and PNNL split results for these uranium isotopes in water are in good agreement.

DOH detected U-236 in several groundwater and seep water samples. No U-236 results were reported by PNNL. Section 3.2.5 discusses the DOH U-236 results.

Discharge Water Samples Split with WMFS and Duratek

The concentrations of Co-60, Cs-137, gross alpha, gross beta, and H-3 in split discharge water samples reported by DOH are all in good agreement with those reported by WMFS and Duratek. Historically, the DOH and DOE contractor discharge water concentrations are in good agreement. Figure 3.2.9 shows historical gross alpha concentrations in 300 DNR discharge water samples split with WMFS.

3.2.5 Discussion of DOH Results

In addition to the split water samples discussed above, DOH collected and analyzed drinking water samples from the LIGO Facility, the FFTF, and from the Edwin Markham elementary school in Pasco; and a groundwater sample from well 699-35-70. DOH also reported C-14 and U-236 in some of the split water samples. Results from these additional DOH samples and analyses are included in the discussion below.

Concentrations of gamma emitting radionuclides in all 2005 water samples analyzed by DOH were below detection limits, except for I-129 in one groundwater well. Gamma emitting radionuclides include Co-60, Cs-134, Cs-137, Eu-152, Eu-154, Eu-155, I-129, Ru-106, and Sb-125. Detection limits are listed in Appendix B. Iodine-129 was detected by DOH in groundwater well 699-35-70 at 7.5 pCi/L. DOH typically detects I-129 in this well, at concentrations ranging from 5 to 35 pCi/L, as can be seen in Figure 3.2.10. All 2005 results for gamma emitting radionuclides in water samples are similar to historical data.

DOH detected C-14 at 470 pCi/L from groundwater well 199-K-27. This well is in the vicinity of a known C-14 groundwater plume at the 100K Area, and the result is similar to historical concentrations detected in other nearby wells.

DOH routinely detects H-3, Sr-90, Tc-99, isotopes of uranium, gross alpha, and gross beta in Hanford water samples. These radionuclides are detected in areas of known groundwater plumes or in areas where groundwater plumes are known to be entering the Columbia River. In 2005, most concentrations reported by DOH for these radionuclides were consistent with historical results.

DOH detected H-3 in groundwater wells at concentrations ranging from below the detection limit to 305,000 pCi/L (well 699-35-70). Concentrations above the 20,000 pCi/L EPA drinking water standard were detected in wells 199-K-109A, 199-K-27, 199-N-14, 699-26-33, 699-35-70, 699-41-1A, and 699-60-60. Tritium (H-3) concentrations in most wells historically sampled by DOH continue to steadily decrease with time. Groundwater wells 199-K-109A and 199-K-27, at the 100K Area, had sharp increases in H-3 concentrations in 2003; however, the concentrations have since been decreasing as seen in Figure 3.2.11.

DOH detected H-3 in most of the riverbank seep water samples, with a maximum concentration of 38,000 pCi/L from a seep at the Old Hanford Town Site. H-3 concentrations at the other seeps were less than 10,000 pCi/L. These results are consistent with historical DOH riverbank seep results. Tritium was also detected at low levels in several of the Columbia River surface water samples, with a maximum concentration of 280 pCi/L adjacent to the 300 Area. Tritium was detected in TEDF discharge water at 80 pCi/L, and in FFTF drinking water at 3,000 pCi/L. Tritium was not detected in the LIGO or Edwin Markham drinking water samples.

DOH detected Sr-90 in groundwater wells at concentrations ranging from below the detection limit to 2,700 pCi/L (well 199-K-109A). Concentrations above the 8 pCi/L EPA drinking water standard were detected at wells from the 100F, 100K, and 100N Areas, where the 2005 results are consistent with historical concentrations at these locations. Concentrations of Sr-90 in riverbank seep water ranged from below the detection limit to 3 pCi/L at a seep in the 100K Area. Strontium-90 was not detected in the 100N Area seep water sample or in any of the Columbia River surface water samples.

DOH detected Tc-99 in groundwater wells at concentrations ranging from below the detection limit to 170 pCi/L (well 699-60-60). Technitium-99 was detected in Old Hanford Town Site seep water at 55 pCi/L, and was not detected in any of the Columbia River surface water samples. The concentrations of Tc-99 measured in 2005 water samples are consistent with historical results, and all concentrations are below the EPA drinking water standard of 900 pCi/L.

DOH detected total uranium (the sum of all uranium isotopes) concentrations in water samples ranging from below the detection limit to 107 pCi/L at a 300 area riverbank seep. Total uranium was also detected above the EPA drinking water standard of 21 pCi/L at groundwater well 399-1-17A in the 300 Area (40 pCi/L). The 2005 results at these locations are consistent with historical results.

Isotopic uranium results are typcially reported for U-234, U-235, and U-238. Uranium-236 is another isotope of uranium, one that does not occur in nature, but rather is a byproduct of Hanford reactor operations. Uranium-236 is occasionally detected in Columbia River sediments and in water samples. In 2005, DOH detected U-236 in a groundwater samples from the 100H and 300 Areas, and in a riverbank seep from the 300 Area. Concentrations ranged from 0.3 to 1.2 pCi/L, and the 2005 concentrations are consistent with historical results.

Gross alpha and gross beta analyses are for the purpose of screening, and are generally indicative of the presence of uranium isotopes and Sr-90, respectively. For samples where both gross alpha and uranium concentrations were analyzed, the gross alpha concentrations were typically consistent with the sum of concentrations from all uranium isotopes. For samples where both gross beta and Sr-90 concentrations were analyzed, gross beta concentrations were typically consistent with twice the Sr-90 concentrations (gross beta analysis detects the beta emissions from both Sr-90 and its daughter, Y-90).

Summary

Radionuclides detected in groundwater wells include C-14, H-3, I-129, Sr-90, Tc-99, and isotopes of uranium. Most radionuclide concentrations in 2005 were similar to historical data, and were detected in the vicinity of known groundwater plumes.

Radionuclides detected in riverbank seep water include H-3, Sr-90, Tc-99, and isotopes of uranium. Most radionuclide concentrations in 2005 were similar to historical data, and were detected in the vicinity of where groundwater plumes are known to be entering the Columbia River.

Radionuclides detected in surface water include H-3 and isotopes of uranium. Most radionuclide concentrations were either below detection limits or were similar to background concentrations detected at Priest Rapids Dam upstream of the Hanford Site. Elevated H-3 concentrations were detected in near-shore Columbia River surface water from the Old Hanford Townsite. However, all surface water concentrations were below EPA drinking water standards.

Radionuclides detected in drinking water samples include H-3. However, all concentrations were below EPA drinking water standards (20,000 pCi/L for H-3).

Radionuclides detected in discharge water include H-3. All concentrations were below limits set by the Department of Natural Resources. These limits are: 15 pCi/L gross alpha, 50 pCi/L gross beta, and 20,000 pCi/L H-3.

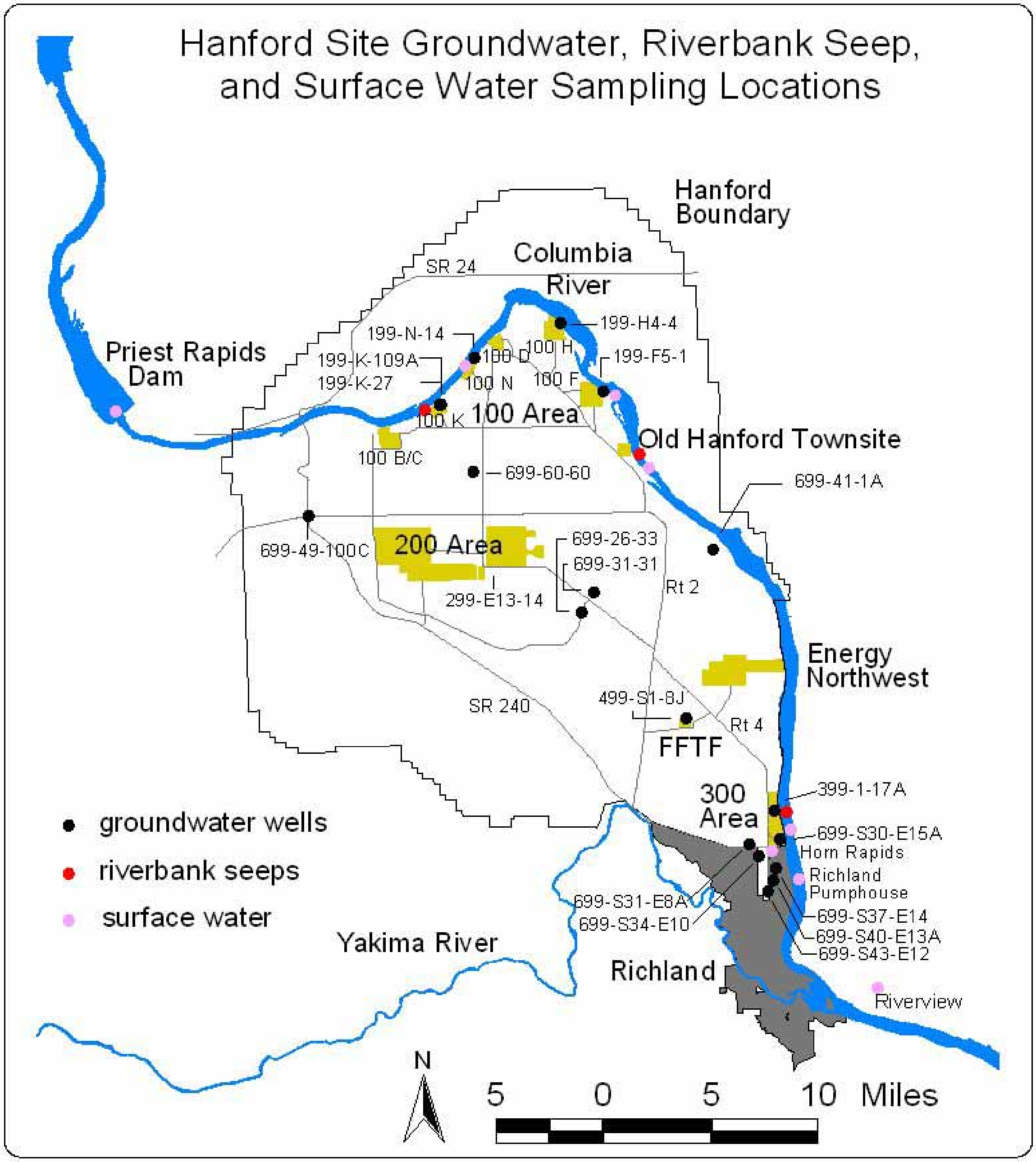

Figure 3.2.1 Water Monitoring Locations

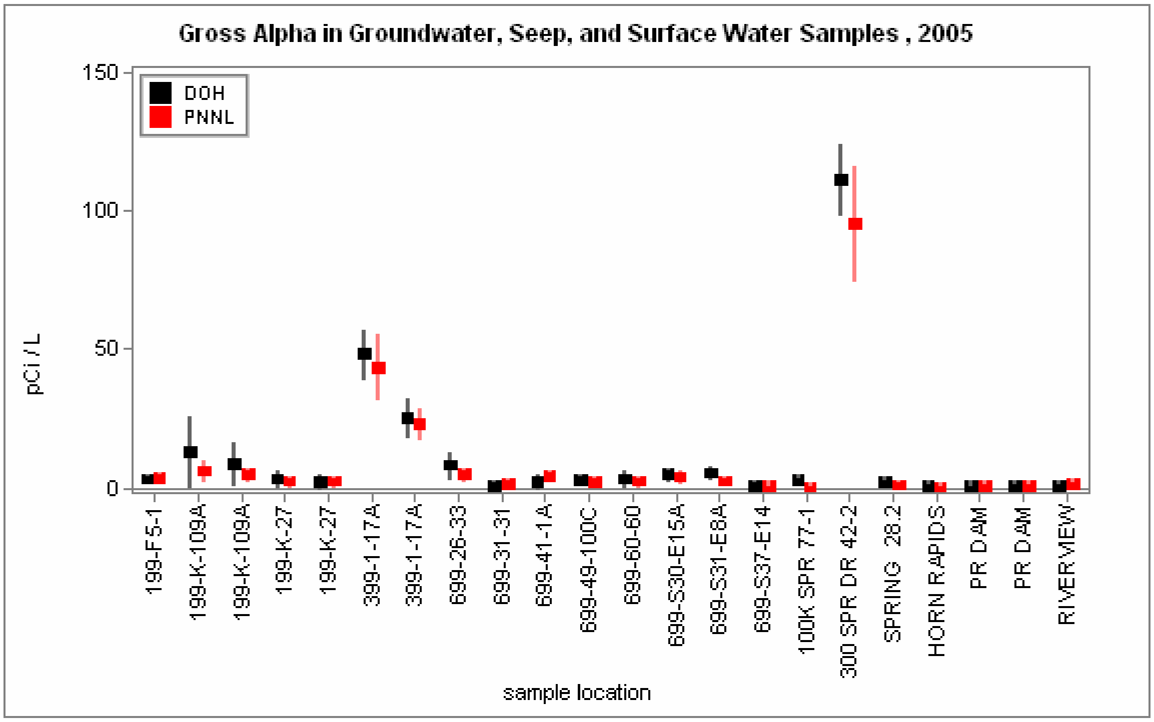

Figure 3.2.2 DOH and PNNL Gross Alpha Concentrations in Water Samples

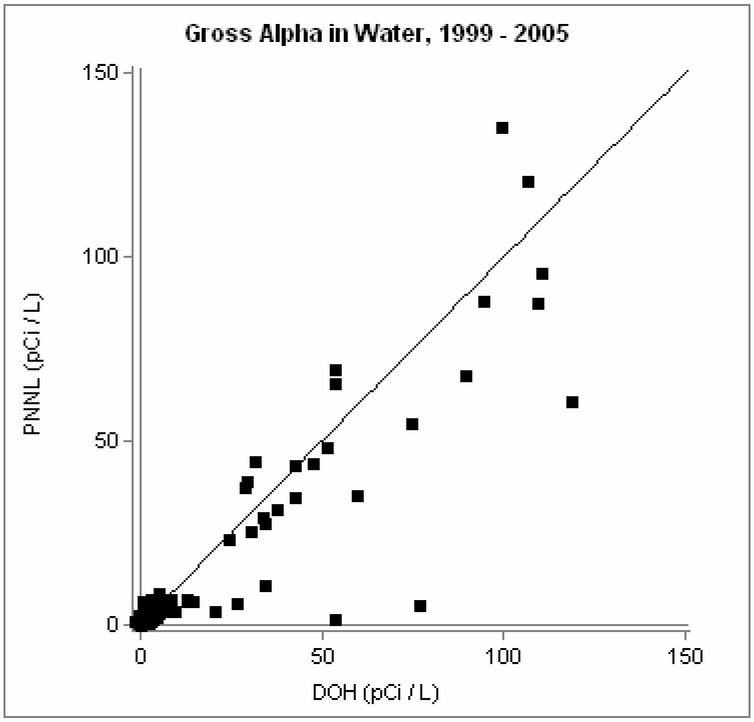

Figure 3.2.3 DOH and PNNL Scatter Plot for Historical Gross Alpha Concentrations in Water Samples

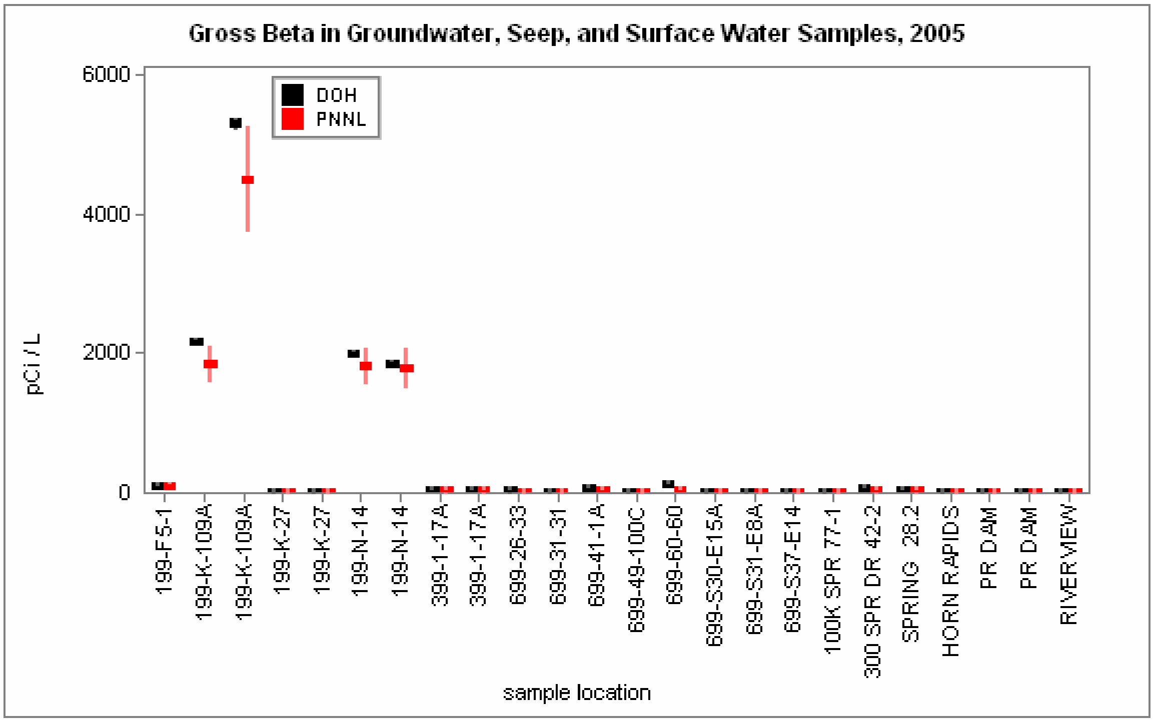

Figure 3.2.4 DOH and PNNL Gross Beta Concentrations Water Samples

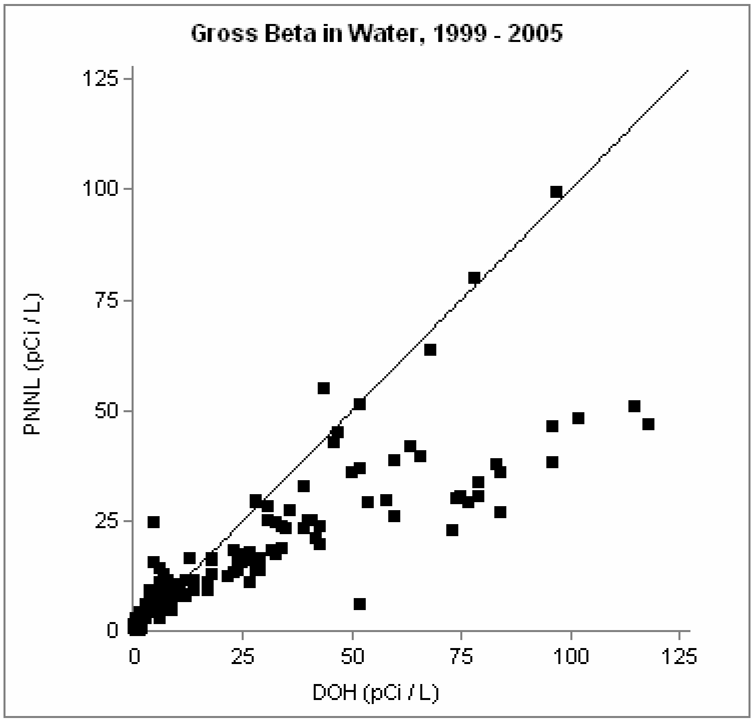

Figure 3.2.5 DOH and PNNL Scatter Plot for Historical Gross Beta Concentrations in Water Samples (results less than 125 pCi/L)

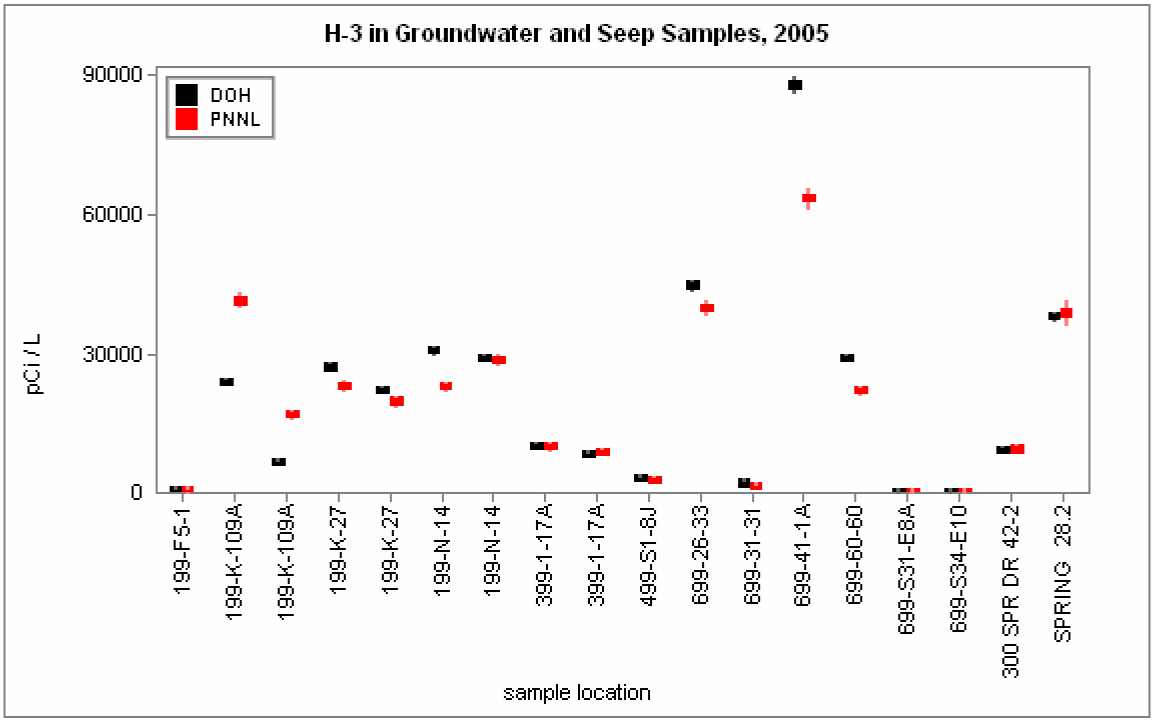

Figure 3.2.6 DOH and PNNL H-3 Concentrations in Water Samples for Concentrations Greater Than 100 pCi/L

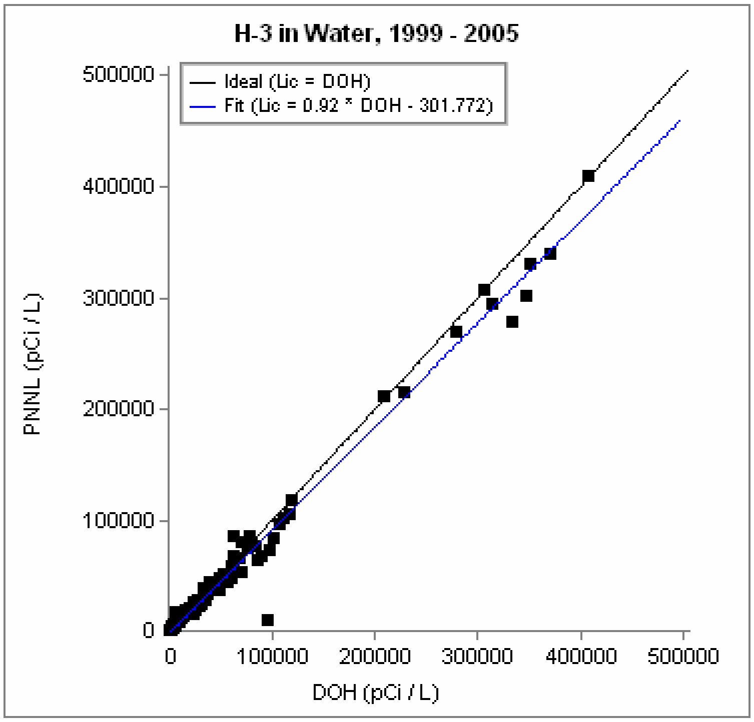

Figure 3.2.7 DOH and PNNL Scatter Plot for Historical H-3 Concentrations in Water

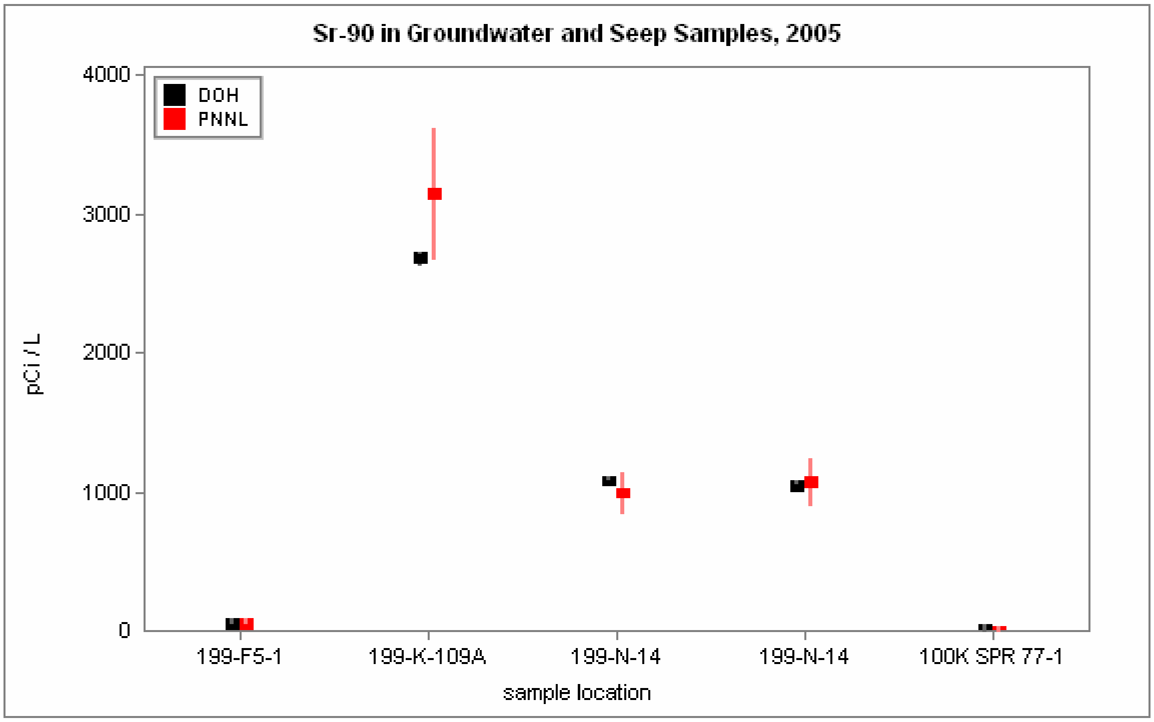

Figure 3.2.8 DOH and PNNL Sr-90 Concentrations in Water Samples for Concentrations Greater Than the DOH Detection Limit of 0.7 pCi/L

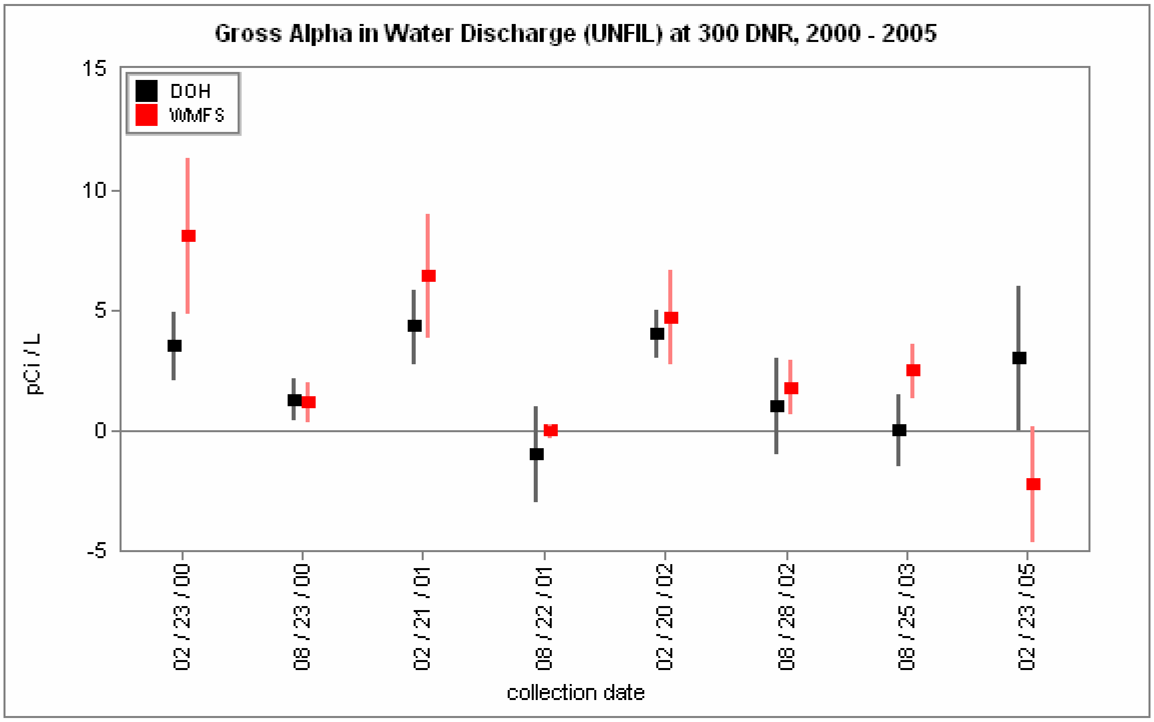

Figure 3.2.9 DOH and WMFS Historical Gross Alpha Concentrations in Discharge Water at the 300 DNR TEDF Facility

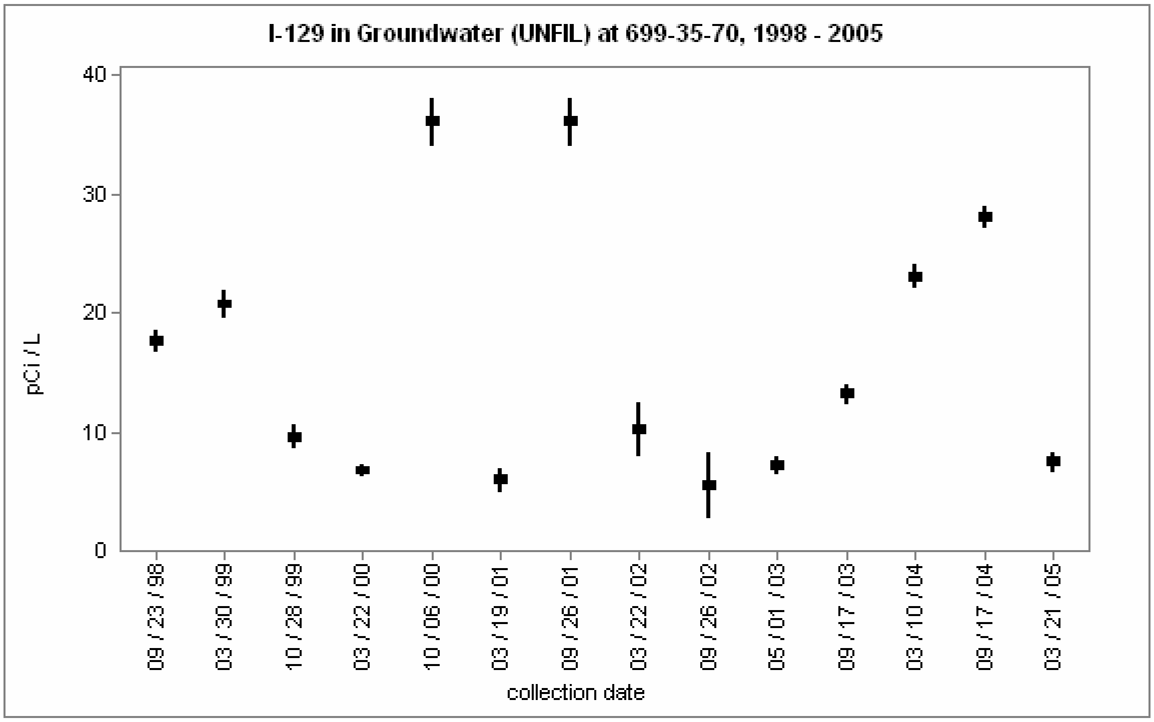

Figure 3.2.10 Historical I-129 Concentrations in Groundwater Well 699-35-70

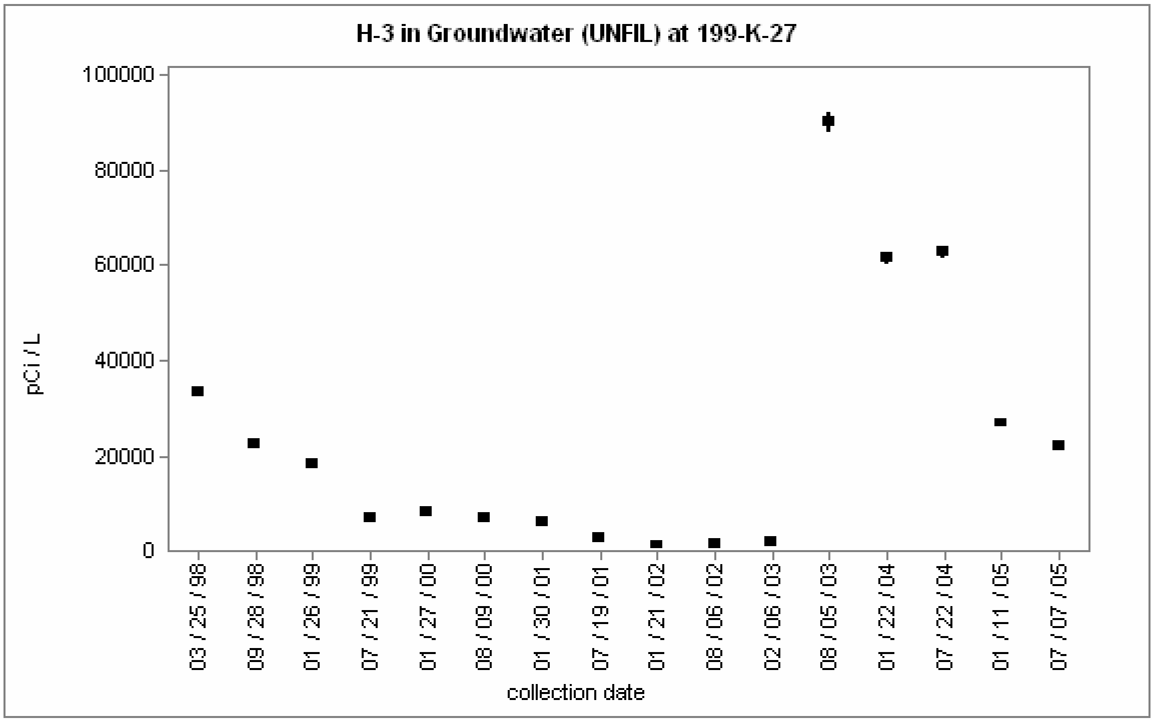

Figure 3.2.11 Historical H-3 Concentrations in Groundwater Well 199-K-27

3.3 External Gamma Radiation Monitoring

Major Findings:

- The DOH and DOE contractor results are in good agreement.
- Radiation exposure rates at most DOH TLD locations on the Hanford Site are consistent with historical results and are similar to rates at locations outside the Hanford perimeter.
- Exposure rates near the KE Basins at Hanford's 100K Area were anomalously high in 2005 due to temporary outdoor storage of radioactive materials. Exposure rates at the closest public access point, the Columbia River, were consistent with background.

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 may contribute to man-made sources of gamma radiation. In addition to oversight of the DOE monitoring program, DOH compares on-site and off-site TLD results to determine if Hanford is impacting workers or the public.

3.3.2 Monitoring Locations

In 2005, DOH operated 25 ambient gamma radiation monitoring sites under the Hanford Environmental Oversight Program, five of which are colocated with Duratek, and 20 of which are colocated with PNNL. The site locations are shown in Figure 3.3.1. Thirteen of the TLD locations are located near Hanford facilities or contaminated areas. Three sites (Yakima and Wye Barricades, and LIGO Facility) are located on the Hanford Site, but away from contaminated areas. Six of the sites (Stations 4, 6, 8, and 56, Byer's Landing; and Benton County Shops) are located just outside the Hanford Site perimeter. The remaining three sites (Othello, Toppenish, and Yakima Airport) are significantly distant from the Hanford Site. Many of the TLD sites are colocated with air monitoring sites.

3.3.3 Monitoring Procedures

TLDs are deployed on a quarterly basis, with the TLDs retrieved at the end of each calendar quarter. The DOH TLDs are 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 milliroentgen 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 five colocated sites are shown in Figure 3.3.2, and the DOH and PNNL TLD results for the twenty colocated sites are shown in Figures 3.3.3 through 3.3.6. Each of these figures show the first, second, third, and fourth quarter results for each site. As can be seen, there is good agreement between the DOH and DOE contractor results, as the two data sets follow the same trends. However, close inspection of the figures indicates that the Duratek and PNNL dose rates are typically slightly higher than those reported by DOH.

DOH/Duratek and DOH/PNNL scatter plots for the colocated TLD sites are shown in Figures 3.3.7 through 3.3.10. Historical results and results for only 2005 are shown in separate figures. The small discrepancy between DOH/Duratek and DOH/PNNL results is seen in the scatter plots by the preponderance of points to the left of the solid black line, which indicates that the DOE contractor is reporting slightly higher exposure rates (about 10%) than DOH. This discrepancy is small, and is not considered significant.

3.3.5 Discussion of DOH Results

DOH typically measures the highest radiation exposure rates at site 100N-1, which is within Hanford's 100N Area. In 2005, the average exposure rate at this site was 0.28 mR/day. A person spending 365 days at this location would receive approximately 22 mrem/year greater than the annual background exposure rate from outside the Hanford perimeter (perimeter locations are discussed below). This exposure rate is well below radiation exposure limits for workers, and is also below the DOE limit of 100 mrem/year to the public from DOE operations. There is no public access to this location on the Hanford Site.

The historical data for site 100N-1 are shown in Figure 3.3.11. Exposure rates at this site have been decreasing over time due to the natural decay of Co-60 surface contamination (half life = 5 years) at the 100N Area. With the recent cleanup of contaminated surface soil, exposure rates over the past few years now appear constant at rates only slightly higher than those at perimeter locations.

Anomalous results were seen in 2005 at location KE Basin within Hanford's 100K Area. Figure 3.3.12 shows historical TLD data at this location. Data from 2006 are included in this figure to completely show the trend. Radioactive material was temporarily stored outside of the KE Basin facility in 2005 and 2006. The TLD detected increased radiation exposure rates due to this material. The storage area was properly posted and access was restricted. Measurements along the Columbia River at the 100K Area, the closest public access point, did not detect elevated exposure rates.

The highest annual exposure rate at the KE Basin, from June, 2005 to June, 2006, was approximately 140 mrem/year greater than the annual background exposure rate from outside the Hanford perimeter. This exposure rate is well below radiation exposure limits for workers. Exposure rates have returned to normal during the last half of 2006. All other sites monitored by DOH had 2005 TLD data which were consistent with historical results.

With the exception of sites 100N-1 and KE Basin discussed above, the annual average exposure rate from all other sites near contaminated or operating facilities was 0.22 mR/day (data shown in Figures 3.3.2 and 3.3.3), which is identical to the annual average exposure rate from sites at Hanford but away from contaminated facilities (data shown in Figure 3.3.4) and from sites outside the Hanford perimeter (data shown in Figure 3.3.5). Therefore, it appears that most areas on the Hanford Site monitored by DOH do not contribute additional exposure rates above background.

The annual average exposure rate at locations distant from Hanford, 0.18 mR/day (data shown in Figure 3.3.6), is slightly lower than the rate at perimeter locations. All TLD monitors at distant locations are located in areas where the ground is covered by concrete or gravel, whereas locations at the Hanford perimeter and on the Hanford Site are directly over soil. For example, the location at Yakima Airport is on the concrete tarmac at the airport. Concrete and gravel will shield the terrestrial radiation component of background that comes from natural radioactive elements in the earth's crust. Therefore, lower exposure rates are expected at these distant locations.

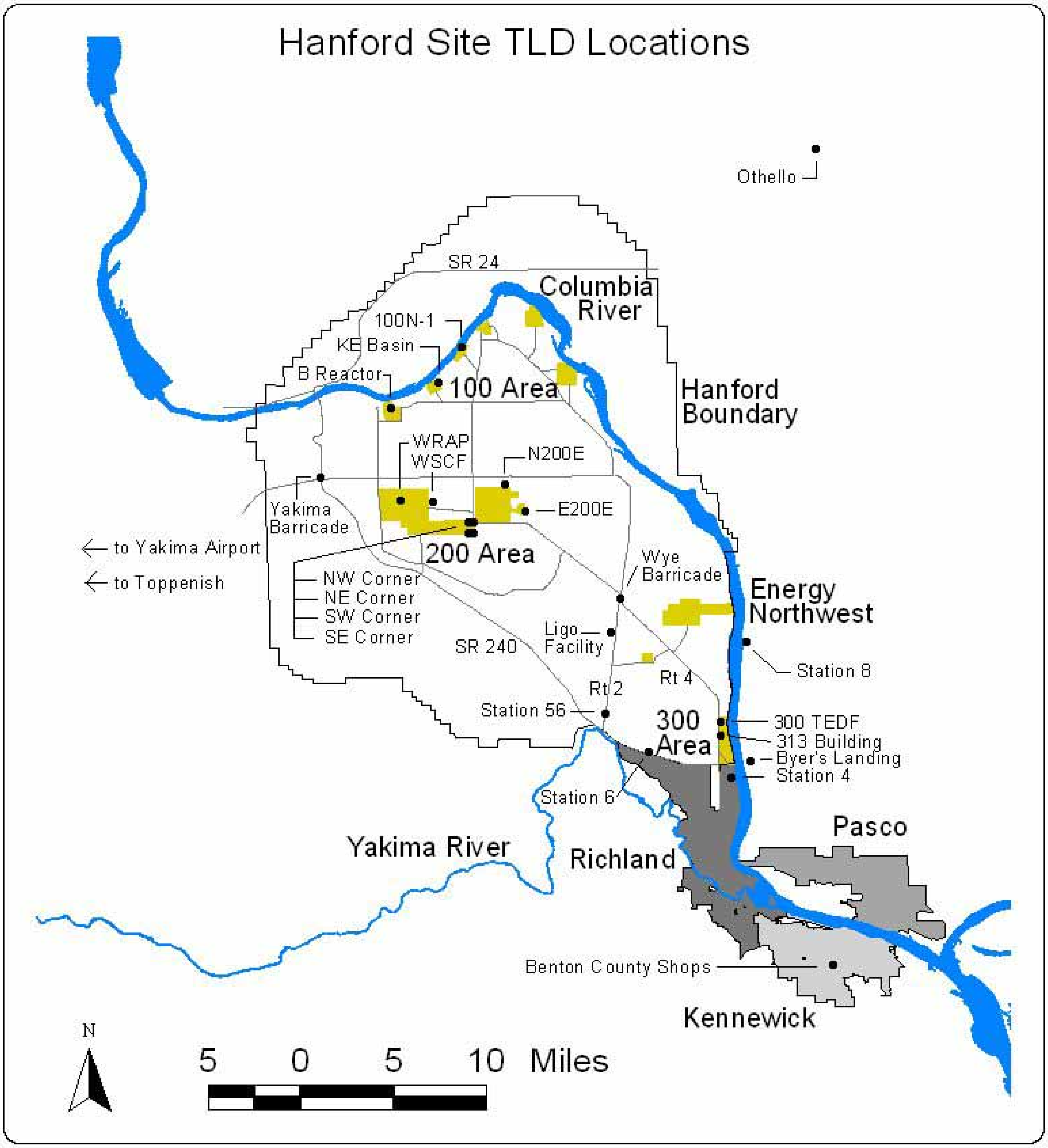

Figure 3.3.1 External Radiation Monitoring (TLD) Locations

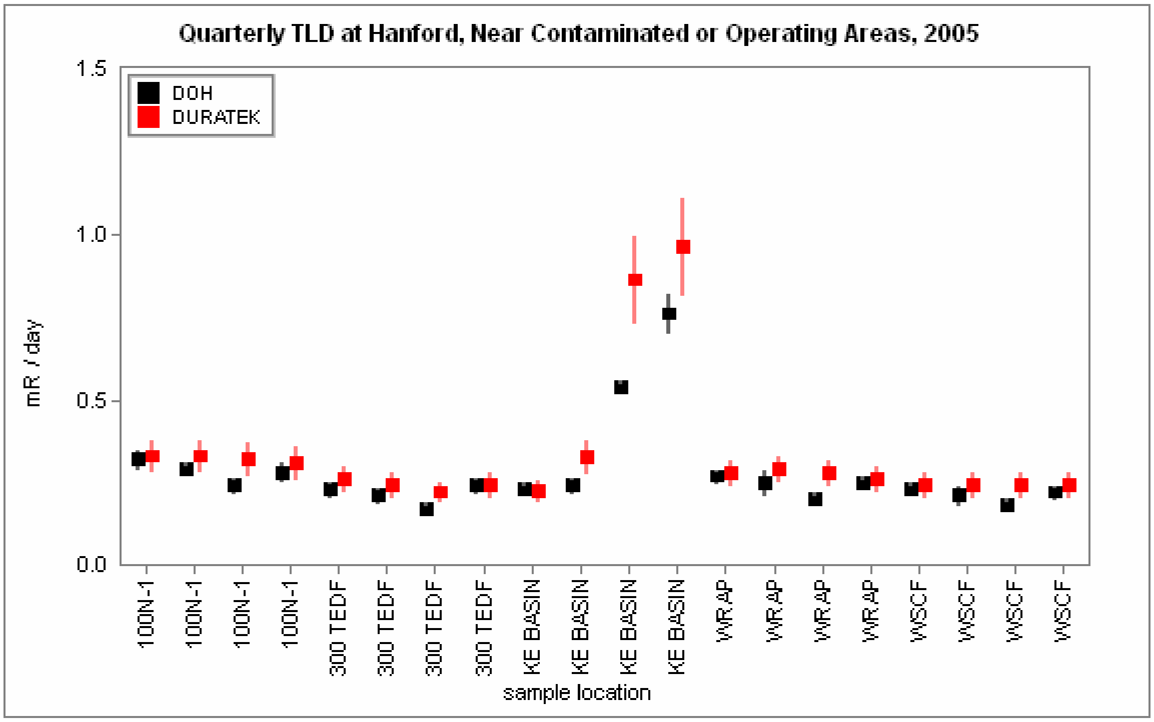

Figure 3.3.2 DOH and Duratek Quarterly TLD Results at Sites Near Operational or Contaminated Facilities

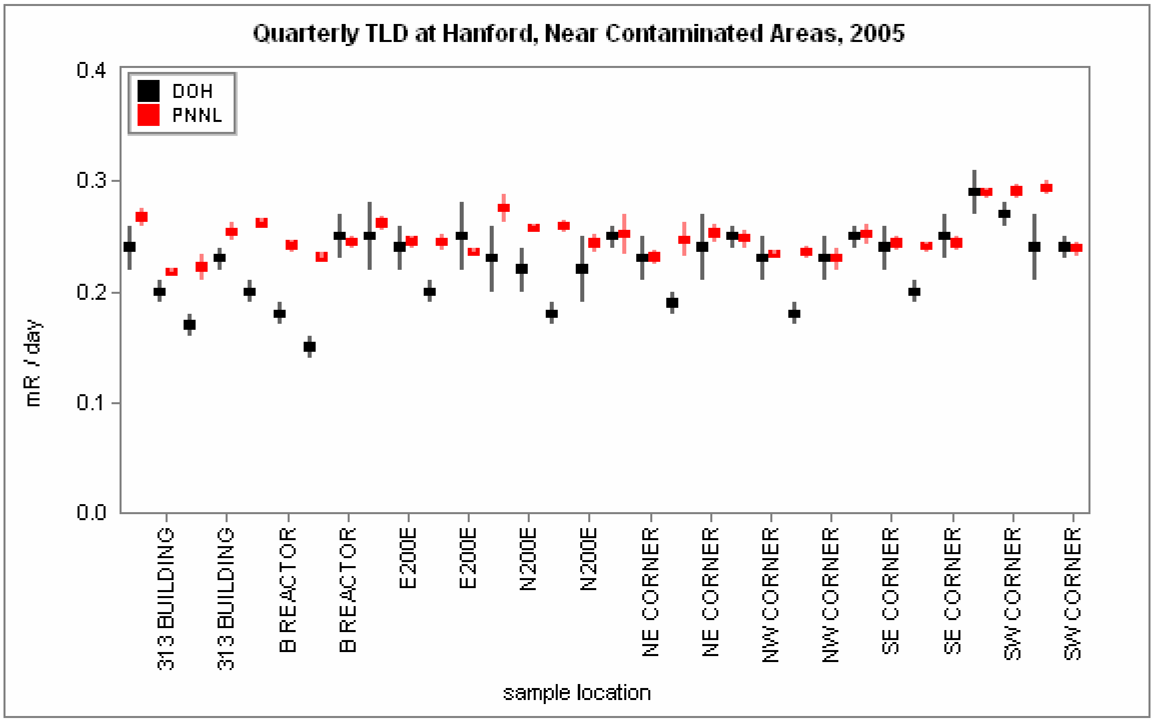

Figure 3.3.3 DOH and PNNL Quarterly TLD Results at Sites Near Operational or Contaminated Facilities

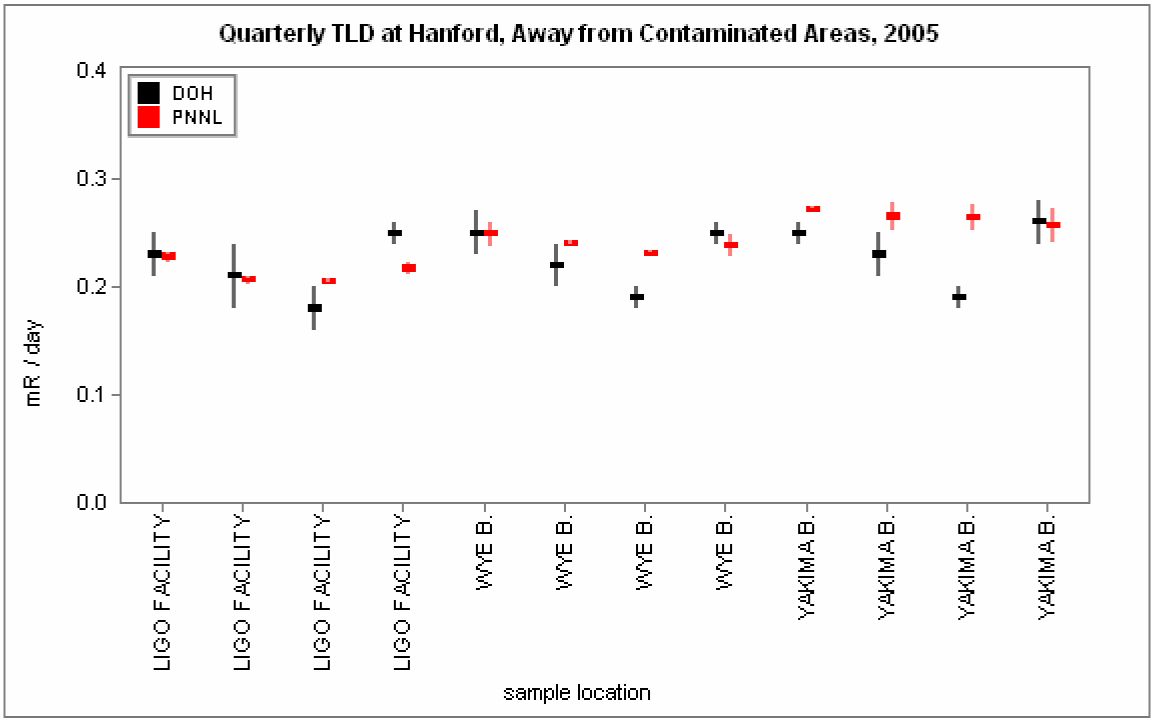

Figure 3.3.4 DOH and PNNL Quarterly TLD Results at Sites Away from Operational or Contaminated Facilities

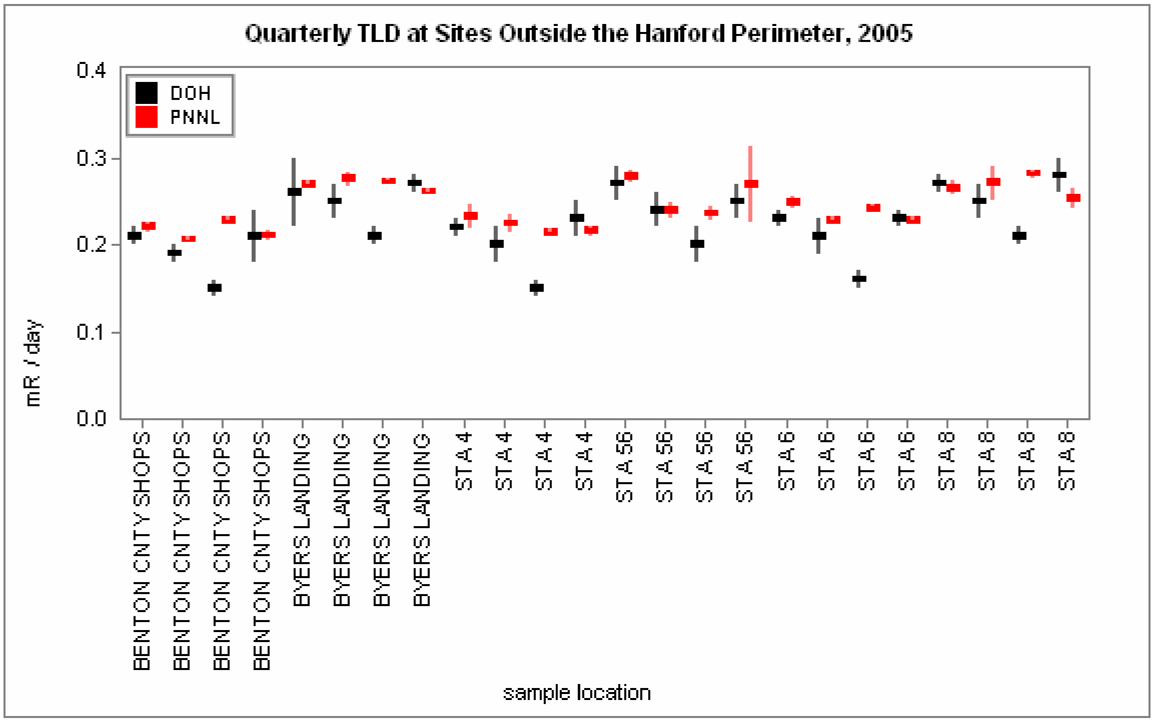

Figure 3.3.5 DOH and PNNL Quarterly TLD Results at Sites Located Outside the Hanford Perimeter

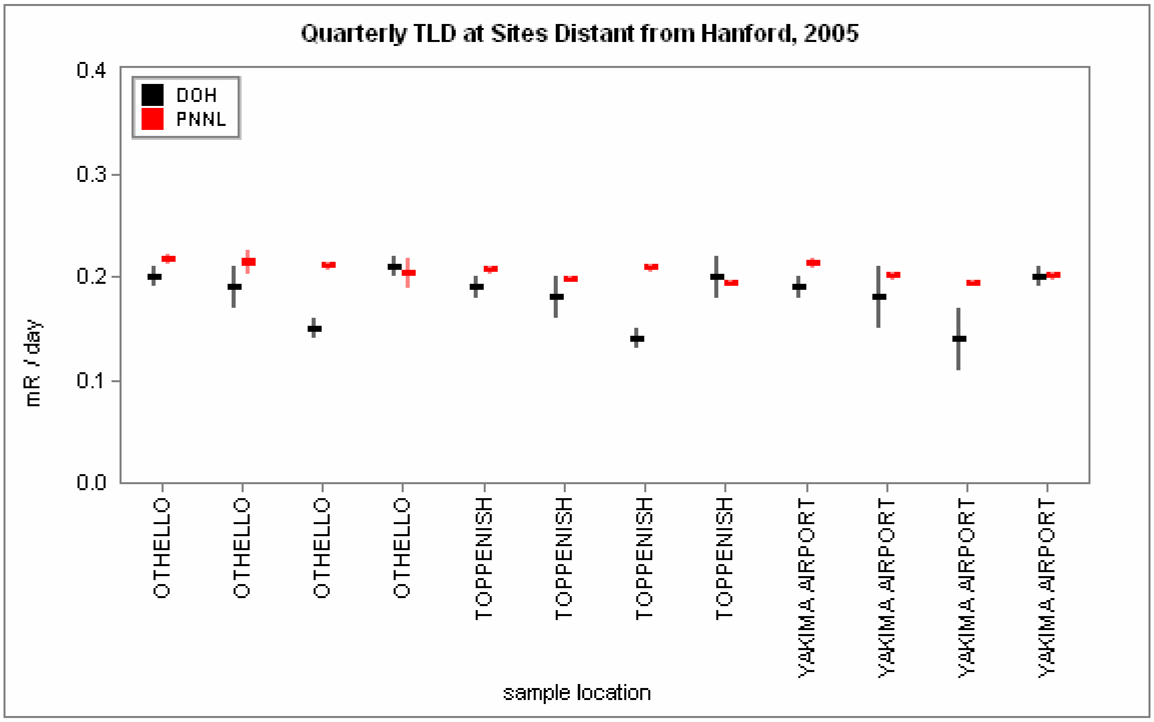

Figure 3.3.6 DOH and PNNL Quarterly TLD Results at Sites Distant from Hanford

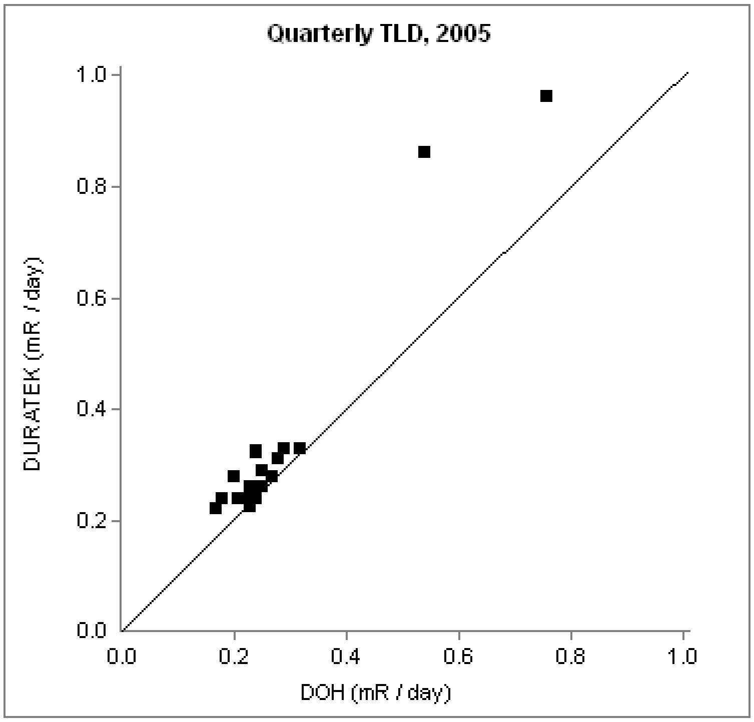

Figure 3.3.7 DOH and Duratek Scatter Plot for TLD Results

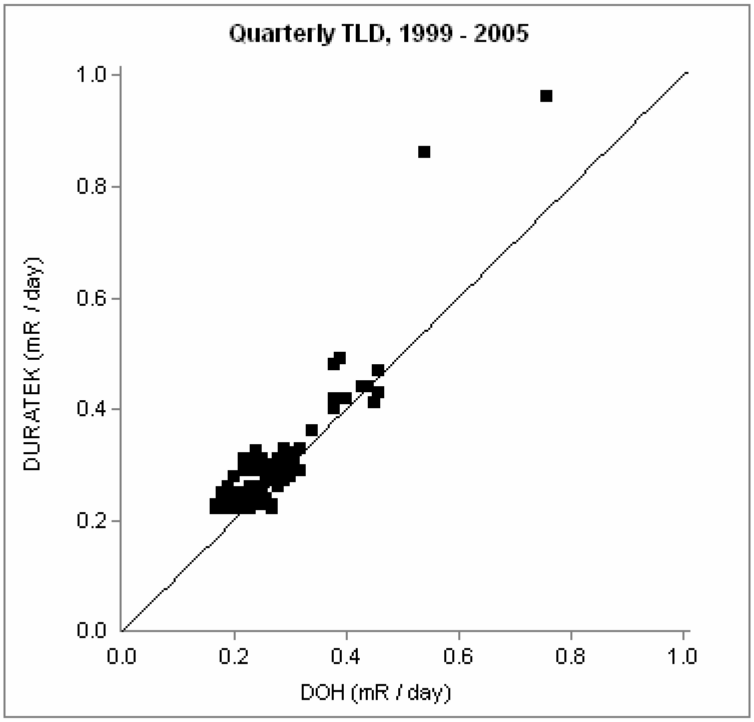

Figure 3.3.8 DOH and Duratek Scatter Plot for Historical TLD Results

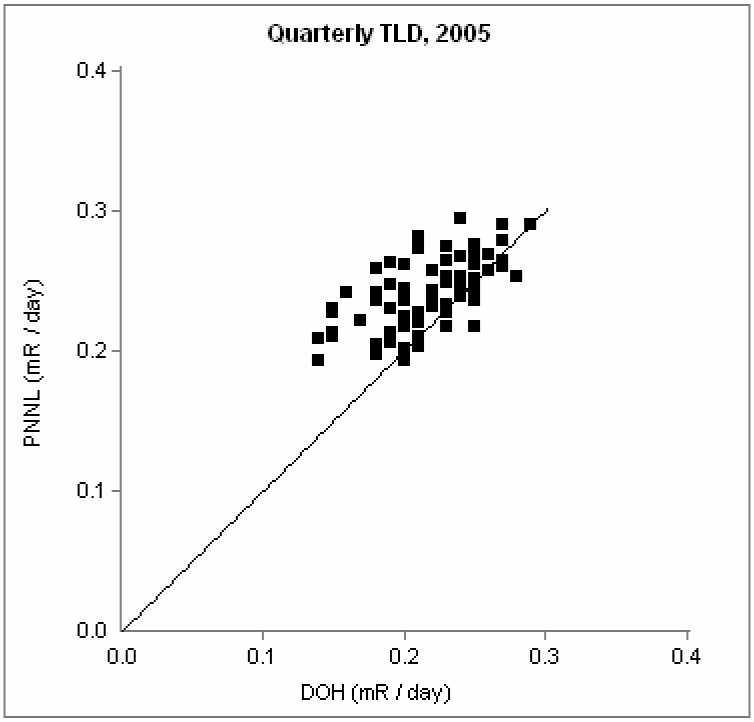

Figure 3.3.9 DOH and PNNL Scatter Plot for TLD Results

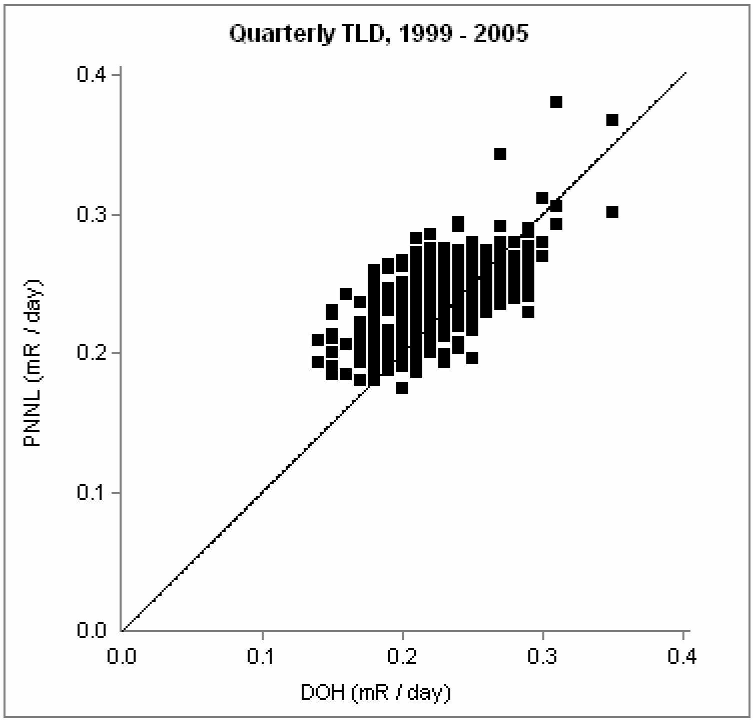

Figure 3.3.10 DOH and PNNL Scatter Plot for Historical TLD Results

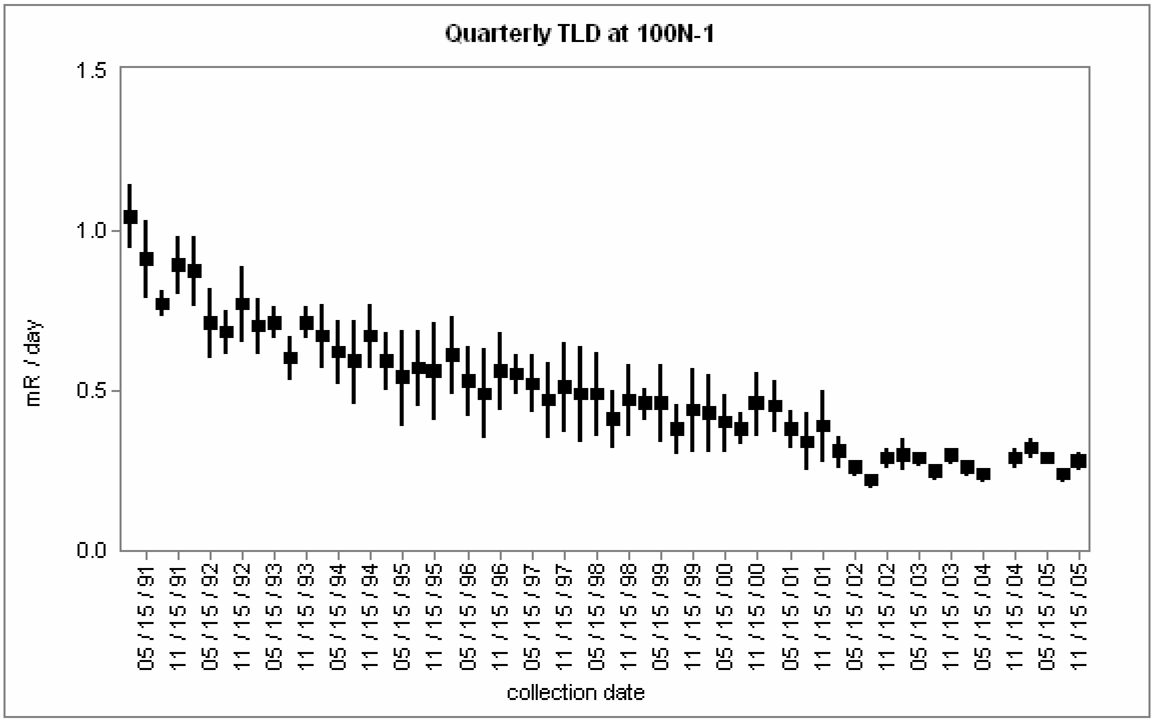

Figure 3.3.11 DOH Historical TLD Results at Location 100N-1 in the 100N Area

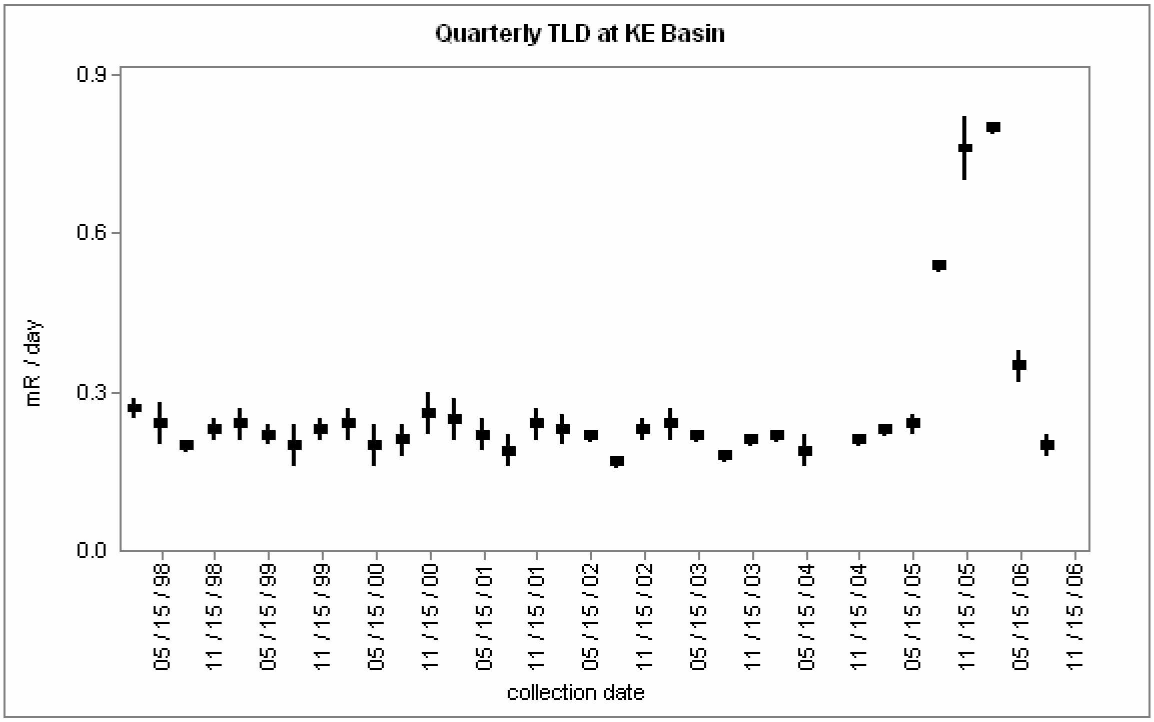

Figure 3.3.12 DOH Historical TLD Results at Location KE Basin in the 100K Area

3.4 Soil and Sediment Monitoring

Major Findings:

- DOH and PNNL results in sediment and soil samples are in good agreement for all radionuclides, except for isotopes of uranium. The discrepancy in uranium originates from a difference in DOH and PNNL laboratory analytical methods.
- Concentrations of radionuclides in most sediment and soil samples are either consistent with those at background locations or are in the range of activity that has been historically observed at Hanford.

3.4.1 Purpose and General Discussion

Contaminated soil and river sediments are a potential source of radiation exposure for people and biota in the environment. Human exposure may result from direct exposure to contaminated soil/sediment; ingestion of contaminated soil/sediment; ingestion of water contaminated by sediment resuspension; inhalation of contaminants resuspended in air; or ingestion of fish, animals, plants, or farm products exposed to contaminated soil and sediments.

Radionuclides in soil and sediment originate from many sources, including natural terrestrial sources, atmospheric fallout from nuclear weapons tests, and contaminated liquid and gaseous effluents. In addition, contaminants can reach Columbia River sediments from erosion of contaminated soil and flow of contaminated groundwater. Cesium-137, Sr-90, and plutonium isotopes are radionuclides consistently seen in soil or sediments since they exist in world-wide fallout as well as in effluents from the Hanford Site. Uranium, also consistently seen in soil and sediment, occurs naturally in the environment in addition to being present from Hanford operations.

3.4.2 Monitoring Locations

In 2005, four soil samples and seven Columbia River sediment samples were split with PNNL. The soil samples were collected from the Hanford Reach National Monument at locations near Vernita Bridge on Highway 240 and McGee Ranch (all four sites are labeled HRNM in the figures). The sediment samples were collected upriver from Hanford at Priest Rapids Dam, on the Hanford Site at the 100F Area slough, the Old Hanford Townsite, and the 300 Area; and downriver from Hanford at McNary Dam.

Priest Rapids Dam, being upstream from Hanford, is considered a background location. McNary Dam is the first dam downstream from Hanford, and therefore is expected to have the highest radionuclide concentrations. 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 2005, on-site sediment sample locations included the 100F and 300 Areas, and the Old Hanford Townsite.

3.4.3 Monitoring Procedures

Soil samples were collected by compositing four one-square foot areas, each excavated to a depth of one inch. The composited samples were split with PNNL and dried prior to analysis. 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. Sediment samples were collected by PNNL and then split with DOH. The samples were first dried, then analyzed for gamma emitting radionuclides, strontium 90, isotopic uranium, and isotopic plutonium. Analytical methods for soil and sediment are identical.

3.4.4 Comparison of DOH and Contractor Data

The DOH and PNNL split soil and sediment sample concentrations for the gamma emitting radionuclides Co-60, Cs-137, Eu-152, Eu-154, Ru-106, and Sb-125 are in good agreement. Except for Cs-137 and Eu-152, all of the results are below detection limits. The split Cs-137 and Eu-152 results are shown in Figures 3.4.1 and 3.4.2.

The split Sr-90 results, shown in Figure 3.4.3, are in good agreement, although there is a significant difference in detection limits as indicated by the size of the uncertainty bars in the figure. Most of the DOH results are considered detected, as the concentrations are above the DOH detection limit of 0.002 pCi/g. However, the PNNL detection limit is much larger, and therefore many of the PNNL results are considered below their detection limit.

All of the split results for the alpha emitting radionuclides Am-241, Pu-238, and Pu-239/240 are in good agreement. The split Pu-239/240 results in are shown in Figure 3.4.4. All of the Am-241 and Pu-238 results are below detection limits.

The DOH and PNNL split soil and sediment results for isotopes of uranium are in fair agreement. The split U-238 results in soil for 2005 are shown in Figure 3.4.5. In addition, the historical U-238 results for both soil and sediment (1999 through 2005) are shown in a scatter plot in Figure 3.4.6. The slope of the best-fit straight line to the data indicates that on average, the PNNL U-238 concentrations are approximately 85% of the concentration reported by DOH. The agreement for U-234 and U-235 is similar.

This discrepancy in uranium results for sediment originates from different laboratory procedures. DOH completely dissolves soil and sediment samples prior to analysis and reports uranium present in the entire sample, whereas the contractor laboratory reports only the uranium that can be leached from the surface of the soil or sediment granules. A similar discrepancy is seen in the U-235 and U-234 soil results (not shown).

3.4.5 Discussion of DOH Results

Radionuclides consistently identified by DOH in soil and sediment samples collected in 2005 include Cs-137, U-234, U-235, and U-238. Uranium-233 (lower limit of detection approximately 0.1 pCi/g), was not detected in any of the sediment samples. The Cs-137 results are attributed to world-wide fallout as a result of nuclear weapons testing, and most of the uranium results are attributed to natural background.

Concentrations of Cs-137 in sediment ranged from 0.2 to 0.3 pCi/g, and the concentrations in soil ranged from 0.15 to 0.5 pCi/g. All Cs-137 concentrations in 2005 samples are consistent with historical results, and most are similar to those measured at the background location at Priest Rapids Dam.

Most of the sediment samples, including the background location near Priest Rapids Dam, had U-234 and U-238 concentrations near 1 pCi/g. The maximum concentration of 2.9 pCi/g was found in the sample from the 300 Area shoreline (see Figure 3.4.5). Historically, it is typical to measure U-234 and U-238 concentrations near 3 pCi/g in 300 Area sediment samples. Higher uranium concentrations in sediment are expected from the 300 Area, since a known uranium groundwater plume is entering the Columbia River at this location.

Concentrations of U-234 and U-238 in the soil samples are all near 0.6 pCi/g, which is consistent with background. Uranium 235 concentrations in both sediment and soil ranged from less than the detection limit of 0.02 pCi/g to 0.09 pCi/g. These U-235 concentrations measured in 2005 are consistent with historical results.

Other radionuclides identified in some of the sediment and soil samples include Eu-152, Pu-239/240, Sr-90, and U-236.

DOH detected Eu-152 in several sediment samples, with concentrations ranging from 0.05 to 0.12 pCi/g (see Figure 3.4.2). All 2005 Eu-152 concentrations in sediment are consistent with historical results. The maximum concentration was found at McNary Dam, where Eu-152 is historically detected in sediment. Europium-152 has not been detected by DOH at the Priest Rapids Dam background location.

Plutonium 239/240 is often detected in sediment and soil samples, as it is typically found in the environment originating from world-wide fallout of nuclear weapons testing. Sediment concentrations from samples collected in 2005 ranged from below the detection limit of 0.005 pCi/g to 0.01 pCi/g, and soil concentrations ranged from 0.006 to 0.014 pCi/g (see Figure 3.4.4). In both cases, the concentrations found in 2005 are consistent with historical results.

There is no significant difference in historical Pu-239/240 concentrations in sediment from sampling locations upstream (Priest Rapids Dam) and downstream (McNary Dam) of Hanford, as the historical average at both locations is approximately 0.009 pCi/g.

The Pu-239/240 concentrations measured in the Hanford Reach National Monument soil samples (site HRNM in Figure 3.4.4) are consistent with concentrations typically measured in environmental soil samples, which range from below the detection limit to 0.03 pCi/g.

Strontium-90 concentrations in sediment samples collected in 2005 ranged from below the detection limit to 0.016 pCi/g (see Figure 3.4.3). Strontium-90, which is found in the environment from world-wide fallout of nuclear weapons testing, has been historically detected in sediment samples from both Priest Rapids Dam (upstream of Hanford) and McNary Dam (downstream of Hanford). There is no significant difference in historical Sr-90 concentrations between the upstream and downstream locations, as they both average approximately 0.017 pCi/g.

The Sr-90 concentrations measured in the Hanford Reach National Monument soil samples (site HRNM in Figure 3.4.4) are consistent with concentrations typically measured in environmental soil samples.

Uranium-236 is a byproduct of Hanford reactor operations and it is occasionally detected by DOH in Columbia River sediment samples. Historical U-236 concentrations range from below the detection limit of 0.02 pCi/g to 0.26 pCi/g. DOH measured a concentration of 0.05 pCi/g from the 300 Area shoreline sample collected in 2005. PNNL did not report a U-236 concentration for this sample.

Americium-241, Co-60, Cs-134, Eu-154, Eu-155, and Pu-238 were not detected in any of the DOH sediment and soil samples collected in 2005.

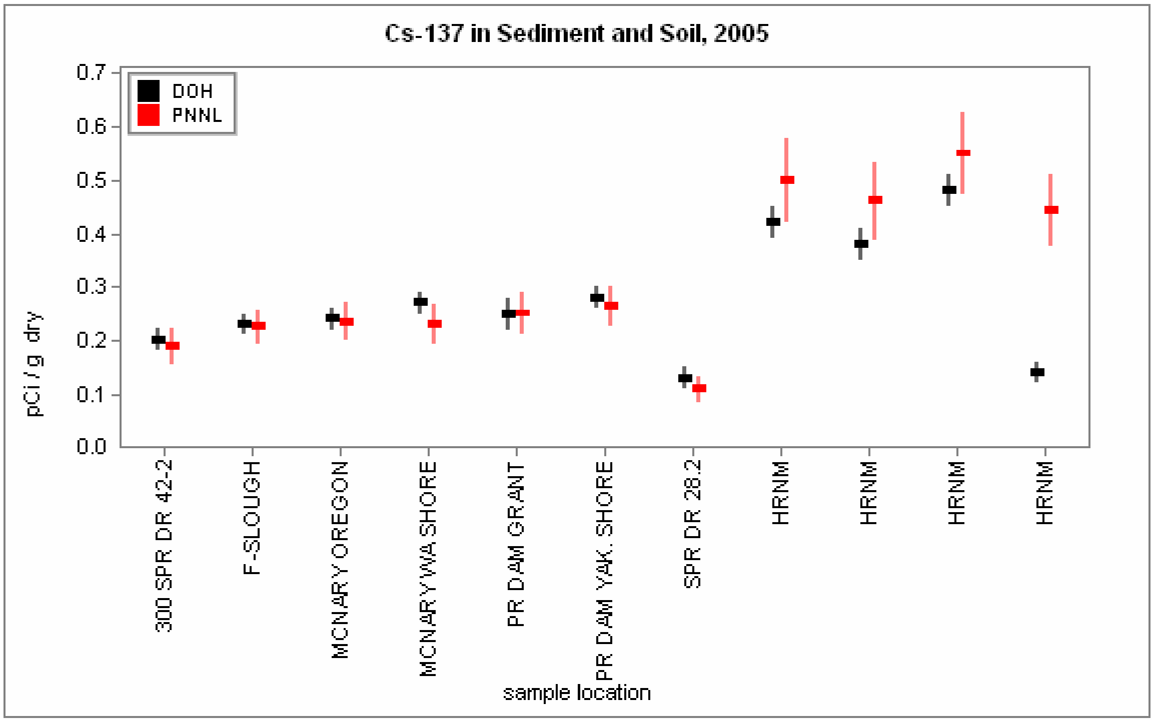

Figure 3.4.1 DOH and PNNL Cs-137 Concentrations in Sediment and Soil Samples

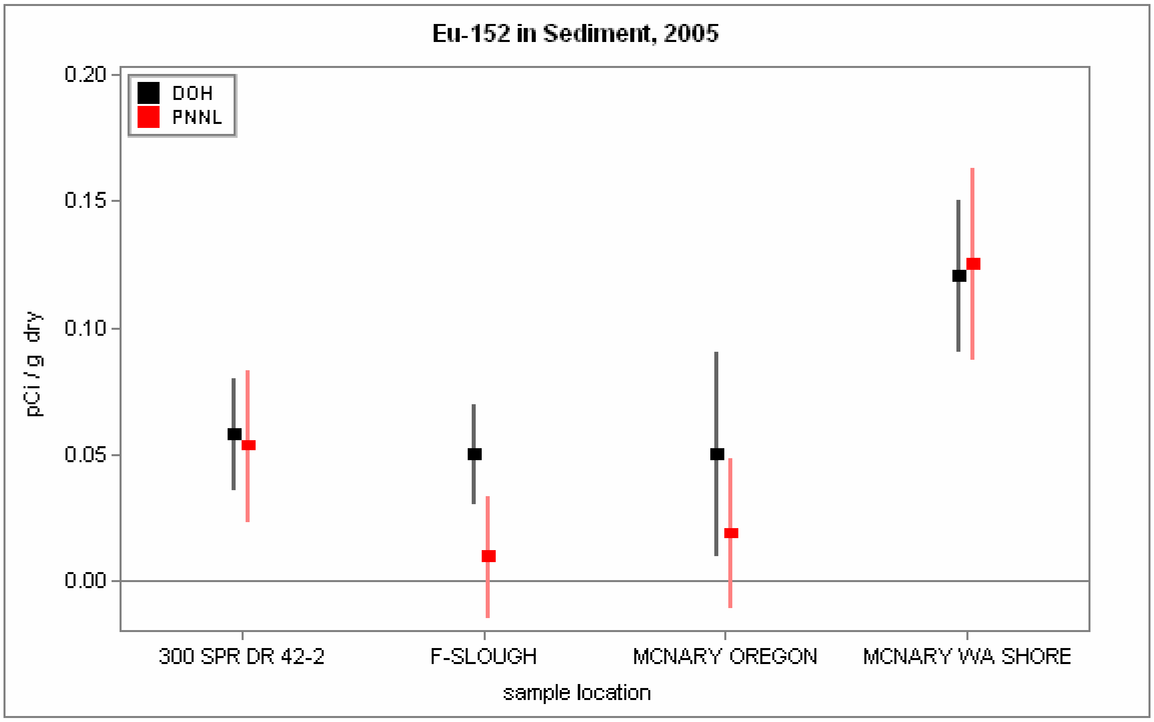

Figure 3.4.2 DOH and PNNL Eu-152 Concentrations in Columbia River Sediment

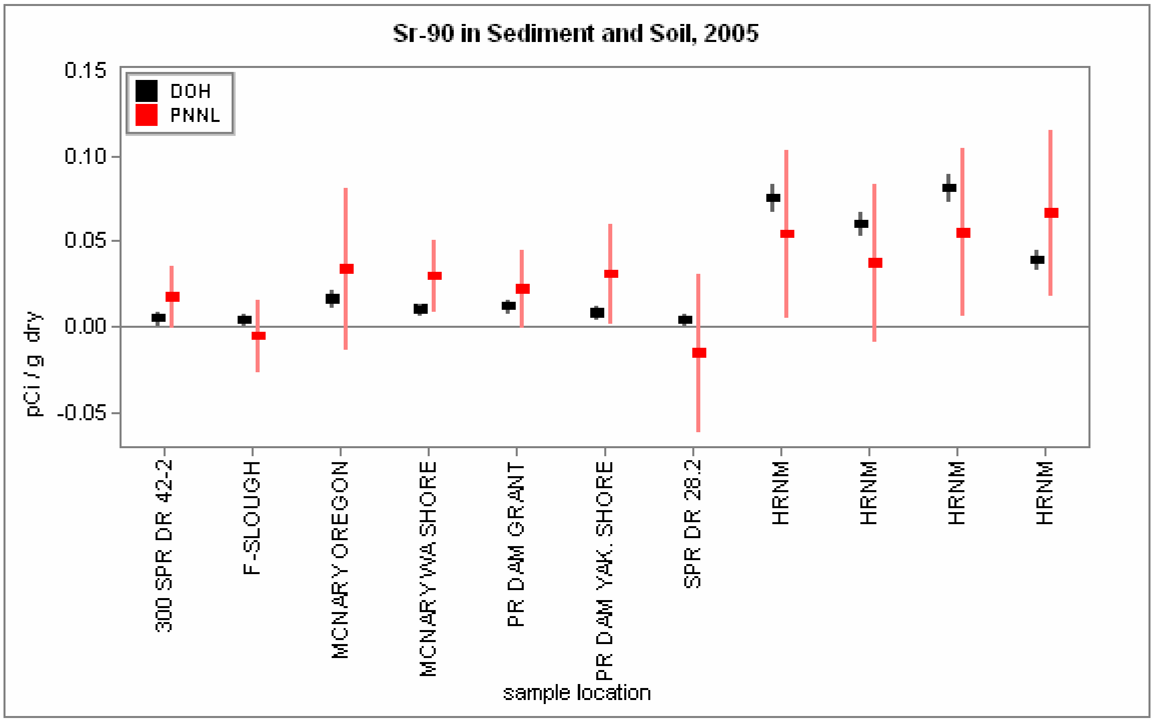

Figure 3.4.3 DOH and PNNL Sr-90 Concentrations in Sediment and Soil Samples

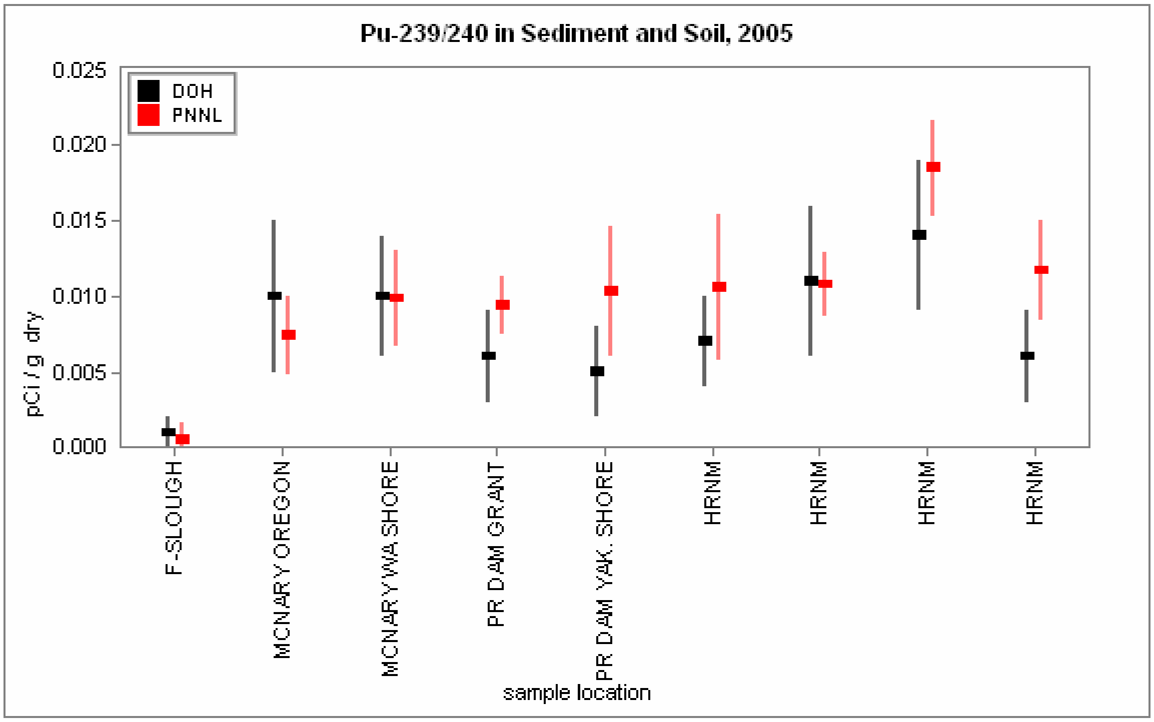

Figure 3.4.4 DOH and PNNL Pu-239/240 Concentrations in Sediment and Soil

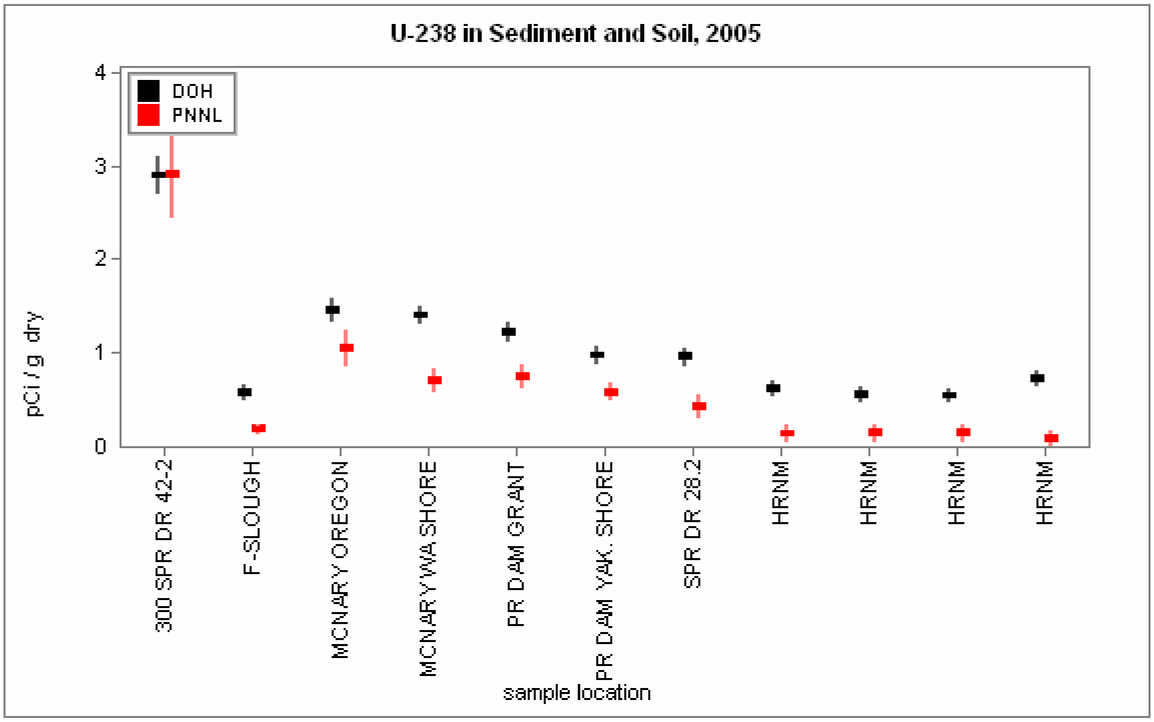

Figure 3.4.5 DOH and PNNL U-238 Concentrations in Sediment and Soil Samples

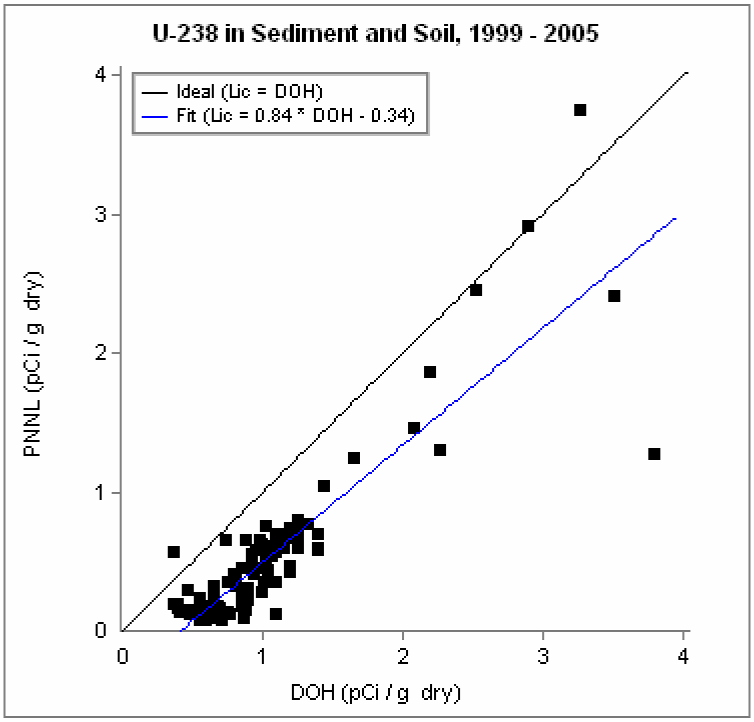

Figure 3.4.6 DOH and PNNL Scatter Plot for Historical U-238 Concentrations in Sediment and Soil

3.5 Farm Products Monitoring

Major Findings:

- All DOH and DOE contractor results are in good agreement.
- All radioactivity concentrations measured by DOH are below detection limits.

3.5.1 Purpose and General Discussion

The Department of Health and DOE contractors monitor farm products; i.e., food and wine, to determine if airborne contamination has deposited on plants that may be consumed by people. The food products, radionuclides analyzed, and number of samples for 2005 are listed in Table 3.5.1.

Farm Product	Analyte	Number of Samples
Honey	Co-60, Cs-137, Pu-238, Pu-239, Sr-90, total uranium	2
Cherries	Co-60, Cs-137, Sr-90	2
Asparagus	Co-60, Cs-137, Sr-90, U-234, U-235, U-238	1
Leafy Vegetables	Co-60, Cs-137, Sr-90	1
Potato	Co-60, Cs-137, Sr-90	1
Wine	Co-60, Cs-137, H-3	4

Table 3.5.1 Radionuclides Analyzed in Food and Farm Products

3.5.2 Monitoring Locations

All of the farm products were collected at locations which are nearby, but off-site of the Hanford Reservation. Samples were collected from farms located in the areas of Riverview, Sagemoor, Horn Rapids, East Wahluke, Ringold, Sunnyside, Yakima Valley, and the Columbia Valley.

3.5.3 Monitoring Procedures

Farm product samples were collected by PNNL and then split with DOH. 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 are reported in pCi/g wet weight.

3.5.4 Comparison of DOH and Contractor Data

All of the DOH and PNNL radionuclide concentrations reported for split food and wine samples are in good agreement, and all split results are below detection limits. PNNL has not yet published their results for H-3 in the 2005 wine samples, so a comparison of those results with the DOH results has not been made in this report. Historically, most of the DOH and PNNL concentrations in split food and wine samples are in good agreement.

3.5.5 Discussion of DOH Results

All reported concentrations of Co-60, Cs-137, H-3, Sr-90, Pu-238, Pu-239/240, and isotopes of uranium in farm product samples collected in 2005 are below the detection limits listed for food in Appendix B. Historically, DOH occasionally detects small concentrations of Sr-90 in farm produce around the Hanford Site, with concentrations ranging from 0.01 to 0.1 pCi/g. However, Sr-90 was not detected in 2005 samples. DOH also occasionally detects small concentrations of H-3 in wine samples; however, H-3 was not detected in 2005.

3.6 Fish and Wildlife Monitoring

Major Findings:

- DOH and PNNL results are in good agreement for gamma emitting radionuclides, and are in good to poor agreement for Sr-90.
- All of the DOH results for gamma emitting radionuclides are below detection limits.

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, vegetation, or water. In 2005, DOH split one wildlife sample and two fish samples. The type of samples, radionuclides analyzed, and number of samples are listed in Table 3.6.1.

Sample Type	Analyte	Number of Samples	Sample Location
Rabbit Bone	Sr-90	1	100N Area
Rabbit Meat	Co-60, Cs-137	1	100N Area
Bass Carcass	Sr-90	2	Hanford Town Site
Bass Meat	Co-60, Cs-137	2	Hanford Town Site
Whitefish Carcass	Sr-90	1	100N Area
Whitefish Meat	Co-60, Cs-137	1	100N Area

Table 3.6.1 Radionuclides Analyzed in Fish and Wildlife

3.6.2 Monitoring Locations

The sample locations are listed in Table 3.6.1. The rabbit was collected from near the 100N Area, the whitefish from the Columbia River near the 100N Area, and the two bass samples from the Columbia River near the Old Hanford Town Site. No fish or wildlife samples from background locations were collected for split sample analysis in 2005.

3.6.3 Monitoring Procedures

Fish and wildlife samples were collected and split by PNNL. Carcass and bone samples were analyzed for Sr-90, while the meat samples were analyzed for gamma emitting radionuclides, primarily Co-60 and Cs-137.

3.6.4 Comparison of DOH and Contractor Data

The DOH and PNNL Co-60 and Cs-137 concentrations for split fish and wildlife samples are in good agreement, and all results are below detection limits. No other gamma emitting radionuclides were detected.

The DOH and PNNL Sr-90 concentrations for split fish and wildlife samples are also in good agreement. Historically, the agreement between DOH and PNNL Sr-90 results in fish and wildlife range from good to fair to poor.

3.6.5 Discussion of DOH Results

All DOH Co-60 and Cs-137 concentrations in fish and wildlife samples are below the detection limits. No other gamma emitting radionuclides were detected in these samples.

Strontium-90 was detected at low concentrations in all three fish samples collected in 2005, with concentrations ranging from 0.018 to 0.026 pCi/g. The highest result was from the bass sample collected at the 100F Area slough. The Sr-90 concentrations measured in 2005 fish samples are similar to those measured by DOH in historical fish samples.

Strontium-90 was also detected in the 100N Area rabbit sample at 0.047 pCi/g. The Sr-90 concentration measured in the 2005 rabbit sample is similar to those measured by DOH in historical wildlife samples.

DOH detected U-234 and U-238 in the whitefish sample, at concentrations of 0.003 pCi/g. PNNL did not report uranium concentrations from this sample.

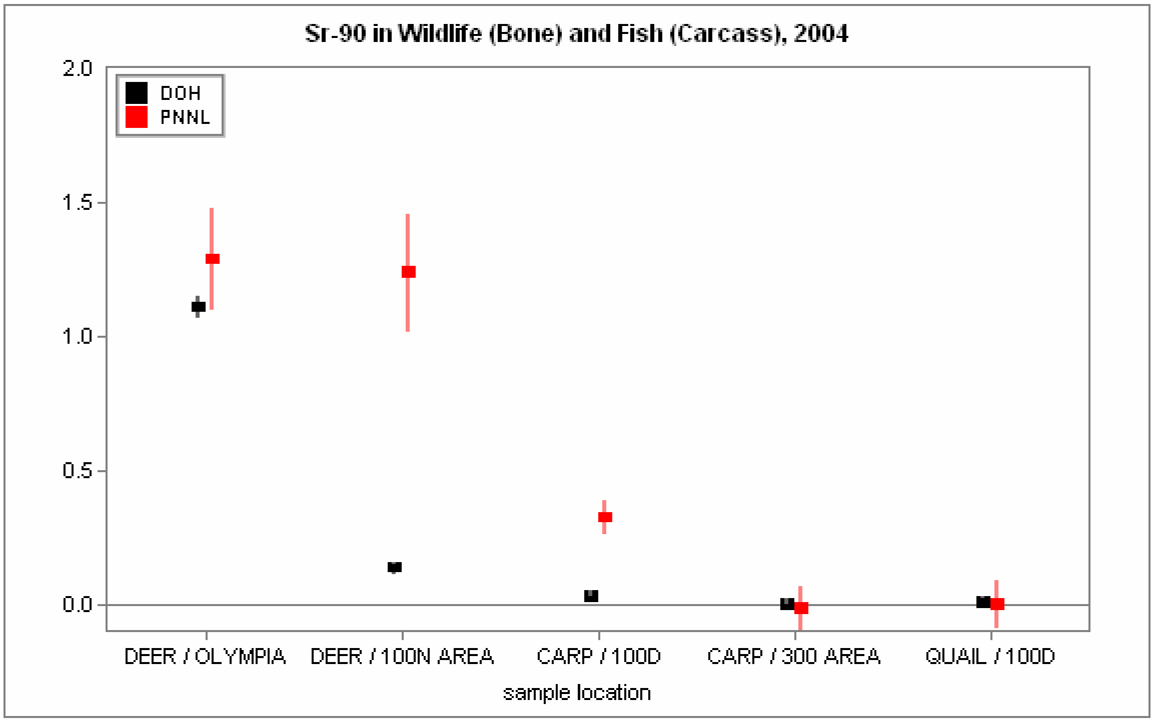

Figure 3.6.1 DOH and PNNL Sr-90 Concentrations in Fish and Wildlife

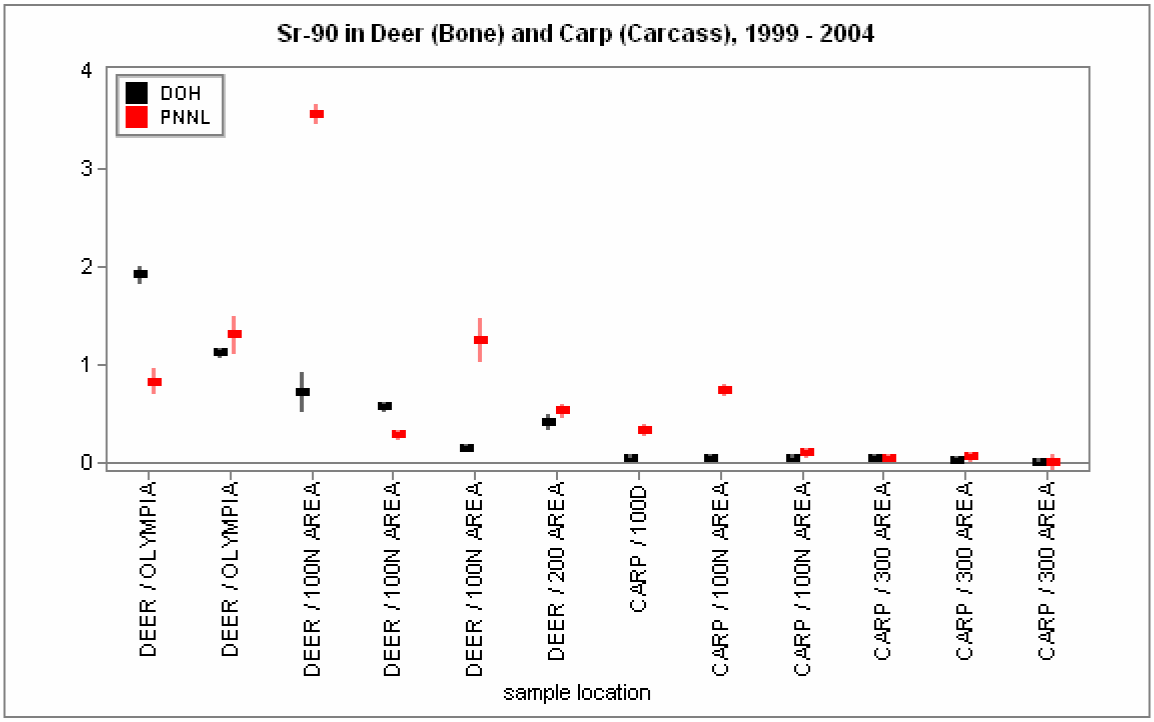

Figure 3.6.2 DOH and PNNL Historical Sr-90 Concentrations in Deer Bone and Carp Carcass Samples

3.7 Vegetation Monitoring

Major Findings:

- DOH and DOE contractor results are in good agreement.
- Concentrations of gamma emitting radionuclides are below detection limits.
- Low concentrations of Sr-90 were detected in alfalfa samples, and the concentrations measured in 2005 are consistent with historical results.

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. DOH split three vegetation samples with PNNL in 2005. The type of vegetation, radionuclides analyzed, and number of samples are listed in Table 3.7.1.

Type of Vegetation	Analyte	Number of Samples
Alfalfa	Co-60; Cs-134, 137; Eu-152, 154, 155; Sr-90	3

Table 3.7.1 Radionuclides Analyzed in Vegetation

3.7.2 Monitoring Locations

Three alfalfa samples were collected from farms located in the Horn Rapids, Sagemoor, and Riverview areas, all in the predominant downwind direction (to the southeast) of the Hanford Site.

3.7.3 Monitoring Procedures

The vegetation samples were collected in the summer of 2005 and split with PNNL. DOH and PNNL independently analyzed the samples. The measured radionuclide concentrations are reported in pCi/g.

3.7.4 Comparison of DOH and Contractor Data

All of the DOH and PNNL split vegetation results are in good agreement. As an example, the DOH and PNNL Sr-90 results in alfalfa samples are shown in Figure 3.7.1. The DOH and PNNL concentrations of gamma emitting radionuclides are all below detection limits.

3.7.5 Discussion of DOH Results

The DOH concentrations of gamma emitting radionuclides (including Co-60, Cs-134, 137, and Eu-152, 154, 155) are all below the detection limits listed in Appendix B. Strontium-90 was detected in all three alfalfa samples, with concentrations ranging from 0.01 to 0.05 pCi/g. The Sr-90 concentrations measured in 2005 are consistent with historical concentrations, as shown in Figure 3.7.2. The historical average Sr-90 concentration in alfalfa is 0.06 pCi/g, which likely originates from world-wide fallout.

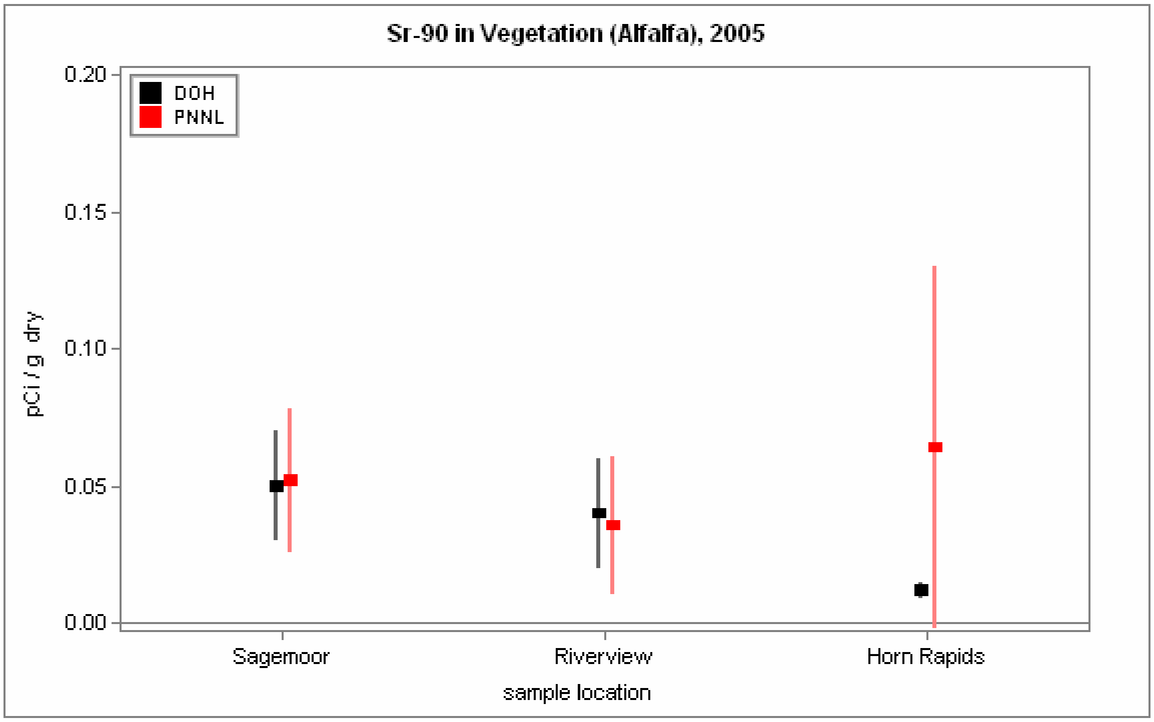

Figure 3.7.1 DOH and PNNL Sr-90 Concentrations in Alfalfa Samples

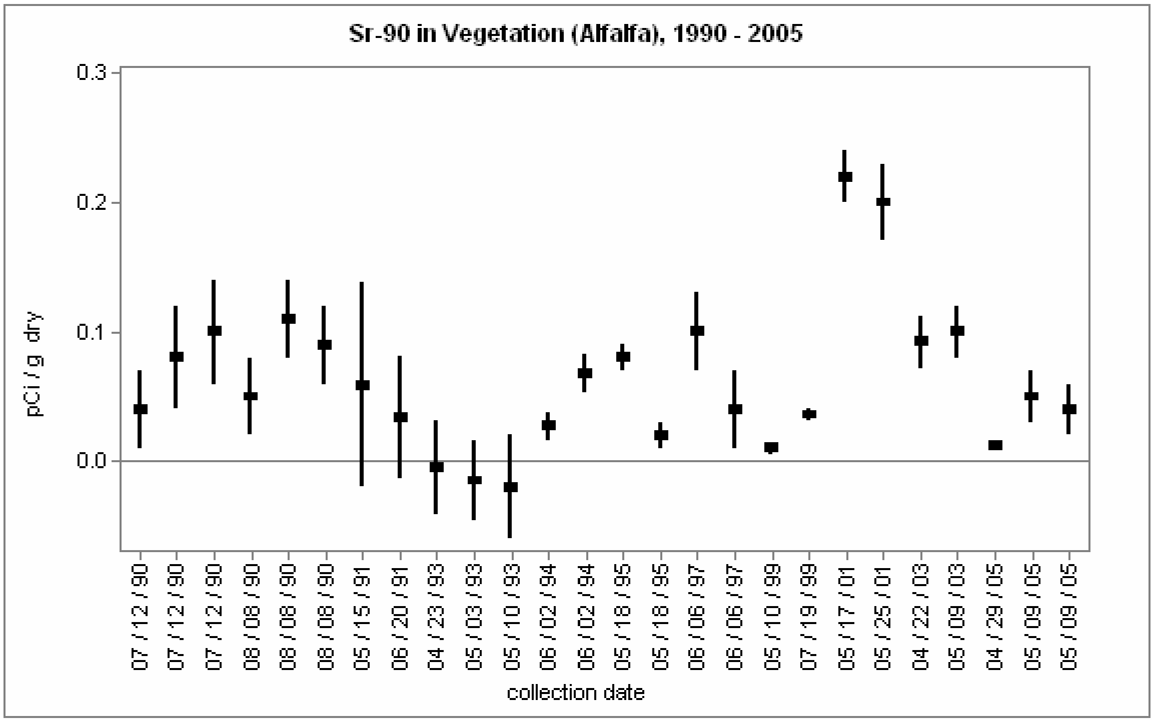

Figure 3.7.2 DOH Historical Sr-90 Concentrations in Alfalfa Samples

4. Summary of Discrepancies Between DOH and DOE Contractor Results

Categories of ‘good’, ‘fair’, and ‘poor’ are used to describe the agreement between DOH and DOE contractor results. This section summarizes all data described as fair or poor.

The DOH and DOE contractor colocated biweekly gross beta results in air samples are in fair agreement. The DOH and DOE data follow the same trends; however, differences in concentration up to a factor of two are common, and there is a small systematic discrepancy between the two data sets. At the lower end of the range of reported concentrations, DOE consistently reports higher values than DOH. At the upper end of the range of concentrations, DOH consistently reports higher values than DOE. In most cases, the discrepancy is less than a factor of two. This discrepancy observed in 2005 is also evident in historical DOH and DOE results.

The DOH and DOE colocated composite uranium results in air samples are in fair agreement. The data generally follow the same trends; however, DOE consistently reports concentrations that are significantly lower than the concentrations reported by DOH. This discrepancy, which is observed in historical data, results from different laboratory procedures.

The DOH and PNNL split gross alpha and gross beta results in water samples are in fair agreement. The data generally follow the same trends; however, a systematic discrepancy is observed in which DOH disproportionately reports higher concentrations than PNNL. This discrepancy observed in 2005 is also evident in historical DOH and PNNL results.

The DOH and PNNL split H-3 results in water samples are in fair agreement. The data generally follow the same trends; however, a systematic discrepancy is observed in which DOH generally reports slightly higher concentrations than PNNL. The discrepancy is small, with an average difference in concentrations of 8%. This discrepancy observed in 2005 is also evident in historical DOH and PNNL results.

Historically, DOH and PNNL split I-129 results in water samples, most of which are groundwater, are in poor agreement. Three problems have been identified. First, for samples in which I-129 is detected, DOH typically reports concentrations significantly lower than those reported by PNNL. Second and perhaps related to the first problem, for samples in which I-129 is not detected, DOH reports a disproportionate number of negative results, more so than statistically expected. This suggests a negative bias in the DOH laboratory analysis method. Third, some PNNL results are reported at concentrations greater than the sample’s minimum detectable activity (MDA); however, the results are tagged as not detected. This suggests that PNNL’s I-129 MDA is not correctly calculated.

DOH is currently working on four steps to resolve these I-129 issues. The first step, which has been completed, was to review the DOH laboratory procedures. DOH identified potential sources of error with sample preparation, sample holding times, and detector calibration. The detector calibration has been investigated and while some bias cannot be ruled out, it is not sufficient to account for the discrepancies observed in the split sample results. It is suspected that collectively, the sample preparation and processing protocols likely caused most of the DOH under-reported I-129 concentrations. DOH will conduct a set of experiments designed to determine the extent to which these factors contribute to the bias. Upon completion of these experiments, DOH procedures will be revised to eliminate the contributing factors. These revisions will be incorporated starting with samples collected in 2007, and will be used to guide interpretation of historical data.

For the second step, DOH will propose sample collection practices specifically designed to optimize analysis of I-129. Current practices call for samples to be collected in the field, acidified, and transported to the laboratory. At the laboratory, a portion of the sample is pH neutralized and the I-129 is concentrated using a resin material with high specificity for I-129. This portion is taken after all other analyses are completed to ensure that sufficient sample is available for those tests. The problem with the current collection practice is that the acid addition, which is good for keeping most radionuclides in solution, causes iodine to volatilize. Furthermore, iodine is strongly adsorbed by plastics, so that some quantity is likely lost to the walls of the container. Trapping the iodine on resin as soon as the sample is collected will eliminate this problem. DOH proposes to collect a separate amount of groundwater specifically for I-129 analysis. This sample will be unacidified and the resin will be added at the time of sample collection.

The third step in resolving the I-129 issues is to target several groundwater wells with historically elevated concentrations of I-129 for split sample collection and analysis starting in 2007. This will provide results over a wider range of activity with which to evaluate the changes in collection practices and laboratory procedures.

Fourth, DOH will review PNNL’s laboratory’s procedures for I-129 analysis. Findings will be discussed in future reports

The DOH and PNNL split uranium results in sediment and soil samples are in fair agreement. The data generally follow the same trends; however, a systematic discrepancy is observed between the two data sets. PNNL typically reports uranium concentrations that are significantly lower than the values reported by DOH. This discrepancy, which is observed in historical data, results from different laboratory procedures.

Historically, DOH and PNNL results for Sr-90 concentrations in farm products, fish and wildlife, and vegetation samples range from good to fair to poor agreement. In 2005, all of the Sr-90 results were in agreement.

The uranium discrepancies discussed above are understood, and originate from different laboratory procedures. All other discrepancies are under investigation, and the findings will be discussed in future annual reports.

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 phenomenon 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 of radioactive materials include 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. An element is delineated by its chemical name followed by its 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 is therefore a radioisotope of carbon.

All radioisotopes will eventually decay, by emitting radiation, and will become 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 the 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 the becquerel which is 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 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 of the effects from 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 of 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 health effects data 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 - Laboratory a priori Lower Limits of Detection

Air Cartridge (pCi/m^3)

	Nuclide	Volume (m^3)	Method*	Standard LLD (100 min.)
Gamma	I-131*	450	INGe	2.00E-02

Air Filter (pCi/m^3)

	Nuclide	Volume (m^3)	Method	Standard LLD (100 min.)
Beta	Gross	450	αβ Cntr	1.00E-03

Quarterly Composite Air Filter (pCi/m^3)

	Nuclide	Volume (m^3)	Method	Standard LLD (400 min.)
Gamma	Be-7	5200	INGe	8.00E-02
	Co-60	5200	INGe	1.00E-03
	Cs-134	5200	INGe	2.00E-03
	Cs-137	5200	INGe	1.00E-03
				Standard LLD (1000 min.)
Alpha	Nat U	5200	Alpha Spec	2.50E-05
	U-234	5200	Alpha Spec	2.50E-05
	U-235	5200	Alpha Spec	1.00E-05
	U-238	5200	Alpha Spec	2.50E-05

Semi-Annual Composite Air Filter (pCi/m^3)

	Nuclide	Volume (m^3)	Method	Standard LLD (400 min.)
Gamma	Be-7	10400	INGe	4.00E-02
	Co-60	10400	INGe	5.00E-04
	Cs-134	10400	INGe	1.00E-03
	Cs-137	10400	INGe	5.00E-04

Semi-Annual Composite Air Filter (pCi/m^3) Continued

	Nuclide	Volume (m3)	Method	Standard LLD (1000 min.)
Alpha	Nat U	10400	Alpha Spec	1.25E-05
	U-234	10400	Alpha Spec	1.25E-05
	U-235	10400	Alpha Spec	5.00E-06
	U-238	10400	Alpha Spec	1.25E-05
	Pu-238	10400	Alpha Spec	5.00E-06
	Pu-239/240	10400	Alpha Spec	5.00E-06

Food (pCi/g)

	Nuclide	Mass (g)	Method	Standard LLD (1000 min.)
Alpha	Nat U	20	Alpha Spec	2.00E-03
	U-234	20	Alpha Spec	1.50E-02
	U-235	20	Alpha Spec	1.00E-03
	U-238	20	Alpha Spec	2.00E-03
	Pu-238	20	Alpha Spec	3.00E-03
	Pu-239	20	Alpha Spec	2.00E-03
	Th-230	20	Alpha Spec	5.00E-03
	Th 232	20	Alpha Spec	2.00E-03
	Am-241	20	Alpha Spec	2.00E-03
	Ra – 226	20	αβ Cntr	6.00E-04

Milk (pCi/L)

	Nuclide	Volume (L)	Method	Standard LLD (400 min.)
Gamma	K-40	3	INGe	3.00E+01
	I-131	3	INGe	2.00E+00
	Cs-134	3	INGe	2.00E+00
	Cs-137	3	INGe	2.00E+00
	Ba-140	3	INGe	9.00E+00
				Standard LLD (1000 min.)
	I-131	4	IXR/INGe	7.00E-01
				Standard LLD (100 min.)
Beta	Sr-90	1	Nitric Acid/ αβ Cntr	7.00E-01

Meat (pCi/g)

	Nuclide	Mass (g)	Method	Standard LLD (1000 min.)
Gamma	K-40	400	INGe	1.40E-01
	Mn-54	400	INGe	7.00E-03
	Co-58	400	INGe	7.00E-03
	Co-60	400	INGe	8.00E-03
	Cs-137	400	INGe	6.00E-03
	I-131	400	INGe	2.00E-02
	Ra-226(DA)	400	INGe	2.50E-01
	Am-241(GA)	400	INGe	2.00E-02
Alpha	Nat U	10	Alpha Spec	4.00E-03
	U-234	10	Alpha Spec	3.00E-03
	U-235	10	Alpha Spec	2.00E-03
	U-238	10	Alpha Spec	3.00E-03
	Pu-238	10	Alpha Spec	5.00E-03
	Pu-239	10	Alpha Spec	4.00E-03
	Am-241	10	Alpha Spec	4.00E-03
Beta	Sr-90 (bone)	5	Nitric Acid/ αβ Cntr	2.00E-01

Shellfish (pCi/g)

	Nuclide	Mass (g)	Method	Standard LLD (400 min.)
Gamma	I-131	400	INGe	6.00E-03
	Co-60	400	INGe	6.00E-03
	K-40	400	INGe	1.00E-01

Soil/Sediment (pCi/g)

	Nuclide	Mass (g)	Method	Standard LLD (1000 min.)
Alpha	Nat U	1	Alpha Spec	4.00E-02
	U-234	1	Alpha Spec	3.00E-02
	U-235	1	Alpha Spec	2.00E-02
	U-238	1	Alpha Spec	3.00E-02
	Pu-238	10	Alpha Spec	5.00E-03
	Pu-239	10	Alpha Spec	4.00E-03
	Th-230	1	Alpha Spec	4.00E-02
	Th 232	1	Alpha Spec	4.00E-02
	Am-241	10	Alpha Spec	4.00E-03
	Ra - 226	1	αβ Cntr	1.00E-01
	Ra-226(DA)	600	INGe	2.00E-02
				Standard (100 min.)
Alpha	Gross	0.1	αβ Cntr	4.00E+01
				Standard LLD (1000 min.)
Gamma	K-40	600	INGe	1.50E-01
	Mn-54	600	INGe	1.00E-02
	Co-60	600	INGe	1.00E-02
	Zn-65	600	INGe	2.00E-02
	Zr-95	600	INGe	1.00E-02
	Ru-103	600	INGe	1.50E-02
	Ru-106	600	INGe	1.00E-02
	Sb-125	600	INGe	2.00E-02
	Cs-134	600	INGe	1.20E-02
	Cs-137	600	INGe	1.50E-02
	Ce-144	600	INGe	5.00E-02
	Eu-152	600	INGe	1.50E-02
	Eu-154	600	INGe	1.50E-02
	Eu-155	600	INGe	2.00E-02
	Ra-226(DA)	600	INGe	1.00E-01
	Am-241(GA)	600	INGe	2.00E-02
	Tot U(GA)	600	INGe	2.00E-01
				Standard (100 min.)
Beta	Sr-90	150	Nitric Acid/	1.80E-03
	Tc-99	10	3M/LS	2.00E-01
	Gross beta	0.4	αβ Cntr	1.50E+00

Vegetation (pCi/g except H-3 which is expressed as pCi/L)

	Nuclide	Mass (g)	Method	Standard LLD (1000 min.)
Alpha	Nat U	10	Alpha Spec.	8.00E-03
	U-234	10	Alpha Spec.	6.00E-03
	U-238	10	Alpha Spec.	6.00E-03
	Pu-238	10	Alpha Spec.	5.00E-03
	Pu-239	10	Alpha Spec.	4.00E-03
	Am-241	10	Alpha Spec.	4.00E-03
Gamma	K-40	100	INGe	3.00E-01
	Mn-54	100	INGe	4.00E-02
	Co-60	100	INGe	4.00E-02
	Zn-65	100	INGe	1.50E-01
	Zr-95	100	INGe	2.00E-01
	Ru-106	100	INGe	4.00E-01
	Cs-137	100	INGe	4.00E-02
	I-131	100	INGe	4.00E-02
	Am-241(GA)	100	INGe	2.00E-01
				Standard LLD (100 min.)
Beta	Gross	0.4	αβ Cntr	1.50E+00
	Sr-90	20	Nitric Acid/ αβ Cntr	5.00E-02
	Tc-99	5	3M/LS	1.50E+00
	Nuclide	Volume (L)	Method	Standard LLD (200 min.)
	C-14	0.0002	Oxid/LS	3.00E+02
	H-3	0.002	LS	5.00E+02

Water (pCi/L)	Nuclide	Volume (L)	Method	Standard LLD (1000 min.)	Standard LLD (100 min.)
Alpha	Nat U	0.5	Alpha Spec	1.30E-01	
	U-234	0.5	Alpha Spec	8.00E-02	
	U-235	0.5	Alpha Spec	6.00E-02	
	U-238	0.5	Alpha Spec	8.00E-02	
	Ra-226	0.5	αβ Cntr		2.00E-01
	Pu-238	0.5	Alpha Spec	8.00E-02	
	Pu-239	0.5	Alpha Spec	6.10E-02	
	Th-230	0.5	Alpha Spec	1.00E-01	
	Th 232	0.5	Alpha Spec	1.00E-01	
	Am-241	0.5	Alpha Spec	8.00E-02	

				Standard LLD (1000 min.)
Gamma	Am-241	3	INGe	1.00E+01
	Ba-140	3	INGe	9.00E+00
	Ce-144	3	INGe	1.30E+01
	C0-58	3	INGe	1.50E+00
	Co-60	3	INGe	2.00E+00
	Cr-51	3	INGe	1.60E+01
	Cs-134	3	INGe	2.00E+00
	Cs-137	3	INGe	2.00E+00
	Eu-152	3	INGe	5.00E+00
	Eu-154	3	INGe	5.00E+00
	Eu-155	3	INGe	8.00E+00
	Fe-59	3	INGe	3.00E+00
	I-129	3	IXR/LEP	8.00E-01
	I-131	3	INGe	2.00E+00
	K-40	3	INGe	3.00E+01
	Mn-54	3	INGe	1.50E+00
	Nb-95	3	INGe	2.00E+00
	Ru-103	3	INGe	2.00E+00
	Ru-106	3	INGe	1.50E+01
	Sb-125	3	INGe	5.00E+00
	Sn-113	3	INGe	2.00E+00
	Zn-65	3	INGe	3.00E+00
	Zr-95	3	INGe	2.00E+00

Water (pCi/L) Continued

	Nuclide	Volume (L)	Method	Standard LLD (200 min.)	Standard LLD (100 min.)
Beta	H-3	0.010	Dist/LS	6.00E+01	
	C-14	0.010	LS	1.50E+02	
	Sr-90	1	Nitric Acid/ αβ Cntr		7.00E-01
	Tc-99	0.5	3M/LS		4.00E+00
Gross	Alpha	0.1	αβ Cntr		4.00E+00
	Beta	0.5	αβ Cntr		1.00E+00

*LLD for Air Cartridge is 3 days

METHOD

Preparation Methods

IXR = Ion Exchange Resin
Nitric Acid
3M = 3M Ion Exchange Disks
Oxid = Oxidation

Counting Methods

INGe = Intrinsic Germanium Detector
αβ Cntr = Alpha, Beta Counter
Alpha Spec = Alpha Spectrometry
LS = Liquid Scintillation
LEP = Low Energy Photon Detector

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 radioisotope 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	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).

Gross Alpha / Gross Beta	A screening test that reports alpha particle activity in a sample. The test is not intended to identify specific radioisotopes. The tests are primarily used to evaluate trends. In addition, screening tests are used to determine if further radioisotope specific analysis is necessary; and if radioisotope analyses has been carried out, to determine if the activities from specific radioisotopes account for all of the activity found in the screening test.
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 on humans.
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 is 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 are 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 two 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