WASHINGTON PUBLIC POWER SUPPLY SYSTEM

WASHINGTON PUBLIC POWER SUPPLY SYSTEM

NUCLEAR PLANT 2

1998 ANNUAL RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT

JANUARY 1 to DECEMBER 31, 1998

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

Prepared by

J.E. McDonald and L.S. Schleder
Washington Public Power Supply System
Richland, WA

and

C.A. Mendola
Teledyne Brown Engineering Environmental Services
Westwood, NJ

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 EXECUTIVE SUMMARY

The Washington Public Power Supply System Radiological Environmental Monitoring Program (REMP) evaluates the radiological impact of Plant 2 operations on the environment in the Airborne, Direct Radiation, Waterborne, and Ingestion pathways as specified in the Offsite Dose Calculation Manual (ODCM). Samples are also collected at locations specified by the Site Certification Agreement (SCA) with the State of Washington Energy Facility Site Evaluation Council (EFSEC. The Supply System's Plant 2 is a 1200 MW commercial nuclear power plant that achieved initial criticality on January 19, 1984.

Samples of air, water, milk, soil, sediment, fish and garden produce were collected throughout the year and analyzed for radionuclides specific to plant operations. Radiation levels were also monitored continuously during 1998 with thermoluminescent dosimeters (TLDs).

The samples were collected in established areas near the plant and at other locations which could be affected by Plant 2 effluents. This information was compared to samples taken in areas that were unlikely to be affected by plant operations. The 1998 REMP data was also compared to data collected during previous years of plant operation and to the data collected prior to initial plant operation.

Most of the results of samples collected by the REMP during 1998 were below detection levels. Some analyses, such as gross beta in air and water, were above the detection level for nearly all samples. This is due to the low detection limit for the gross beta analysis and also to the abundance of naturally occurring beta-emitting radionuclides in the environment. Other results above detection levels, such as cesium-137 in soil and sediment, reflect the effect of past Hanford activities or fallout from Chernobyl and past nuclear weapons testing.

Tritium concentration in discharge water, though higher than in 1997, continued to be lower than the mean levels observed from the 1992 through 1996 periods. This reduction is due to an ongoing reduction in the volume of the radwaste discharges to the Columbia River.

The REMP analytical results and TLD results were demonstrated to be accurate through intercomparison programs, which are provided as part of the quality assurance activities, conducted during 1998. Such intercomparisons tested the performance of the Supply System monitoring program to other monitoring programs using known radioactive standards. The Supply System REMP analytical contractor performed well in the Environmental Measurements Laboratory (EML) Quality Assessment Program, Environmental Protection Agency Intercomparison Studies, and the Analytics, Inc. Cross Check Comparison Program conducted during 1998.

The analytical results from samples collected by the REMP in 1998 remained consistent with the results of environmental samples collected during the preoperational period and prior operational years. Based on the data, no significant new trends or changes in the environmental radiological levels around the plant were observed.

2.0 DEFINITIONS

Airborne Activity Sampling: Continuous sampling of air through the collection of particulates and radionuclides on filter media.

Periodic soil samples are collected for gamma isotopic analysis to provide information on deposition to the soil from airborne releases.

Alpha Particle (α): A charged particle emitted from the nucleus of an atom having a mass and charge equal in magnitude of a helium nucleus.

Becquerel (Bq): One disintegration per second. One picocurie (pCi) equals 0.037 becquerel.

Beta Particle (β): Charged particle emitted from the nucleus of an atom, with a mass and charge equal in magnitude to that of an electron.

Blank Sample: A sample of the same media as the field sample being analyzed but without the radionuclide(s) being measured. It enables correction for the inherent sample background.

Composite Sample: A series of single collected portions (aliquots) analyzed as one sample. The aliquots making up the sample are collected at time intervals that are very short compared to the composite period.

Control Station: A background sampling location, i.e., a location not likely to be affected by plant effluents due to its distance and/or direction from Plant 2.

Counting Error: An estimate of the two-sigma uncertainty associated with the sample results based respective count times.

$$+/-2\sqrt{(SampleCPM / CountTime + BkgCpm / CountTime)}$$

Curie (Ci): 3.7×10^{10} disintegrations per second, or 2.22×10^{12} disintegrations per minute.

Direct Radiation Monitoring: The measurement of radiation dose at various distances from the plant is assessed through the use of thermoluminescent dosimeters and pressurized ionization chambers.

DOH: Washington State Department of Health.

EFSEC: Energy Facility Site Evaluation Council.

FFTF: U.S Department of Energy's Fast Flux Test Facility near Plant 2. Also known as the 400 Area.

Flow Proportional Sampling: Sample collection volume or frequency determined as a function of the flow rate of the water being sampled.

Grab Sample: A single discrete sample drawn at one point in time.

Indicator Station: A sampling location that could be affected by plant effluents due to its proximity and/or direction from Plant 2.

Ingestion Pathway Monitoring: The ingestion pathway includes milk, soil, fish, garden produce. Also sampled (under special circumstances) are other media such as vegetation and animal products such as eggs and meat when additional information about particular radionuclides is needed.

Lower Limit of Detection (LLD): The smallest concentration of radioactive material in a sample that will yield a net count (above system background) that will be detected with 95% probability with a 5% probability of a false conclusion that a blank observation represents "real" signal.

$$LLD = 4.66Sb / (2.22 * Vol * Eff * Yield * e^{(-\lambda\pi)})$$

Where LLD is the "*a priori*" or 'before-the-fact' measurement and not "*a posteriori*" or 'after-the-fact' measurement.

Mean: The average, i.e., the sum of results divided by the number of results.

Microcurie: 3.7×10^{4} disintegrations per second, or 2.22×10^{6} disintegrations per minute.

Milliroentgen (mR): 1/1000 Roentgen; a unit of exposure to X or gamma radiation.

NIST: National Institute of Standards and Technology.

NPDES: National Pollutant Discharge Elimination System

NRC: U.S. Nuclear Regulatory Commission.

ODCM: Offsite Dose Calculation Manual. Licensing document that contains the program requirements formerly contained in the Technical Specifications.

Picocurie (pCi): 1 x 10^{-12} Curie or 2.22 disintegrations per minute; one millionth of a microcurie.

REMP: Radiological Environmental Monitoring Program.

Range: The difference between the smallest and largest results.

Restricted Area: Any area to which access is controlled for purposes of protection of individuals from exposure to radiation and radioactive materials.

Results: The results of sample collection are discussed and interpreted by comparing them to similar measurements made during the preoperational and previous operational periods and to the detection capabilities associated with the current methods of analysis.

Roentgen: Unit of exposure to X or gamma (γ) radiation in air.

Site Certification Agreement (SCA): The Plant 2 licensing agreement with the State of Washington.

Spike Sample: A sample containing a known concentration of the radionuclide(s) being measured.

Standard Deviation: A measure of the scatter of a set of observations (or samples) around their mean value. Indicated by (σ).

Standard Error of the Mean: An estimate of the uncertainty associated with the mean of observation (or sample) averages.

$$SE = \sqrt{(\frac{S^2}{n})}$$

where S^2, the variance is

$$S^2_m = 1(n-1)\sum^n (Xi - X)^2$$

SWTF: Sanitary Waste Treatment Facility; sanitary waste processing facility for Plant 2, WNP-1 and Department of Energy's 400 area.

TEDA: triethylene diamine

Thermoluminescent Dosimeter (TLD): A TLD contains a phosphor that stores energy from exposure to radiation and emits that energy in the form of light when heated.

3.0 INTRODUCTION

3.1 Site Description

The Washington Public Power Supply System's Nuclear Plant 2 is located in a sparsely populated shrub-steppe region within the Department of Energy's Hanford Site in southeastern Washington. The plant is approximately three miles west of the Columbia River and is surrounded on all sides by uninhabited desert land. The nearest population centers are Richland, Pasco and Kennewick, which are 12 miles south, 18 miles southeast, and 21 miles southeast, respectively. The nearest privately owned lands are located approximately four miles ENE of the plant, across the Columbia River. Given the prevailing wind directions, shown in the 1998 wind frequency distribution in Figure 3-1, the focus of REMP sampling is the farming region east of the plant site.

Because Plant 2 is located on the Hanford Site, other potential sources of radioactive materials are in close proximity to Plant 2. For this reason, sampling locations near the plant provide useful information for separating the potential effects of Plant 2 from those of the other sources on the Hanford Site.

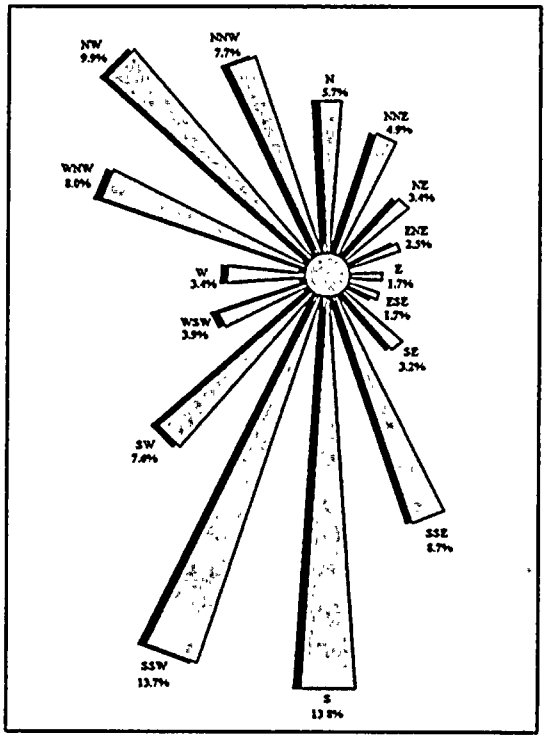

Figure 3-1 Average Wind Direction During 1998

3.2 Program Background

The REMP is designed to conform to the regulatory guidance of the Nuclear Regulatory Commission (NRC) as provided by Regulatory Guides 4.1[1] and 4.8[2], including the Radiological Assessment Branch Technical Position[3].

The quality assurance aspects of the program and the thermoluminescent dosimetry are conducted in accordance with Regulatory Guides 4.15[4] and 4.13[5]. The REMP also must adhere to the requirements of the Washington Energy Facility Site Evaluation Council (EFSEC)[6], the Plant 2 Technical Specifications[7] and the Offsite Dose Calculation Manual (ODCM)[8]. These requirements cover not only the environmental sampling and sample analysis aspects of the program, but also the reporting and quality assurance requirements of the program.

The preoperational phase of the program, which lasted from March 1978 until initial criticality in January 1984, provided a baseline of background environmental data. The variability in the background levels of radioactivity is due to differences in geologic composition, Chernobyl and nuclear weapons test fallout, meteorological conditions and seasonal changes.

REMP environmental samples are analyzed by a contract analytical laboratory. Teledyne Brown Engineering Environmental Services in Westwood, New Jersey has performed the analysis of REMP samples since June 1986. The thermoluminescent dosimeters used in the REMP to assess the direct radiation were processed in the past by the Supply System. In 1996, the Supply System contracted with ThermoNUtech to process the environmental TLDs. Battelle Pacific Northwest Division became the environmental TLD processor in 1998. The work is performed at their Richland, Washington laboratory.

Any radiological effect of Plant 2 on the environment must be distinguished from the normal variation in background radiation levels and from the effects of other sources of radioactive effluents in the area. The monitoring results obtained during each year of the plant's operation are compared to the preoperational data and to data from previous operating years to determine whether a significant accumulation of plant-produced radionuclides has occurred in the environment.

Quarterly averages of the results are also compared to the NRC non-routine reporting levels listed in the ODCM. In addition to evaluating the environmental concentrations against federal standards or limits, the REMP also compares the results to state standards[11, 12, 13]. The results are discussed and interpreted by comparing them to similar measurements made during the preoperational and previous operational periods and to the detection capabilities associated with the current methods of analysis. The quality assurance and quality control aspects of the program are also discussed in this report.

3.3 Program Objectives

The REMP provides a mechanism for determining whether the levels of radioactivity in the plant environs are within established limits and to ensure that the accumulation of radionuclides in the environment will not become significant as a result of plant operations.

While in-plant monitoring programs are used to ensure that 10CFR20[9] and 10CFR50[10] criteria for releases of radioactive effluents are met, the REMP provides supplemental verification that the concentrations of radionuclides in the environment are not greater than anticipated.

4.0 PROGRAM DESCRIPTION

The requirement for the Radiological Environmental Monitoring Program (REMP) is defined by the WNP-2 Offsite Dose Calculation Manual (ODCM). The sampling plan presented in Table 4-1 in this report shows which samples are required by the ODCM and the Site Certification Agreement (SCA). The table also provides a summary of the sample locations, collection frequency, and types of analyses performed. The methods of sampling and sampling frequencies utilized in the program have been determined by such factors as the half-lives and major exposure pathways for the radionuclides potentially released from the plant to the surrounding environment.

4.1 Sample Locations

Eighty-three sample locations were included in the 1998 monitoring program. Seventy-eight indicator and two control (i.e. background) stations were located within 10 miles (16 kilometers) of Plant 2. Three additional control stations and two indicator stations were outside the 10-mile radius from the plant. Sample stations are listed in Table 4-2 by meteorological sector, sample media and approximate distance from the plant. The numbers and locations of sample stations are based primarily on factors such as population distribution and meteorological conditions and also on station accessibility, security, and the requirements of applicable regulations. Other factors, such as the need to monitor locations which could be impacted by Plant 2 operations, influence the location of REMP sampling sites.

The REMP sampling locations listed in Tables 4-1 and 4-2 are shown in Figures 4-1 and 4-2. Figure 4-3 provides a more detailed map of sampling locations in the Sunnyside/Grandview area. Figure 4-4 shows the relative locations of the storm drain outfall and pond (Station 101) and the Sanitary Waste Treatment Facility (Station 102). Also shown are the containerized storage area (Station 118), the cooling tower landfill (Station 119), and the spray pond drainfield (Station 120) which are special interest stations.

4.2 Land Use Census

The land use census for areas within 5 miles of Plant 2 was performed in August. The objectives of the land use census are to identify the locations of the nearest milk animal, residence, and garden greater than 50 m^2 (500 ft^2) producing broadleaf vegetation. This information is used to determine whether any site located during the census has a calculated dose or dose commitment greater than the sites currently monitored for the same exposure pathway. If a new location with a higher dose commitment is found, routine sampling of that dose pathway would be initiated at that new site.

The results of the 1998 land use census within 5 miles of Plant 2 are given in Table 4-3. No changes from the 1997 land use census were observed. No milk animals are located within the 5-mile radius. The nearest milk location is located 7.2 miles east-southeast of Plant 2.

4.3 Sampling Methods

Environmental samples were collected by Supply System personnel according to the program plan in Table 4-1. Documented procedures for sample collection and TLD handling are contained in the Supply System's Environmental and Analytical Laboratory Instruction (EALI) manual. The sample analyses procedures are prepared and maintained by the analytical contractor and reviewed by the Supply System prior to implementation.

The following sections describe the sampling and preparation methods.

4.3.1 Direct Radiation

During 1998, thermoluminescent dosimeters (TLDs) were used to determine the direct radiation levels at sixty (60) monitoring locations listed in Table 4-1. Control station TLDs (background) are located at Station 9A in Sunnyside and Station 119-Control, 0.2 mile south-southeast of the plant. The remaining TLDs served as indicator TLDs throughout the year.

Two sets of TLDs placed three feet above ground were employed at each location. One set of TLDs were exchanged on a quarterly basis (Quarterly TLDs) and the other exchanged on an annual basis (Annual TLDs). Exposure received by the field TLDs during transport to the TLD sites was monitored by a set of trip control dosimeters that accompanied the field dosimeters to and from the field locations. Another set of TLDs were used as building controls that were used to determine the exposure of the TLDs at the controlled storage location. The TLD exposure during transport to and from the field was determined by subtracting the difference between the building control results and the trip control results.

Since 1995, the REMP has used Harshaw Model 8807 TLDs. During 1996 and 1997 these TLDs were supplied and processed by ThermoNutech (a subsidiary of Eberline Dosimetry). Battelle Pacific Northwest Division took over the program in 1997 and processes the environmental dosimeters on a Harshaw Model 8800 Hot Gas TLD Reader. This reader is calibrated weekly and immediately prior (same day) to processing environmental TLDs. The reader is calibrated in generic units (gU) using calibration dosimeters irradiated to known exposures of Cs-137. Each group of environmental TLDs that is processed includes "blank" unirradiated TLDs and processing control dosimeters irradiated by Battelle to a known quantity of Cs-137. In addition, "blind spiked" irradiated TLDs are submitted by the Supply System for processing along with the environmental TLDs. The processing results from these QA TLDs are used to demonstrate reader performance during environmental TLD processing and to trend reader performance over time.

A file containing "raw" element readings in gU is generated when the Harshaw TLD reader processes the environmental TLDs. This file is used by the Supply System to calculate environmental doses by applying "relative response" factors (gU/R) to convert the element 3 and 4 TLD readings to the Roentgen equivalent reading, then subtracting background and transit doses measured by control TLDs. Since the TLD reader is calibrated to provide 1 gU = 1 mR, reported doses are the background corrected average of the element 3 and 4 readings for each station. Doses are reported in mR, no correction to dose equivalent is applied.

The exposure values determined for calibration dosimeters, as well as the exposures of QA

dosimeters (processing control dosimeters), are based on a National Institute of Standards and Technology (NIST) traceable Cs-137 source. The exposure values for the audit dosimeters (spiked dosimeters) are based on the calculated field strength of a Supply System Cs-137 source. Ionization chamber measurements made during TLD exposure are used to confirm the calculated exposure. If the calculated exposure and the ionization chamber reading differ by 5% or more, an investigation is performed to resolve the difference.

Two Reuter Stokes pressurized ionization chambers (PICs) provided additional capability for measuring direct radiation exposure. These units are no longer part of the routine monitoring program, but they are used in special monitoring situations and maintained as back-up monitoring systems.

4.3.2 Airborne Particulate/Iodine

Air particulate and air iodine (I-131) samples were obtained through the use of portable, low volume (1.5 cfm) constant flow-rate sampling units at each of twelve locations. The samples drawn at Station 9A (Figure 4-3) were considered control samples; the ones drawn at the other locations (Figure 4-1) were indicator samples. Air particulate samples were collected by drawing air through a 47mm diameter glass fiber filter. Air iodine samples were collected by drawing air through a 57mm diameter TEDA impregnated charcoal cartridge. The particulate air filter and charcoal cartridge were placed in tandem, particulate filter first, in a holder that attached to the air inlet of the sampler unit. The sampler units were placed in ventilated metal weatherproof housings mounted on elevated platforms at each air sample location. The filter media are changed weekly and shipped to the analytical contractor for analysis within one or two days of collection.

4.3.3 Water

There were nine locations for water sampling in 1998: three for the evaluation of river/drinking water, one for plant discharge water, three for groundwater, one for the storm drain water, and one for sanitary waste water. One river/drinking water location, Station 26, was used for evaluation of the plant intake water. This sample location is also used for a drinking water sample since Plant 2 draws its drinking water from the intake water. It is considered the river/drinking water control sample because it si located upstream of the plant discharge. Two additional locations, Stations 28 and 29, were used to evaluate the water at the two nearest drinking water locations, the Department of Energy 300 Area and the Richland Water Treatment Plant. These two stations were considered indicator stations.

The ODCM requirement for a downstream water sample "near but beyond the mixing zone" was met by sampling water from Station 27, the plant discharge line to the Columbia River. This sample reflects the radioactivity present in the plant discharge prior to any river dilution, rather than the concentrations that would be found after dilution in the mixing zone. Water is drawn at this location because it was not feasible to perform flow-proportional composite sampling in the mixing zone area of the river downstream from the plant discharge point. The Station 27 sample was also considered an indicator sample.

Composite samplers are installed at the Columbia River pumphouse to monitor the plant intake water (Control Station 26), and the cooling tower discharge line (Station 27). There are also

composite samplers at the two drinking water locations (Stations 28 and 29). The samplers collect 25-ml aliquots of water at regular intervals of time or flow. Non-routine analyses on the drinking water samples include strontium-90 and iodine-131 analysis. Strontium-90 analysis is required when the gross beta activity exceeds either 8 pCi/liter or ten times the mean of the previous three months' activity for a specific location. Iodine-131 analysis is required when the dose calculated for the consumption of water exceeds one millirem per year. During 1998, neither of these analyses were required.

There are three wells within the vicinity of Plant 2 that are used as groundwater sampling locations. These are a deep well on the Plant 2 site (0.1 mile north of the Reactor Building) and two wells on the WNP-1 site (1.2 miles downgradient from Plant 2). Water from the Plant 2 well can be used as a backup source for drinking and fire protection. Water from the WNP-1 wells supplies the drinking and fire protection water for the WNP-1 site. Although none of these wells draw from the unconfined aquifer, they are considered indicator samples. Quarterly grab samples were taken from each of these wells. One gallon (3.8 liters) was collected from each well for gamma analysis and one liter was drawn for tritium analysis.

Water samples were collected from the storm drain outfall (Station 101) using a flow proportional composite sampler. These samples were analyzed for gross beta, gamma and tritium. EFSEC Resolution No. 259 for the Sanitary Waste Treatment Facility (SWTF; Station 102) requires a monthly sample to be taken at the headworks (102B) which was analyzed for gamma and tritium and two samples prior to discharge (102C) which were taken at the discharge weir of the south pond. Those samples were analyzed for gross alpha, gross beta, gamma and tritium. In addition, one sample was taken from the west end of each pond and analyzed for gross beta, gamma and tritium.

Beginning in April of 1997, the SWTF began receiving sanitary waste from the U.S. Department of Energy's 400 Area. The Supply System installed a flow meter and composite sampler on the 400 Area sewer line just above where the 400 Area/Plant Support Facility (PSF) intertie is located. This sampler takes a flow-proportional composite sample that is collected and analyzed monthly. Gross alpha and beta analyses, tritium analysis, and gamma analysis were performed on each sample.

4.3.4 Soil

As required by the Site Certification Agreement (EFSEC Resolution No. 260[6]), annual soil samples were taken at the indicator stations, Stations 1, 7, 21 and 23. One sample was taken at the control location, Station 9A (Figure 4-3). Quarterly soil samples were collected at two special interest locations, Station 101 and Station 118, as shown in Figures 4-4.

Each sample was collected from an area of approximately one square foot to a depth of approximately one-inch. Approximately two kilograms of soil were collected in each sample. Soil samples were shipped to the analytical contractor after collection and analyzed for gamma activity.

If the gamma isotopic analysis indicates that cesium levels in any of the indicator samples exceeds ten (10) times the level in the control sample, a strontium analysis is performed on the sample(s). No strontium analysis was required during 1998.

4.3.5 Sediment

River sediment samples were collected in April and October 1998. The upstream sediment samples (Station 33) were collected from a location approximately two miles upriver from the plant discharge. The downstream samples (Station 34) were collected approximately one mile downstream of the plant discharge. Each sample consisted of approximately two kilograms of the shallow surface sediment scooped from below the waterline. The samples were shipped to the analytical contractor.

Sediment samples were also taken from the storm drain (Station 101) outfall and pond and the SWTF (Station 102) north stabilization pond. Sediment sampling in these locations was performed in a manner similar to river sediment sampling. Special care was taken to prevent loss of the fine particulates in the sediment. In addition, formalin was added to the sanitary pond sediment prior to shipping, to inhibit gas formation within the sample container.

A 2-kilogram sample of dried cooling tower sediment was collected from the sediment disposal cell (Station 119) within thirty days of the completion of cleaning the cooling towers. In 1998 the cooling towers were cleaned once, hence, only one sample was collected for gamma spectrometry analysis.

4.3.6 Fish

The annual fish sampling was performed in late September and early October. Fish samples collected from the Columbia River (Station 30 in Figure 4-1) were indicator samples, whereas the fish collected on the Snake River (Stations 38 and 38A in Figure 4-2) were control samples.

Three separate fish samples, consisting of an anadromous species and two other species generally considered edible or potentially edible (such as carp, catfish and whitefish) were collected at each location. All the fish were collected using electro-shocking except the samples of the anadromous species, which were collected from the Ringold hatchery on the Columbia River and at the Lyons Ferry Fish Hatchery on the Snake River. The fish were filleted to obtain approximately one kilogram of edible flesh per sample. The fillets were placed in clean plastic bags and frozen until shipment to the analytical contractor. Fish are sampled annually unless elevated radiation levels related to plant operations are observed, in which case sampling is conducted semiannually.

4.3.7 Milk

Milk samples were collected monthly January through March and October through December and twice a month during the spring and summer months when the cows were likely to be grazing or on fresh feed. Enough raw milk was collected from each sampling location to obtain a one-gallon sample after the cream had been skimmed off. The samples were refrigerated overnight and the cream skimmed off the next morning. The milk samples were chilled and shipped to the analytical contractor within a day of collection.

Routine samples were collected from two indicator locations (Stations 36 and 64) across the Columbia River in Franklin County. Milk samples were also collected at one indicator station (Station 9B) and one control location (Station 96) in the Sunnyside/Grandview area (in Figure 4-3). Station 9B in Sunnyside serves as an indicator station because a portion of the feed for the cows at

that location is hay from Franklin County north of Pasco. That factor makes it unsuitable for use as a control location. In March, the Station 96 dairy ceased operation, resulting in the loss of the control station. In April, routine garden produce samples from Station 9C were used as a substitute while other dairies in the area were checked for suitability as a new control location. These dairies were all eliminated due to their use of feed grown in the Franklin County area, which is downwind from Plant 2. Beginning in August, samples of feed grown at Station 9B were taken monthly as a substitute for the lost control station.

4.3.8 Garden Produce

Samples of local garden produce were collected monthly from April to September when the produce was readily available. When possible, three types of produce samples (a root crop, fruit, and a leafy vegetable) were collected at each location. The indicator samples were collected from a region in a predominant downwind direction (Station 37 in Figure 4-2) where crops are irrigated with Columbia River water. The control samples were obtained from produce stands in the Sunnyside area (Station 9C in Figure 4-3), the direction least likely to be affected by plant effluents. Apples were collected in September from Station 91, the Rio Vista Farms orchard, which is irrigated with Columbia River water.

4.3.9 Vegetation

The annual sample of vegetation growing in the storm drain pond was collected in June. Cattails and grasses were the principal types of vegetation collected. Approximately two kilograms of sample were collected each time. Care was taken to avoid including the roots or soil from around the roots in the samples.

4.4 Analytical Procedures

The analytical procedures used for the 1998 REMP samples are described below. Teledyne Brown Engineering Environmental Services performed all routine analyses of REMP samples during 1998.

4.4.1 Gross Beta Activity on Particulate Filters

The particulate filters were counted in a gas flow-proportional counter after a delay of five or more days to allow for the radon-222 and radon-220 (thoron) daughter products to decay. An unused air particulate filter was counted as the blank with each weekly set of filters.

4.4.2 Measurement of Gamma Emitters

A shielded Ge(Li) detector system was coupled to a computer-based data acquisition system which performed pulse height and gamma energy analysis. The information collected about each peak was compared to a library of known peaks. Isotopic identification was performed as was the radioactivity calculation which used the appropriate fractional gamma ray abundance, half-life, detector efficiency, and net counts in the peak region.

Milk and Water

A 1-liter Marinelli beaker was filled with a representative aliquot of the sample. The sample was then counted for at least 1000 minutes (16.7 hours).

Foodstuff

As much of the edible portion of the sample as possible was loaded into a tared Marinelli beaker and weighed. The sample was then counted for at least 1000 minutes (16.7 hours).

Vegetation

As much sample as possible was placed in a 1-liter Marinelli beaker and counted for approximately 1000 minutes (16.7 hours). The sample was not dried prior to counting, so the results are given in terms of wet weight.

Soils and Sediments

A large quantity of the sample was dried at a temperature below 100°C. As much sample as possible was loaded into a tared 1-liter Marinelli beaker and weighed. The sample was then counted for at least 360 minutes (6 hours).

Charcoal Cartridges (Air Iodine)

Charcoal filters were counted up to five at a time, with one positioned on the face and up to four on the side of the calibrated Ge(Li) detector. The detection limit for a charcoal cartridge was uniquely determined for each filter and by using its position. In the event that iodine-131 would have been observed in the initial counting of a set, each charcoal cartridge in the set was then positioned separately on the face of the detector and counted.

Air Particulate Filters

Four air particulate filters for a quarterly composite from each field station were aligned one in front of another and counted for at least 360 minutes (6 hours).

4.4.3 Gross Beta Activity in Water

A one-liter aliquot of each sample was evaporated to a small volume and transferred to a stainless steel planchet. The sample was dried under heat lamps, cooled, then counted on an automatic beta proportional counter. The results were calculated using empirical self-absorption curves, which enabled the correction of effective counting efficiency, based on the sample residue mass.

4.4.4 Iodine-131 in Water

Two liters of sample were first equilibrated with a stable iodide carrier. A batch treatment with anion exchange resin was used to remove iodine from the sample. The iodine was then stripped from the resin with sodium hypochlorite solution, reduced with hydroxylamine hydrochloride, and extracted into carbon tetrachloride as free iodine. It was then back-extracted as iodide into a

sodium bisulfite solution and precipitated as palladium iodide. The precipitate was weighed for chemical yield and mounted on a nylon planchet for low-level beta counting. The chemical yield was corrected by measuring the stable iodide content of the water with a specific ion electrode. During 1998, this procedure was used only on intercomparison samples, since the doses calculated via ODCM methodology for the consumption of drinking water did not exceed one millirem per year.

4.4.5 Tritium in Water

The analysis of tritium in water was performed utilizing liquid scintillation. Liquid scintillation requires 10 milliliters of water mixed with 10 milliliters of liquid scintillation "cocktail." The mixture was then counted in an automatic liquid scintillation detector.

4.4.6 Strontium-89 and 90 in Water, Milk and Soil

During 1998, strontium analyses were not required for any routine REMP water, milk or soil samples. It was used for intercomparison water and sediment analyses. The techniques used to analyze for strontium in the various media are described below.

Water

Stable strontium carrier was added to one liter of sample and the volume is reduced by evaporation. Strontium was precipitated as $Sr(NO_3)_2$ using fuming (90%) nitric acid.

Milk

Stable strontium carrier was added to one liter of sample. The sample is then evaporated and ashed in a muffle furnace. The ash was dissolved and strontium precipitated as a phosphate. The sample was then redissolved and strontium precipitated as $Sr(NO_3)_2$ using fuming (90%) nitric acid.

Soil and Sediment

The sample was first dried under heat lamps and a 10-gram aliquot was taken. Stable strontium carrier was added and the sample was leached in hydrochloric acid. After filtering the mixture, phosphates were then precipitated, collected by filtration, and dissolved in nitric acid. Strontium was precipitated as $Sr(NO_3)_2$ using fuming (90%) nitric acid. A barium chromate scavenge and an iron (ferric hydroxide) scavenge were then performed. Stable yttrium carrier was added and the sample was allowed to stand for five days or more for yttrium ingrowth. Yttrium was then precipitated as hydroxide, dissolved and reprecipitated as oxalate. The yttrium oxalate was mounted on a nylon planchet and counted in a low-level beta counter to infer strontium-90 activity. Strontium-89 activity was determined by precipitating $SrCO_3$ from the sample after yttrium separation. This precipitate was mounted on a nylon planchet and covered with an 80 mg/cm^2 aluminum absorber for low-level beta counting.

4.4.7 Iodine-131 in Milk

Two liters of sample were first equilibrated with stable iodide carrier. A batch treatment with anion exchange resin was used to remove iodine from the sample. The iodine was then stripped from the

resin with sodium hypochlorite solution, reduced with hydroxylamine hydrochloride, and extracted into carbon tetrachloride as free iodine. It was then back-extracted as iodide into sodium bisulfite solution and precipitated as palladium iodide. The precipitate was weighed for chemical yield and mounted on a nylon planchet for low-level beta counting. The chemical yield is corrected by measuring the stable iodide content of the milk with a specific ion electrode.

4.5 Data Analysis Methods

Since mid-1984, the results of the REMP analyses have been presented as net results calculated from the gross or total counts determined for each radionuclide minus the background counts of the counting or detection instrument. Consequently, for several sample types, the results range from negative to positive numbers. This manner of presenting environmental data prevents the bias and loss of individual results inherent in the use of "less than" (<) values, where the "less than" numbers can have a variety of meanings, such as "less than the lower limit of detection (LLD)." A listing of the LLDs determined for each analysis is provided in Table 4-4 as a reference when reviewing the sample results.

Plots of the sample results versus time are used to represent the results for analyses such as gross beta on air particulate filters, where the results are normally above the lower limits of detection. In such cases, the indicator station results are plotted with the control station results for easy comparison. Other data analysis techniques, such as frequency distributions, are also used to represent the data and to determine whether trends that could be attributed to Plant 2 operations are evident. Thermoluminescent dosimeter (TLD) data is presented in terms of the net mR/day exposure rate. These results are determined from the total exposure (in mR) calculated for each TLD from its total thermoluminescent output minus the TLD background, minus any transit (or trip) exposure received during distribution and retrieval, and divided by the number of days the TLD was in the field. Frequency distributions and graphs of TLD data by meteorological sector and distance from the plant are used to interpret trends in the results.

TLD data summaries include the term "standard error." The standard error, which is the estimate of the precision of the mean, is used for the means of quarterly and annual data and is an indicator of the uncertainty associated with the results. The mean results of the quarterly TLDs are compared with the results of annual TLDs and expressed as a ratio by dividing the quarterly results by the annual result.

TABLE 4-1
RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM PLAN

SAMPLE TYPE[a]	SAMPLE STATION[b] NUMBER	SAMPLING AND COLLECTION FREQUENCY[c]	TYPE AND FREQUENCY OF ANALYSIS
1. AIRBORNE			
Particulates and radioiodine (6/12)[d]	1, 4-8, 9A, 21, 23, 40, 48, and 57	Continuous sampling; weekly collection	Particulate: Weekly gross beta[e]; gamma isotopic[f] of quarterly composite (by location) Iodine: Weekly gamma analysis.
Soil[g](0/7)	9A, 1, 7, 21 and 23, 101, 118	Annually Quarterly or more often as needed.	Gamma isotopic[f]; strontium-90[h] Gamma isotopic
2. DIRECT RADIATION			
TLD[i](34/61)	1-8, 9A, 10-25, 40-47, 49-51, 53-56, 71-86 (1S-16S)[j], 119B, 119-Control, 120-East	Quarterly, annually	Thermoluminescent output; quarterly and annual processing.
PIC	Various locations, as needed [k]	Continuous recording, as needed	Exposure rate accumulated on mag card and in internal memory
3. WATERBORNE			
River/Drinking Water[l] (3/4)	26, 27, 28 and 29	Composite aliquots[m]; monthly collection	Gamma isotopic[f], gross beta, quarterly; tritium composite; strontium-90[n]; I-131[o]
Storm Drain Water (1/1)	101	Composite aliquots[m], weekly collection; grab samples	Gamma isotopic[f], tritium, gross beta
Sanitary Waste Treatment Facility Water (1/1)	102	Monthly, annually, pre-discharge and as needed.	Gamma isotopic[f], gross beta, gross alpha, tritium
Ground Water (2/3)[p]	31, 32, and 52	Quarterly	Gamma isotopic[f]; tritium
River Sediment (1/2)[q]	33 and 34	Semiannually	Gamma isotopic[f]
Sanitary Waste Treatment Facility Sediment (1/1)	102	Monthly or more often as needed	Gamma Isotopic[f]
Cooling Tower Sediment Disposal Area (0/1)	119	Within 30 days following Cooling Tower cleaning event	Gamma Isotopic[f]
4. INGESTION			
Milk[r] (4/4)	9B, 36, 64 and 96[s]	Semimonthly during grazing season, monthly at other times	Gamma isotopic[f]; iodine-131; strontium-90[t]
Fish[u] (2/2)	30, 38	Annually [v]	Gamma isotopic[f]
Garden Produce[w](1/3)	9C, 91[x] and 37	Monthly during growing season in the Riverview area of Pasco and a control near Grandview; annual collection at Station 91.	Gamma isotopic[f]
Vegetation (1/1)	101	Annually	Gamma isotopic[f]

TABLE 4-1 (cont.)
RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM PLAN

(a) The fraction in parentheses for each sample type indicates the ratio of ODCM-required sample locations to the total number of sample locations currently being monitored in the surveillance program. The SCA also requires certain numbers of sampling stations for each type of media.

(b) The underlined sample location designates a control station.

(c) Deviations are permitted if samples are unobtainable due to hazardous conditions, seasonal availability, malfunction of automatic sampling equipment, or other legitimate reasons. Such deviations are documented in Section 5.

(d) The SCA requires nine or more air sampling stations.

(e) Particulate sample filters will be analyzed for gross beta after at least 24 to 48 hours to allow for the decay of radon daughter products. If gross beta activity is greater than 10 times the mean of the result for the control, Station 9A, gamma isotopic analysis shall be performed on the individual sample.

(f) Gamma isotopic means identification and quantification of gamma-emitting radionuclides that may be attributable to the effluents of Plant 2.

(g) Soil samples are collected to satisfy the requirements of the SCA for Plant 2. The SCA requires that soil samples be collected at five air sampling locations.

(h) Strontium-90 analysis shall be performed on any indicator soil sample having cesium results greater than ten times the results for the control location.

(i) TLD refers to thermoluminescent dosimeter. For purposes of the REMP, a TLD is a phosphor card (31.75mm x 44.75mm x 0.4mm) with eight individual read-out areas (four main dosimeter areas and four back-up dosimeter areas) in each badge case. TLDs used in the REMP meet the requirements of Reg Guide 4.13[5] and ANSI N545-1975, except for specified energy-dependence response. Correlation factors are available for energy ranges with response outside of specified tolerances.

(j) TLD Stations 71-86 are special interest stations and are not included among the 34 routine TLD stations required by the ODCM Table 6.3.1.1-1 (3.12-1). Their alternate designations are 1S-16S. The SCA requires that 25 or more TLD stations are located within a 10-mile radius of the plant.

(k) Pressurized ion chambers (PICs) are not required as part of the routine monitoring program, but they are required by the SCA to be maintained as a supplemental or backup system. PICs were used routinely at various locations during 1998 to provide supplemental information.

(l) The term "river/drinking water," instead of "surface/drinking water," is used throughout this report because the surface water is taken from the Columbia River. Station 26, Plant 2 makeup water intake from the Columbia River is both an upstream surface, or river, water sample and the drinking water control sample location. Station 28 (300 Area) and Station 29 samples are drinking water samples. The Station 27 sample, which is drawn from the plant discharge line, is taken in place of a "downstream" water sample near but beyond the mixing zone. It reflects the radioactivity present in the plant discharge prior to any river dilution. The SCA requires two drinking water locations downstream from the plant discharge and requires sampling from the plant intake and discharge water. Station 101, the storm drain pond, and Station 102, the Sanitary Waste Treatment Facility, are represented individually because they are unique sampling locations requiring special attention.

TABLE 4-1 (cont.)
RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM PLAN

(m) Composite (integrated grab) samples are collected with equipment that collects an aliquot at time intervals that are short relative to the compositing period.

(n) When the gross beta activity in drinking water exceeds 8 pCi/liter, a strontium-90 analysis is performed.

(o) When the dose calculated via ODCM methodology for consumption of water exceeds 1 mrem per year, iodine-131 analyses are performed on the drinking water samples.

(p) The SCA requires sampling from wells used for fire protection and as backup drinking water sources.

(q) The SCA requires sediment sample collection upstream and downstream of the plant discharge.

(r) Milk samples will be obtained from farms or individual milk animals which are located in the most prevalent wind directions from Plant 2. Routine milk samples are collected in areas of high dose potential instead of within 5 kilometers, due to the locations of milk animals. The SCA requires at least three milk locations within the 10-mile radius of the plant and one in a control location.

(s) Station 96 is the control station for milk samples because it was determined that the cows at Station 9B in Sunnyside were given feed grown in the Franklin County area across the Columbia River from Plant 2.

(t) If cesium-134 or cesium-137 is measured in an individual milk sample in excess of 30 pCi/1, then the strontium-90 analysis will be performed.

(u) There are no commercially important species in the Hanford Reach of the Columbia River. Most recreationally important species in the area are anadromous (primarily salmonids), which ascend rivers from the sea for breeding. Three fish species will normally be collected by the electroshock technique in the vicinity of the plant discharge (Station 30) and from the Snake River (Station 38). If electro-shocking produces insufficient anadromous fish samples from the Snake River, samples may be obtained from the Lyons Ferry Fish Hatchery. If insufficient anadromous fish samples are produced through electro-shocking on the Columbia River, samples may be obtained at the Ringold Fish Hatchery.

(v) If an impact is indicated, sampling will be conducted semiannually.

(w) Garden produce will routinely be obtained from farms or gardens using Columbia River water for irrigation. One sample of a root crop, leafy vegetable, and a fruit is collected each sample period, if available. The variety of the produce obtained will be dependent on seasonal availability.

(X) Station 91 is an apple orchard irrigated with Columbia River water. The apple crop from Station 91 is sampled annually.

TABLE 4-2
REMP SAMPLE STATIONS AND REQUIREMENTS

SECTOR[a]	STATION[b] NUMBER	DISTANCE[c]	ODCM[d]	STATE[e]	OTHER[f]
N (1)	52	0.1	GW		
	71(1S)	0.3			TLD
	47	0.9		TLD	
	57	0.9	AP/AI		
	18	1.1	TLD	TLD	
	53	7.5	TLD		
NNE (2)	72(2S)	0.4			TLD
	2	1.8	TLD	TLD	
	54	6.5	TLD		
NE (3)	73(3S)	0.5			TLD
	19	1.8	TLD	TLD	
	48	4.5	AP/AI		
	46	5.0	TLD		
ENE (4)	101	0.3			SW[g], SE, SO, VE
	74(4S)	0.4			TLD
	21	1.5		TLD,AP/AI, SO	
	20	1.9	TLD	TLD	
	11	3.1		TLD	
	33	3.6		SE	
	45	4.3	TLD		
	44	5.8	TLD		
E (5)	75(5S)	0.4			TLD
	22	2.1	TLD		
	10	3.1	TLD	TLD	
	26	3.2	SW, DW	SW	
	27[a]	3.2		DIS W	
	30	3.3	FI	FI	
	43	5.8	TLD		
ESE (6)	76(6S)	0.4			TLD
	31	1.1	GW	GW	
	32	1.2		GW	
	51	2.1	TLD		
	23	3.0		TLD,AP/AI, SO	
	34	3.5	SE	SE	
	91	4.4		GP	
	8	4.5	TLD, AP/AI	TLD, AP/AI	
	42	5.6	TLD		
	36[a]	7.2	MI	MI	

TABLE 4-2 (cont.)
REMP SAMPLE STATIONS AND REQUIREMENTS

SECTOR[a]	STATION[b] NUMBER	DISTANCE[c]	ODCM[d]	STATE[e]	OTHER[f]
ESE (6)	5	7.7	TLD	AP/AI	
	64	9.7	MI	MI	
	38	26.5	FI	FI	
SE (7)	118	0.3			SO
	77(7S)	0.5			TLD
	24	1.9	TLD	TLD	
	3	2.0		TLD	
	41	5.8	TLD		
	40	6.4	TLD, AP/AI		
SSE (8)	119-Control	0.2		TLD	
	120	0.3			TLD, SE
	102A	0.4		SFW	
	102B	0.4		SFW	
	102C	0.4		SFW	
	102D	0.4			SFW, SE
	102E	0.4			SFW
	78(8S)	0.7			TLD
	25	1.6	TLD	TLD	
	55	6.2	TLD		
	28	7.4	SW, DW	DW	
	4	9.3	TLD, AP/AI	TLD,AP/AI	
	29	11.0	DW	DW	
	37B	16.0	GP	GP	
	37A	17.0		GP	
S (9)	119B	0.2		TLD, SE, PIC	
	79(9S)	0.7			TLD
	1	1.3	TLD	TLD,AP/AI, SO	
	6	7.7	TLD	AP/AI	
	65	8 7			TLD
SSW (10)	80(10S)	0 8			TLD
	50	1.2	TLD	TLD	
	56	7 0	TLD		
SW (11)	81(11S)	0.7			TLD
	13	1.4	TLD	TLD	
	96	36.0	MI	MI	
WSW (12)	82(12S)	0.5			TLD
	14	1.4	TLD	TLD	
	9A,	30.0	TLD,AP/AI	TLD, AI/AP	

TABLE 4-2 (cont.)
REMP SAMPLE STATIONS AND REQUIREMENTS

SECTOR[a]	STATION[b] NUMBER	DISTANCE[c]	ODCM[d]	STATE[e]	OTHER[f]
	9C,	35.0	GP	GP	
WSW (12)	9B	33.0	MI	MI	
W (13)	83(13S)	0.5			TLD
	15	1.4	TLD	TLD	
WNW (14)	84(14S)	0.5			TLD
	16	1.4	TLD	TLD	
	7	2.7	TLD	TLD, AP/AI, SO	
NW (15)	85 (15S)	0.5			TLD
	49	1.2	TLD	TLD	
NNW (16)	86(16S)	0.4			TLD
	17	1.2	TLD	TLD	
	12	6.1		TLD	

FOOTNOTES:

(a) The area in the vicinity of Plant 2 is separated into 16 sectors for reporting purposes. The 16 sectors cover 360 degrees in equal 22.5 degree sections, beginning with Sector 1 (N) at 348.75 TO 11.25 degrees and continuing clockwise through sector 16 (NNW).

(b) The alternate designations for TLD Stations 71-86 are given in parentheses, i.e., 1S-16S.

(c) Distances are estimated from map positions for each location as a radial distance from Plant 2 containment.

(d) ODCM - Offsite Dose Calculation Manual Table 6.3.1.1-1 requirement.

(e) State of Washington Site Certification Agreement requirements.

(f) OTHER – NPDES and special study stations.

(g) The NPDES Permit only requires sampling for tritium.

(h) Duplicate samples, i.e., samples drawn at the same time as the routine samples and submitted for analysis as a quality control check, are collected at this location. The station designation for the duplicate of Station 27 is Station 92 for the first quarter and 72 for the second quarter. The station designation for the duplicate of Station 36 is Station 37.

Sample Type Key:

AI/AP	-Air Iodine	DW	-Drinking Water
FI	-Fish	GP	-Garden/Orchard Produce
GW	-Ground Water	MI	-Milk
PIC	-Pressurized Ion Chamber	SE	-Sediment
SFW	-Sanitation Facility Water	SO	-Soil
SW	-Surface Water	TLD	-Thermoluminescent Dosimeter
VE	-Vegetation	Dis W	-Discharge Water

TABLE 4-3
1998 FIVE MILE LAND USE CENSUS RESULTS

SECTOR[a]	NEAREST RESIDENT[b]	GARDEN (>50M^2)	DAIRY[c] ANIMALS	LIVESTOCK
NE	4.3	none	none	none
ENE	4.1	4.1[d]	none	none
E	4.5	none	none	none
ESE	4.2	4.3[d]	none	none
SE	none	none	none	none

(a) Eleven of the sixteen meteorological sectors within the five-mile radius of Plant 2 are on the federally owned Hanford Site; the remaining land is comprised of 4.5 sq. miles of privately owned farmland. Only those sectors containing points of interest are presented here.

(b) Estimated distances in miles from Plant 2 Reactor Building.

(c) The closest dairy animal locations are at 8.3 miles SE and 7.2 and 9.7 miles ESE. The dairy at 8.3 miles SE is not used for milk sample collection due to the owner's reluctance to participate in the sampling program.

(d) Small garden with broadleaf; samples were not available due to the small amounts grown.

TABLE 4-4
COMPARISON OF TELEDYNE NOMINAL LOWER LIMITS OF DETECTION WITH OFFSITE DOSE CALCULATION MANUAL[8] REQUIRMENTS

MEDIA (UNITS)	ANALYSIS	TELEDYNE LLDs[a]	BTP REQUIRED LLDs
Air	Gross Beta	0.003	0.01
(pCi/m³)	Gamma Spectrometry		
	Cs-134	0.001	0.05
	Cs-137	0.001	0.06
	I-131	0.01	0.07
Water:	Gross Beta	4	4
(pCi/l)	Tritium	300	2000[b]
	I-131	1	—
	Sr-90	1	—
	Gamma Spectrometry		
	Mn-54	10	15
	Fe-59	20	30
	Co-58	10	15
	Co-60	10	15
	Zn-65	20	30
	Zr-95	20	30
	Nb-95	10	15
	Cs-134	10	15
	Cs-137	10	18
	Ba-140	20	60
	La-140	10	15
Soil/Sediment:	Gamma Spectrometry		
(pCi/kg dry)	Co-57	120	—
	Co-60	30	—
	Zn-65	100	—
	Cs-134	30	150
	Cs-137	40	180
	Sr-90	10	—
Fish:	Gamma Spectrometry		
(pCi/kg wet)	Mn-54	20	130
	Fe-59	30	260
	Co-58	20	130
	Co-60	20	130
	Zn-65	30	260
	Cs-134	20	130
	Cs-137	20	150
Milk:	I-131	0.5	1
(pCi/l)	Gamma Spectrometry		
	Cs-134	10	15
	Cs-137	10	18
	Ba-140	20	60
	La-140	10	15
	Sr-90	1	—
Garden Produce:	Gamma Spectrometry		
(pCi/kg wet)	Cs-134	20	60
	Cs-137	20	80
	I-131	30	60

[a] These are the contract LLDs. Actual LLDs may be lower for specific samples.

[b] If no drinking water pathway exists, a value of 3,000 pCi/l may be used.

THIS PAGE INTENTIONALLY BLANK