10.0 Biota Monitoring

10.1 Agricultural Monitoring

ME Hoefer

Food and farm products (cherries, leafy vegetables, milk, potatoes, and tomatoes) were collected in 2015 at locations near the Hanford Site (Figure 10.1; note not all agricultural monitoring locations shown are sampled each year due to program efficiencies, budgetary restrictions and historical trending purposes). These products are used to determine pathway-specific exposure assumptions by way of annual dose calculations based on a 1 mrem/yr (10 mSv/yr) threshold and ingestion pathways for annual intake, assuming 100% of each food originated in the affected area.

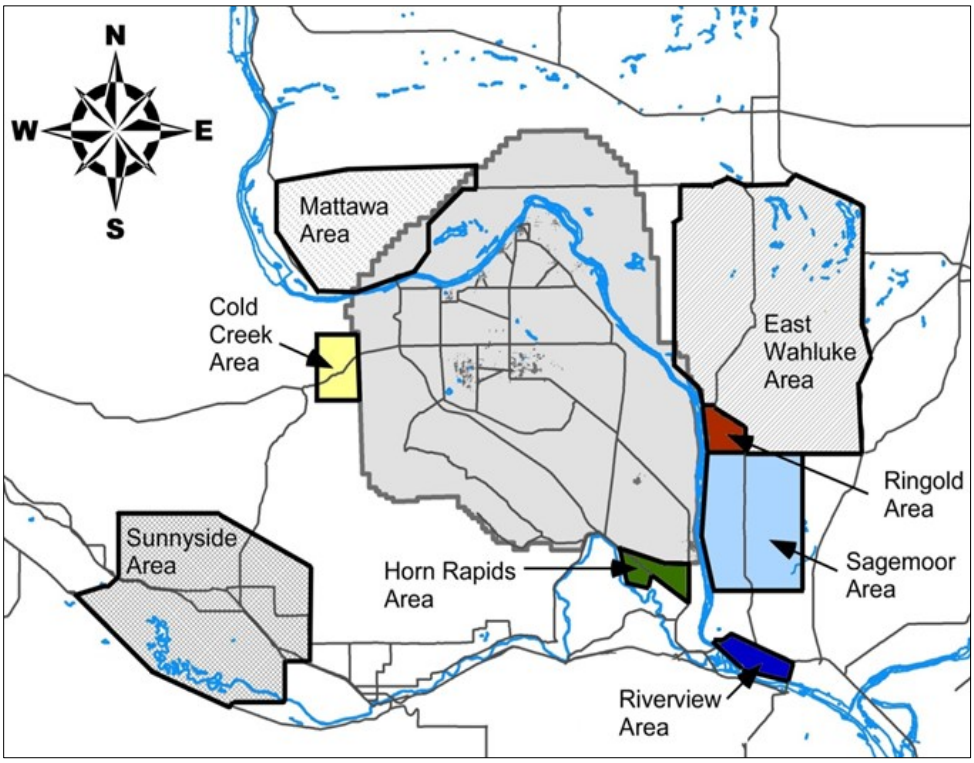


Figure 10.1. Agricultural Monitoring Locations

Samples analyzed to determine radiological contaminant concentrations were obtained from the following locations:

- generally downwind (east and southeast) of the Hanford Site where airborne emissions or contaminated dust from the site potentially would be deposited
- generally upwind of and distant from the Hanford Site to provide information about reference (background) contaminant levels
- from farms irrigated with water taken from the Columbia River downstream of the Hanford Site.

Sample analyses are used to assess the amounts of Hanford Site-origin contaminants in food and farm products by comparing analytical results obtained from similar samples collected from the same regions

over long periods of time; from samples collected at downwind locations to results from samples obtained from generally upwind or distant locations; and from samples collected in areas irrigated with water withdrawn from the Columbia River downstream of the Hanford Site to analytical results from samples obtained from locations irrigated with water from other regional sources.

Radionuclide concentrations in most food and farm product samples in 2015 were below the analytical laboratory detection levels; however, some potential Hanford Site-produced contaminants (e.g., strontium-90, tritium) were found at low levels in some samples. Data for potassium-40 are included to show the natural radioactive elements that exist in food products relative to concentrations of potential Hanford Site-produced contaminants. Radiological doses associated with potential Hanford Site-produced contaminants are discussed in Section 4.0. Where possible, the measured concentrations are compared to the applicable unusual concentration reporting levels. Unusual concentration reporting levels have been established based on environmental concentrations that would result in a dose of 1 mrem (10 mSv)/yr (DOE/RL-91-50). Agricultural products sampled in 2015 are listed in Table 10.1 and described in the following sections.

Table 10.1. Agricultural Monitoring Location

Product	Sampling Locations	Analytes
Alfalfa	Horn Rapids, Riverview, Sagemoor, Sunnyside	^{14}C, Gamma, Sr-90
Apples	Mattawa, Riverview, Sagemoor, Sunnyside	Gamma, Sr-90
Corn	East Wahluke, Riverview, Sagemoor, Sunnyside	^{14}C, Gamma, Sr-90
Leafy vegetables	East Wahluke, Riverview, Sagemoor, Sunnyside	Gamma, Sr-90
Melons	East Wahluke, Riverview, Sagemoor, Sunnyside	^{14}C, Gamma, Sr-90
Milk	East Wahluke, Sagemoor, Sunnyside	Gamma, Sr-90, Tritium
Potatoes	East Wahluke, Horn Rapids, Riverview, Sagemoor, Sunnyside	Gamma, Sr-90
Tomatoes	Riverview, Sunnyside	Gamma, Sr-90, Tritium
Wine	Columbia Basin, Mattawa, Yakima Valley	Low-level Tritium, Gamma

10.1.1 Milk

Milk samples were obtained quarterly in 2015 from several dairies in the East Wahluke and Sagemoor sampling areas and one dairy in Sunnyside. The Sunnyside dairy closed during the third quarter of 2015, so no data were available for the late summer and fall collections in relation to Sunnyside area milk. Another dairy is currently being sought to return to quarterly collections in all three areas in CY 2016.

The Sagemoor and East Wahluke sampling areas are located near the Hanford Site perimeter and could potentially be affected by airborne contaminants from the site. The Sunnyside area is a reference location generally upwind of the Hanford Site. If milk were obtained from more than one dairy within a sampling area, the milk samples were combined, and the composite sample was analyzed. All samples were analyzed for gamma-emitting radionuclides, tritium, and Sr-90. Milk sampling was conducted because Hanford Site-produced radionuclides have the potential to move through the air-pasture-cow-milk or water-pasture-cow-milk food chains to humans. In recent years, levels of Hanford Site-produced radiological contaminants in milk samples have diminished in conjunction with facility shutdowns and remedial efforts. Concentrations in samples obtained from dairies downwind of the Hanford Site are now similar to levels measured in samples obtained from the dairies generally upwind of the Hanford Site.

Tritium. Tritium was detected in all milk samples collected in 2015. Overall concentrations ranged from a maximum of 44 pCi/L (1.6 Bq/L) in a Sagemoor-area sample to a minimum of 12 pCi/L (0.44 Bq/L) in a Sunnyside-area sample. Annual average concentrations for the three sampling areas were 28 pCi/L (1.0 Bq/L). Specific location average was 35 pCi/L (1.3 Bq/L) for Sagemoor (n=4); 26 pCi/L (0.96 Bq/L) for East Wahluke (n=5); and 19 pCi/L (0.70 Bq/L) for Sunnyside (n=2). Maximum and average concentrations were less than those historically measured at these locations.

Strontium-90. No detectable concentrations were found in 2015 milk samples.

Cesium-137. No synthetic gamma emitters were detected in milk samples collected and analyzed in 2015.

Potassium-40. Naturally occurring potassium-40 was detected in all milk samples collected in 2015. Concentrations ranged from a maximum of 1,600 pCi/L (59 Bq/L) in a Sagemoor area sample to a minimum of 1,370 pCi/L (51 Bq/L) in an East Wahluke sample. The Sunnyside area had a maximum of 1,500 pCi/L (56 Bq/L), and the overall average was 1,476 pCi/L (55 Bq/L) for all results.

10.1.2 Fruit, Vegetables, and Farm Products

Alfalfa, apple, corn, leafy vegetable (e.g., lettuce), melon, potato, and tomato samples were collected from upwind and downwind sampling areas during the 2015 growing season (Figure 10.1; Table 10.1). All samples were analyzed for gamma-emitting radionuclides and Sr-90. Corn, leafy vegetables, and melons were also analyzed for carbon-14 for additional monitoring due to increased concentrations in the 100K area and to further support VIT plant-monitoring. Tomato samples were also monitored for tritium (Table 10.1) and showed no detectable concentrations during 2015.

Three of four leafy vegetable samples collected from the East Wahluke, Sagemoor, and Sunnyside areas had detectable Sr-90 with a maximum concentration of 0.006 pCi/L (2.2E-04 Bq/L), with results falling well within historical levels. All fruit and vegetable concentrations of cesium-137, cobalt-60, and tritium were reported as non-detects and were well within the historical 5-year range. All apple, cherry, corn, leafy vegetable, melon, potato, and tomato samples had detectable concentration levels of naturally occurring potassium-40.

Alfalfa (or similar foraging grass, e.g., Timothy, Orchard, etc.) samples were collected in the Horn Rapids, Riverview, Sagemoor, and Sunnyside areas in 2015. Analyses included gamma-emitting radionuclides and strontium-90. All samples had detectable concentrations of naturally occurring potassium-40, and a single sample from the Riverview area had a maximum detectable concentration of strontium-90 (0.098 pCi/L), similar to the maximum concentration reported in the previous 10 years (0.0975 pCi/L).

10.1.3 Wine

Wine samples were collected from the Columbia Basin, Mattawa area, and the Yakima Valley. All samples were analyzed for gamma-emitting radionuclides and tritium. Average concentrations (26 pCi/L) of vintage 2015 wine fell below historical averages (51 pCi/L) and maximum concentrations (39 pCi/L) found in 2015 also fell well below the 10-year maximum (447 pCi/L). Wine samples had detectable concentration levels of naturally occurring potassium-40 as well.

10.2 Fish and Wildlife Monitoring

JW Wilde

The fish and wildlife species sampled and analyzed for Hanford Site operations-produced contaminants during the 2015 calendar year were mountain whitefish (*Prosopium williamsoni*), white sturgeon (*Acipenser transmontanus*), Nuttall's cottontail rabbit (*Sylvilagus nuttallii*), and Canada goose (*Branta canadensis*). Monitoring fish and wildlife for uptake and exposure to Hanford Site operations-produced contaminants ensures that consumption of fish and wildlife obtained from Hanford Site environs does not pose a threat to human health and provides long-term contamination trends. These species were selected and monitored because they provide a potential pathway for off-site human consumption. Figure 10.2 shows locations on and around the Hanford Site where fish and wildlife were collected in 2015. Samples of fish and wildlife were analyzed for selected (suspected or known to be present) radionuclides and metals (Table 10.2). In addition, samples were collected from locations distant from the Hanford Site to obtain reference (background) contaminant measurements. All fish and wildlife samples were monitored for strontium-90 contamination and analyzed by gamma spectrometry to detect a number of gamma emitters, including cesium-137. Since the 1990s, strontium-90 and cesium-137 have been the most frequently measured radionuclides in fish and wildlife samples.

Table 10.2. Animal Monitoring Analysis

Biota	Off-site Locations	On-site Locations	Gamma	Strontium-90	Trace Metals
Fish (mountain whitefish)	1	3	18	18	4
Fish (white sturgeon)	0	5	10	20	9
Mammals (cottontail)	1	2	14	7	6
Waterfowl (Canada goose)	1	2	9	9	0

Most fish and wildlife samples are collected on and around the Hanford Site and analyzed for human-pathway exposure every 2 to 3 years, with samples obtained at locations determined not to be affected by Hanford Site effluents and emissions approximately every 5 years.

Strontium-90 is present in Hanford Site environments because of past Hanford Site operations and waste disposal practices. Contaminated groundwater entering the Columbia River through shoreline springs in the 100-N and 100-H areas is the primary source of measurable Hanford Site-produced strontium-90 in the Columbia River. Chemically similar to calcium, strontium-90 consequently accumulates in hard tissues rich in calcium such as bones, antlers, and eggshells. In addition, Sr-90 has a biological half-life in hard tissue from 14 to 600 days (PNL-9394, *Ecotoxicity Literature Review of Selected Hanford Site Contaminants*). Hard-tissue concentrations may profile an organism's lifetime exposure to strontium-90; however, because strontium-90 does not accumulate in edible portions of fish and wildlife, it generally does not contribute much to the human dose (NCRP 2009).

Cesium-137 is present in Hanford Site environments because of past Hanford Site operations, waste disposal practices, and from historical worldwide fallout resulting from nuclear weapons testing. Cesium-137 is particularly important to the human food chain because the isotope is chemically similar to potassium and is found in the muscle tissues of fish and wildlife. Cesium-137 is an indicator of recent exposure to radioactive materials because it has a relatively short biological half-life (less than 200 days in muscle and less than 20 days in the gastrointestinal tract [PNL-9394]).

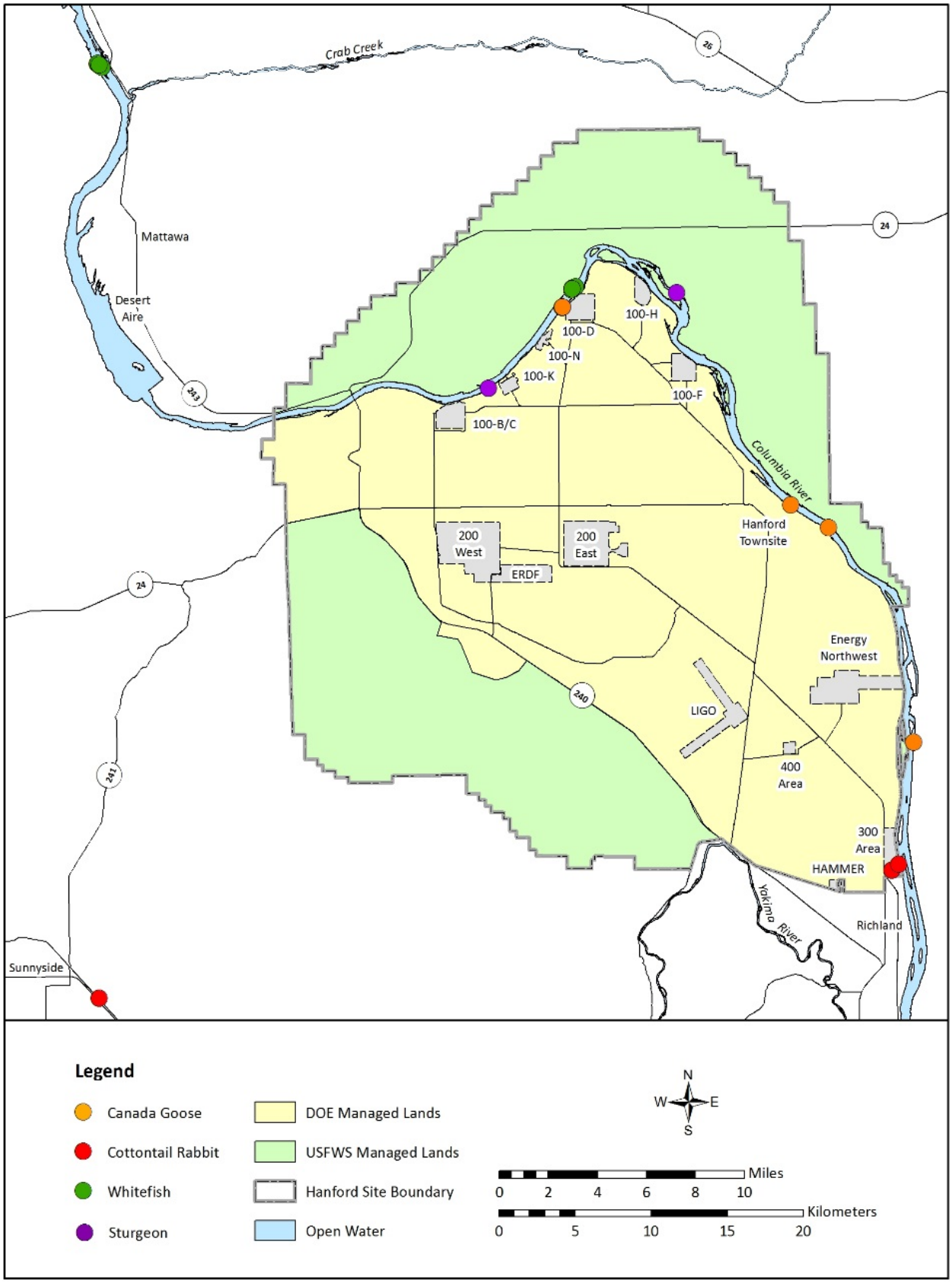


Figure 10.2. Animal Monitoring Locations

Gamma spectrometry results for most radionuclides generally are too low to measure or the concentrations measured are considered artifacts of low background counts. Low background counts occur at random intervals during sample counting and can produce occasional spurious false-positive results. For many radionuclides, concentrations were below analytical laboratory detection levels.

A number of trace metals associated with Hanford Site operations have a potential to accumulate in certain fish and wildlife tissues. These metals are contaminants of potential concern (e.g., copper, lead, and mercury), particularly along the Hanford Site Columbia River shoreline where contaminated groundwater flows into the river. Hanford Site historical operations have resulted in the production of both radiological and non-radiological wastes, including trace-metal emissions in a variety of forms. Liquid and solid wastes that were placed in disposal sites (trenches, cribs, ditches, ponds, and underground storage tanks), and fly ash (produced from burning coal in coal-fired steam/power plants associated with some Hanford Site reactors) released to the atmosphere. The fly ash contains trace metals and natural radionuclides that may have deposited on soil surfaces around the 100 Area reactors.

10.2.1 Mountain Whitefish

In 2015, mountain whitefish were sampled and analyzed for radiological contaminants, since whitefish are sometimes harvested for food along the Hanford Reach of the Columbia River, which could potentially contribute to human exposure through digestion. Many sportsmen have found that the flesh of the whitefish is of good quality, being firm, palatable, and tasty with a bony structure similar to trout.

Sixteen mountain whitefish were collected from three locations along the Hanford Reach, including a reference area (along the 100D shoreline and eight from the reference location at Priest Rapids Lake above Priest Rapids Dam). One whole fish from the 100 Areas and one whole fish from the reference area were sent to the WDOH. Three composite samples including one duplicate were used to achieve sample mass for larger suite of analyses including trace metals. Four fish from the 100 Areas created one composite, and four fish from the reference area made up the other. An additional two composites including a duplicate were comprised of two whitefish to meet mass for the standard Gamma Emitting Analysis and strontium-90 analysis. The following are the radiological results for the 10 mountain whitefish samples analyzed.

Cesium-137. Manmade gamma-emitting radionuclides including cesium-137 were not detected above the reporting limit (0.03 pCi/g [0.001 Bq/g] wet weight) in any of the muscle samples analyzed. These results are consistent with those reported historically near the Hanford Site.

Strontium-90. Strontium-90 was not above the required limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in whitefish samples collected from the reference area and the two Hanford Reach locations.

Uranium. Uranium isotopes were detected in three samples submitted. Two samples were from the reference area above Priest Rapids Dam and a single sample from the Hanford Reach, the detections of which were lower than samples from the reference area. Uranium-234 was reported at 5.50E-04 pCi/g in the 100 Area sample with an average of 6.77E-04 pCi/g in the two reference area samples. Uranium-238 was also lower in the 100 Area sample (4.22E-04 pCi/g) than the average of the reference area samples (7.64E-04 pCi/g).

Trace Metals. Two whitefish samples were analyzed for 18 different trace metal concentrations. Only seven trace metals were detected in samples that were above the analytical detection limit at any location. Table 10.3 provides a summary of the 2015 metal analyses for the whitefish samples.

Table 10.3. Metals Analyses for the Mountain Whitefish Samples

Isotope	Samples	Detects
Aluminum	3	0
Antimony	3	0
Arsenic	3	0
Barium	3	1
Beryllium	3	0
Cadmium	3	0
Chromium	3	0
Copper	3	3
Lead	3	0
Manganese	3	2
Mercury	3	0
Nickel	3	0
Selenium	3	2
Silver	3	0
Thallium	3	0
Thorium	3	2
Uranium	3	1
Zinc	3	3

Surveillance data sets for trace-metal concentrations in fish both on and near the Hanford Site are relatively small with variable results. At this time, no established federal or state adverse-effects values (i.e., benchmark criteria) are available for trace-metal concentrations in fish tissue. Identifying Hanford Site contributions to trace-metal concentrations or drawing conclusions about contribution effects are limited by the factors above. Monitoring fish for uptake and exposure to radionuclides and metals at locations both near to and distant from the Hanford Site will continue to provide important information for tracking the extent and long-term trends of contamination in the Hanford Reach environment.

10.2.2 White Sturgeon

During the week of July 16, 2015, a sudden die-off of large white sturgeon (*Acipenser transmontanus*) occurred in the Columbia River extending from Priest Rapids Dam through the lower Columbia River. The die-off provided an opportunity to collect tissue samples from white sturgeon not normally available. The collection activities took place from the Vernita Bridge down through the 300 Area. All white sturgeon found during the survey were reported to the WDFW with location information and requested measurements. A total of six white sturgeon were found dead within the Hanford Reach. All of the deceased fish ranged from 7 to over 9 feet in length, suggesting that most were at least over 40 years in age. Two of the six white sturgeon found were in a condition acceptable for representative tissue samples to be harvested and submitted for analytical evaluation. Eight samples (four muscles and four carcasses) were processed from the harvested fish tissue (including two duplicates of each tissue type) and sent to the analytical laboratory for analysis.

Cesium-137. Manmade gamma-emitting radionuclides, including cesium-137, were found in all three filet samples analyzed. Average tissue concentrations of cesium-137 were 1.168E-02 pCi/g.

Strontium-90. Strontium-90 was not found above the reporting limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in sturgeon samples collected from the Hanford Reach.

Uranium and Plutonium. Isotopic analysis for uranium and plutonium was performed on all samples. There was no detection of uranium and plutonium above detection limits in any sturgeon samples.

Trace Metals. Seven of the 18 different trace metal analyzed were detected in sturgeon samples above detection limits. Trace metal detections are presented in Table 10.4. Mercury was detected in all samples.

Table 10.4. White Sturgeon Metals Analyses

Isotope	Samples	Detects	Isotope	Samples	Detects
Aluminum	4	0	Manganese	4	2
Antimony	4	0	Mercury	4	4
Arsenic	4	0	Nickel	4	0
Barium	4	4	Selenium	4	2
Beryllium	4	0	Silver	4	0
Cadmium	4	0	Thallium	4	0
Chromium	4	0	Thorium	4	2
Copper	4	4	Uranium	4	0
Lead	4	0	Zinc	4	4

Surveillance data sets for trace-metal concentrations in fish on and near the Hanford Site are relatively small with variable results. At this time, no established federal or state adverse effects values (i.e., benchmark criteria) are available for trace-metal concentrations in fish tissue. Identifying Hanford Site contributions to trace-metal concentrations or drawing conclusions about the effects of this contribution are limited by the factors above. Monitoring fish for uptake and exposure to radionuclides and metals at locations near to and distant from the Hanford Site will continue to provide important information for tracking the extent and long-term trends of contamination in the Hanford Reach environment.

10.2.3 Cottontail Rabbit

Cottontail rabbits are useful for detecting localized radioactive contamination because they have relatively small home ranges, forage or live in potentially contaminated soil, and can enter fenced restricted areas that contain radioactive waste materials. They also may be useful as sentinel organisms both on and off the Hanford Site. In 2015, Nuttall's cottontail were sampled from the 300 Area. Public access to cottontails exposed to Hanford Site environs is limited due to the range size of the animal. The 300 Area poses the largest probability for public contact with rabbits from Hanford environs.

Five cottontail rabbits were collected from the 300 Area, including one from the reference area. A single rabbit from the 300 Area was sent to DOH. The following data are from the remaining four samples analyzed. Results from rabbits collected in 2015 were compared to samples collected in previous years.

Cesium-137. Cesium-137 was not found above detection limits (0.03 pCi/g [0.001 Bq/g] wet weight) in cottontail rabbit samples submitted for analysis in 2015. These results are consistent with a decline in cesium-137 levels in wildlife examined from the preceding years.

Strontium-90. Three rabbit bone samples collected at the Hanford Site in 2015 contained strontium-90 concentrations with an average detection at 0.107 pCi/g (0.0039 Bq/g) wet weight. All strontium detects were from rabbits collected in the 300 Area; the single reference area rabbit had undetectable strontium-90 concentrations. Figure 10.3 shows the historical median (shows average when only two samples are present) and maximum strontium-90 concentrations (pCi/g wet weight) in rabbit bone samples collected

near the Hanford Site and from reference locations from historical sampling events. It should be noted that the Figure 10.3 y-axis is on a log scale, suggesting that 2015 strontium levels are substantially lower than results seen historically in other areas of the site. In addition, maximum concentrations in the figure are represented by the upper bar.

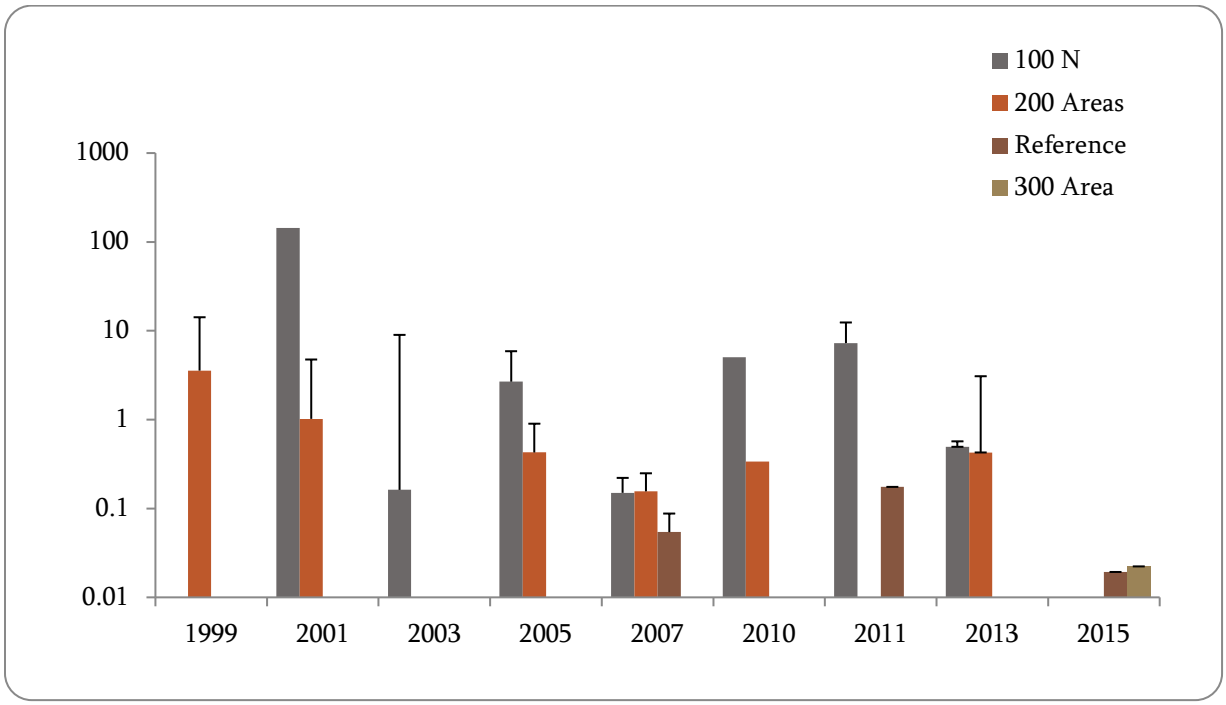


Figure 10.3. Strontium-90 Concentrations in Cottontail Bone Samples

10.2.4 Waterfowl

During 2015, six Canada geese were collected along the Hanford Reach of the Columbia River: three between the Hanford Townsite and the 300 Area, and three near the 100 Areas. Attempts to collect a reference sample goose from the Priest Rapids Lake area were unsuccessful. Sampling efforts focused on young of the year birds whose entire life cycle before collection would have occurred on the Hanford Site. All six geese were monitored for cesium-137 in muscle and strontium-90 in bone. Radionuclide levels found in muscle and bone samples analyzed during 2015 were compared with levels measured in waterfowl samples collected at the Hanford Site over the past eight sample evolutions and with samples collected from reference locations, where available.

Cesium-137. Manmade gamma-emitting radionuclides including cesium-137 were below the detection limit (0.03 pCi/g [0.001 Bq/g] wet weight) for all Canada goose muscle samples analyzed in 2015. These results are consistent with those reported over the past 15 years, illustrating the continued downward trend in worldwide levels of cesium-137 fallout resulting from materials released to the atmosphere during the nuclear weapons testing era (1950s through the 1970s).

Strontium-90. Strontium-90 concentrations were below the analytical detection limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in all Canada goose bone samples collected in 2015. Comparisons of the maximum and median strontium-90 concentrations reported for waterfowl bone samples (collected at the

Hanford Site since 1997) and reference locations are consistent with these results, which do not indicate elevated strontium-90 levels. Figure 10.4 shows the median and maximum strontium-90 concentrations (pCi/g wet weight) and reference waterfowl samples for 2015 compared to previous years. Note that maximum concentrations in the figure are represented by the upper bar.

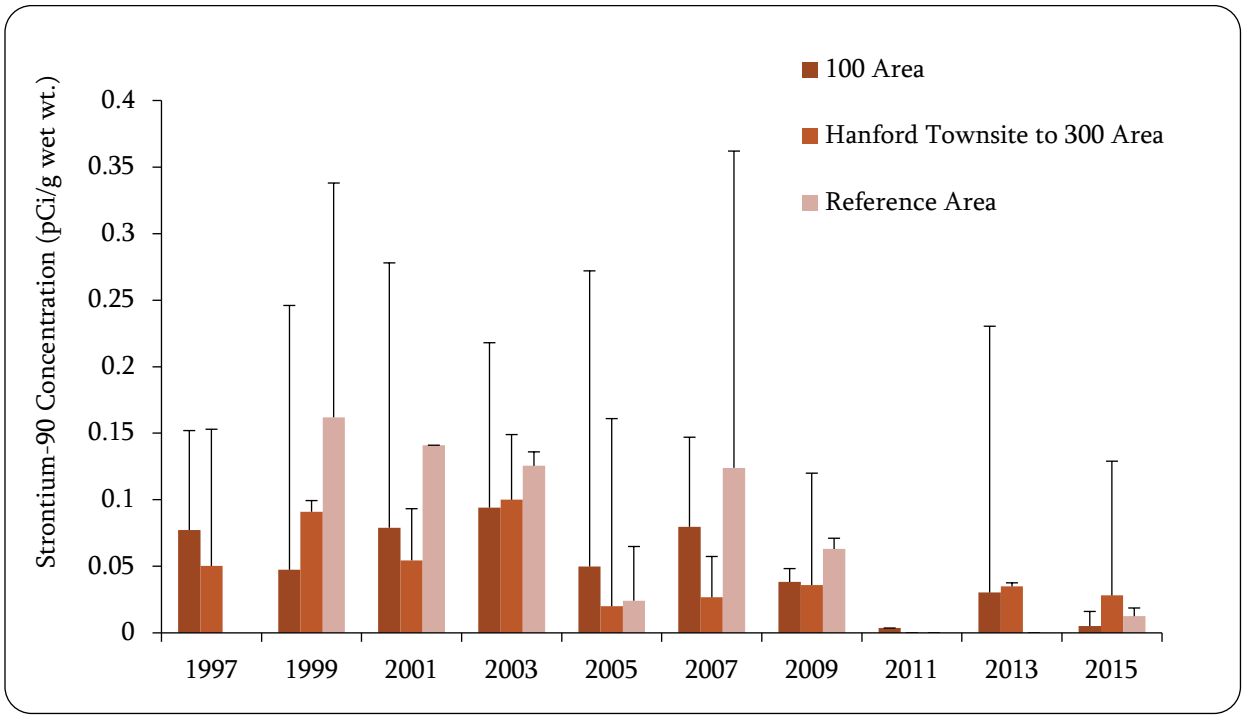


Figure 10.4. Strontium-90 Concentrations in Canada Goose Bone Samples

10.3 Vegetation Monitoring

JW Wilde, KR Turner

Vegetation monitoring conducted on and around the Hanford Site is summarized in this section. Included are discussions of surveying and monitoring of Hanford Site plant populations, monitoring contaminants in perennial vegetation growing near facilities and operations, and controlling contaminated or unwanted vegetation.

Plant populations and habitats that occur on the Hanford Site are surveyed and monitored to assess the abundance, vigor or condition, and distribution of populations and species. These data can be integrated with contaminant monitoring results and used to help characterize potential risks or impacts to biota. Vegetation near on-site facilities and operations is monitored for radiation to determine the effectiveness of effluent monitoring and controls within facilities, assess the adequacy of containment at waste disposal sites, and detect and monitor unusual conditions. Hanford Site and historical off-site vegetation samples are analyzed for information about atmospheric deposition of contaminants in and around operational areas on site and in uncultivated areas off site. These data provide a baseline against which unplanned releases can be compared. Vegetation management activities help prevent, limit, or remove contaminated plants or undesirable plant species. For further information about monitoring and control efforts, purpose, and programs that support them, refer to Section 10.3.3 or DOE/RL-91-50.

Monitoring rabbitbrush and sagebrush leaves and stems provides information about atmospheric deposition of radioactive materials in uncultivated areas and at Hanford Site locations that potentially could be affected by contaminants from Hanford Site operations. Collected on and around the Hanford Site for over 50 years, vegetation samples are maintained in a database to document on- and off-site levels of synthetic radionuclides in vegetation at specific locations. This database contains baseline data against which statistics from unplanned releases from the Hanford Site can be compared.

Vegetation samples were collected on or adjacent to waste disposal sites and from locations downwind and near or within the boundaries of operating facilities and remedial action sites. Samples were collected to evaluate long-term trends in environmental accumulation and potential migration of radioactive material. Contamination in vegetation can occur as the result of surface deposition of radioactive materials from other radiologically contaminated sources or by absorption of radionuclides through the roots of vegetation growing on or near former waste disposal sites.

The number and location of Hanford Site vegetation samples collected are summarized in Table 10.5. Only those radionuclides with concentrations consistently above analytical detection limits are discussed in this section. Data obtained from on-site vegetation samples is used as a qualitative indicator and verification of ambient air sampling results per FF-01. Vegetation samples from off-site locations were collected in 2015 and are discussed in Section 10.3.2.

Table 10.5. Vegetation Monitoring Locations

	Operational Area (discrete samples analyzed)					
Samples Analyzed	**100-N**	**200-East Area**	**200-West Area***	**300 Area***	**400 Area**	**600 Area***
44	2	9	17	1	1	14

*Sample numbers include one or more duplicates

Individual vegetation samples (approximately 17.6 oz [500 g]) consisted of new-growth leaf cuttings taken from the available brushy, deep-rooted species (e.g., sagebrush and/or rabbitbrush). To avoid decimation of any individual plant through overharvesting, samples may consist of mixed biota representing several like members of the sampling-site plant community. Vegetation samples were dried prior to analyses, and analytical results were reported on a dry weight basis.

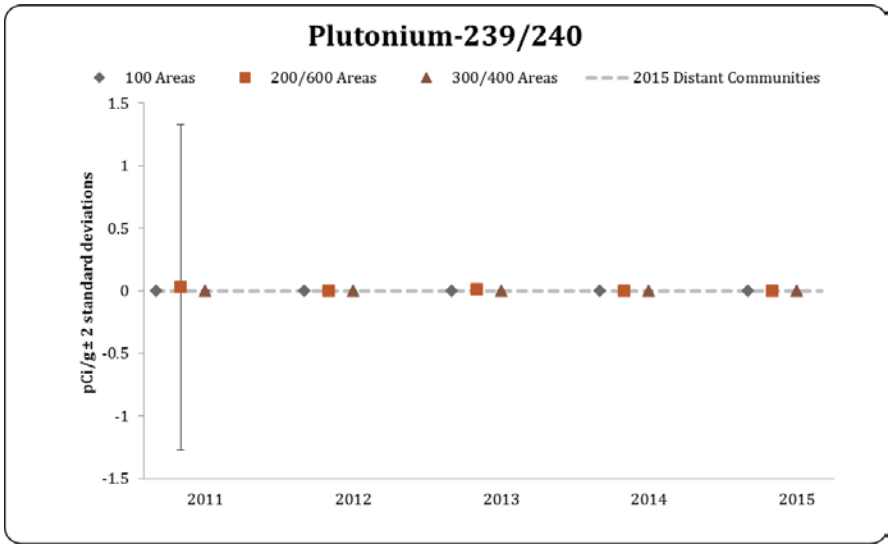
Some vegetation samples were analyzed as single-parent samples (discrete data points), while others were composited with a multi-incremental sampling approach, used when collecting samples from a large given area (i.e., decision unit). Individual samples are processed using a gridded pattern approach and combined with other samples from the decision unit to create a composite sample that represents the decision unit as a whole. This compositing limits the variability of selected environmental contaminant concentrations in a given area and reduces the amount of sampling error due to heterogeneity while allowing for a reproducible mean concentration for the decision unit.

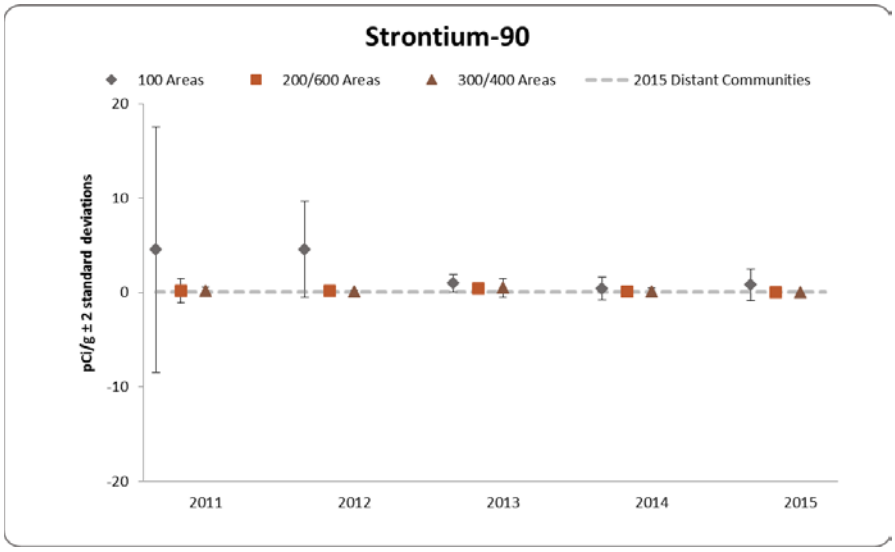
Samples were analyzed for the radionuclides expected to occur in the areas sampled (i.e., gamma-emitting radionuclides [cobalt-60 and cesium-137], strontium-90, uranium isotopes, and/or plutonium isotopes). Selected analytical results were compared to concentrations in samples collected during 2015 at off-site sampling locations in Yakima, Grant, and Franklin counties. Comparisons can be used to determine the differences between contributions from site operations and remedial action sites and contributions from natural sources and worldwide fallout.

10.3.1.1 Vegetation Monitoring Results

Some degree of variability is always associated with collecting and analyzing environmental samples; therefore, variations in sample concentrations annually are expected. In general, radionuclide concentrations in vegetation samples collected from or adjacent to waste disposal facilities in 2015 were higher than concentrations in samples collected farther away, including concentrations measured off site. Generally, the predominant radionuclides were activation and fission products in the 100 Areas, fission products in the 200 Areas and 600 Area, and uranium in the 300 Area and 400 Area.

Uranium-234, uranium-235, and/or uranium-238 were detected in 95 of the 2015 samples. Three samples showed detectable concentrations of cesium-137 and 12 samples showed detectable strontium-90 levels. Concentrations of detected radionuclides were elevated near and within facility boundaries compared to historic concentrations measured at distant communities; however, they remained within the historical range of those collected within facility boundaries. Figure 10.5 shows the Hanford Site average concentration of selected radionuclides for vegetation samples.





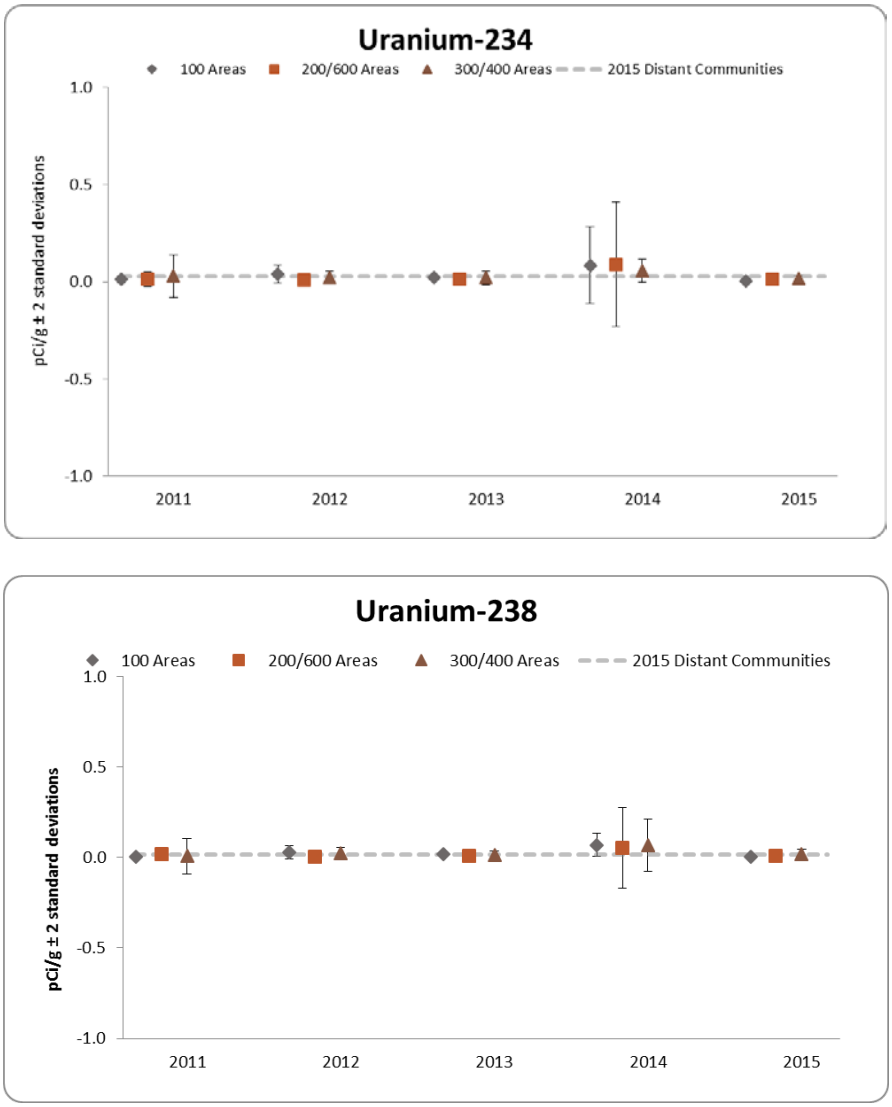


Figure 10.5. Hanford Site Vegetation Average Concentrations of Select Radionuclides

Table 10.6 provides a summary of selected radionuclides detected in vegetation samples collected and analyzed in 2015 and previous years. The average and maximum results are reported for the six primary waste facility/operational areas of interest, including comparative data for the preceding 5 years. Vegetation samples collected in 2015 at locations in the 100-N Area, 200-East Area, 200-West Area, 400 Area, and 600 Area were comparable to those collected in previous years. Vegetation samples collected in the 200 Areas and 600 Area showed concentrations of uranium-234, uranium-235, and uranium-238 that were comparable to historical data. The uranium levels are a result of uranium releases to the environment during past fuel-fabrication operations in that area. The range of strontium-90 concentrations was comparable to historical levels.

Table 10.6. Hanford Site Vegetation Concentrations of Select Radionuclides

Isotope	Hanford Area	2015 Number of Samples	2015 Number of Detects	2015 Average* (pCi/gm)	2015 Maximum† (pCi/gm)	2010–2014 Number of Samples	2010–2014 Number of Detects	2010–2014 Average* (pCi/gm)	2010–2014 Maximum† (pCi/gm)
Cobalt-60	100	2	0	1.1E-02 ± 9.4E-03	1.6E-02 ± 4.0E-02‡	13	0	4.8E-03 ± 3.6E-02	3.6E-02 ± 8.8E-02‡
	200-East	9	0	1.23E-02 ± 4.3E-02	5.1E-02 ± 5.7E-02‡	39	0	-4.2E-03 ± 5.4E-02	5.4E-02 ± 1.1E-01‡
	200-West	17	0	3.5E-03 ± 4.1E-02	6.4E-02 ± 4.7E-02‡	71	0	-5.1E-03 ± 5.0E-02	5.4E-02 ± 8.6E-02‡
	300	1	0	-6.5E-02§	-6.5E-02 ± 6.1E-02‡	36	0	-2.9E-03 ± 6.7E-02	7.4E-02 ± 1.0E-01‡
	400	1	0	2.1E-02§	2.1E-02 ± 5.2E-02‡	4	0	-2.1E-02 ± 2.6E-02	-5.0E-03 ± 1.4E-02‡
	600	14	0	1.4E-02 ± 4.0E-02	6.7E-02 ± 6.5E-02‡	47	1	9.6E-03 ± 9.1E-02	2.6E-01 ± 1.3E-01
Cesium-137	100	2	0	-1.1E-02 ± 9.1E-03	-6.5E-03 ± 3.6E-02‡	13	1	2.2E-02 ± 5.7E-02	8.7E-02 ± 8.5E-02‡
	200-East	9	2	3.7E-02 ± 8.1E-02	1.2E-01 ± 4.3E-02	39	16	7.5E-02 ± 1.4E-01	3.3E-01 ± 1.4E-01
	200-West	17	1	1.9E-02 ± 2.7E-02	4.2E-02 ± 3.7E-02	71	19	6.5E-02 ± 1.3E-01	3.2E-01 ± 1.2E-01
	300	1	0	-6.3E-03§	-6.3E-03 ± 3.6E-02‡	36	9	5.7E-02 ± 1.8E-01	3.6E-01 ± 9.7E-02
	400	1	0	7.7E-02§)	7.7E-02 ± 5.9E-02‡	4	0	1.2E-02 ± 2.9E-02	2.8E-02 ± 3.8E-02‡
	600	14	0	9.4E-03 ± 3.4E-02	4.6E-02 ± 3.6E-02‡	47	12	4.7E-02 ± 1.2E-01	2.0E-01 ± 8.6E-02
Plutonium-238	100	1	0	7.9E-04§	7.9E-04 ± 6.7E-04‡	13	0	-1.4E-03 ± 1.4E-02	6.4E-03 ± 1.4E-02‡
	200-East	9	1	5.0E-05 ± 1.1E-03	1.4E-03 ± 4.6E-04	39	1	1.4E-03 ± 1.2E-02	1.6E-02 ± 1.9E-02‡
	200-West	17	2	9.9E-05 ± 4.1E-04	3.9E-04 ± 3.8E-04	71	2	2.0E-04 ± 1.3E-02	2.7E-02 ± 1.2E-02
	300	1	0	1.8E-04§	1.8E-04 ± 3.3E-04‡	36	1	1.5E-03 ± 1.1E-02	1.9E-02 ± 2.1E-02‡
	400	1	0	-2.4E-05§	-2.4E-05 ± 2.4E-04‡	4	0	-1.4E-03 ± 5.1E-03	8.1E-04 ± 5.4E-03‡
	600	14	0	1.4E-05 ± 3.8E-04	4.2E-04 ± 4.9E-04‡	46	0	2.4E-03 ± 1.6E-02	3.2E-02 ± 2.3E-02‡
Plutonium-239/ -240	100	2	1	1.4E-03 ± 1.3E-03	2.1E-03 ± 1.0E-03‡	13	2	1.9E-03 ± 7.2E-03	9.2E-03 ± 7.3E-03
	200-East	7	1	5.6E-04 ± 5.2E-04	9.2E-04 ± 5.3E-04	40	0	1.4E-03 ± 3.7E-03	5.7E-03 ± 5.6E-03‡
	200-West	17	13	1.2E-03 ± 1.5E-03	3.3E-03 ± 9.8E-04	71	34	3.2E-02 ± 3.2E-01	1.3E+00 ± 2.8E-01
	300	1	0	4.0E-04§	4.0E-04 ± 6.1E-04‡	36	0	1.2E-03 ± 3.6E-03	5.8E-03 ± 5.7E-03‡
	400	1	0	-1.3E-04§	-1.3E-04 ± 4.5E-04‡	4	0	5.6E-04 ± 3.8E-03	3.7E-03 ± 4.3E-03‡
	600	14	4	4.4E-04 ± 1.2E-03	1.9E-03 ± 7.1E-04	47	6	1.9E-03 ± 7.6E-03	1.3E-02 ± 6.8E-03
Strontium-90	100	2	2	7.9E-01 ± 1.1E+00	1.4E+00 ± 2.8E-01	13	10	2.2E+00 ± 7.4E+00	1.3E+01 ± 1.7E+00
	200-East	9	6	1.5E-01 ± 3.2E-01	5.0E-01 ± 1.2E-01	39	19	1.0E-01 ± 1.3E+00	1.0E+00 ± 2.8E-01
	200-West	17	4	3.1E-02 ± 1.1E-01	1.6E-01 ± 4.9E-02	17	14	2.73E-02 ± 5.6E-01	7.4E-01 ± 2.0E-01
	300	1	0	1.7E-02§	1.7E-02 ± 2.9E-02‡	36	10	6.6E-02 ± 5.0E-01	8.4E-01 ± 1.9E-01
	400	1	0	-2.2E-03§	-2.2E-03 ± 2.1E-02‡	4	0	-2.4E-02 ± 3.0E-01	1.5E-01 ± 1.7E-01‡
	600	14	0	1.6E-02 ± 4.5E-02	4.3E-02 ± 3.0E-02‡	47	9	-4.4E-02 ± 9.0E-01	1.3E+00 ± 3.4E-01
Uranium-234	100	2	1	6.5E-03 ± 4.1E-03	8.6E-03 ± 4.5E-03	13	11	3.5E-02 ± 9.7E-02	1.8E-01 ± 1.4E-01
	200-East	9	8	9.4E-03 ± 5.6E-03	1.5E-02 ± 5.6E-03	39	27	4.2E-02 ± 1.8E-01	3.6E-01 ± 1.8E-01
	200-West	17	13	1.5E-02 ± 1.4E-02	3.5E-02 ± 9.9E-03	71	58	2.9E-02 ± 1.3E-01	3.4E-01 ± 1.7E-01
	300	1	1	2.2E-02§	2.2E-02 ± 8.6E-03	36	31	3.1E-02 ± 5.9E-02	1.1E-01 ± 3.5E-02
	400	1	1	1.1E-02§	1.1E-02 ± 5.7E-03	4	2	1.9E-02 ± 2.1E-02	3.6E-02 ± 1.2E-01‡
	600	14	12	1.1E-02 ± 8.5E-03	2.1E-02 ± 7.5E-03	47	29	1.3E-02 ± 7.7E-02	1.3E-01 ± 1.3E-01‡
Uranium-235	100	2	1	3.6E-03 ± 3.5E-03	5.3E-03 ± 3.2E-03	13	2	9.3E-03 ± 2.4E-02	4.4E-02 ± 1.1E-01
	200-East	9	4	4.8E-03 ± 5.3E-03	9.5E-03 ± 4.9E-03	39	5	4.1E-02 ± 3.2E-01	0.0E+00‡
	200-West	17	11	4.9E-03 ± 2.9E-03	7.9E-03 ± 5.5E-03	71	17	7.2E-03 ± 9.2E-02	1.6E-01 ± 1.2E-01
	300	1	0	2.8E-03§	2.8E-03 ± 3.9E-03‡	36	9	3.6E-03 ± 1.1E-02	9.6E-03 ± 6.5E-03‡
	400	1	0	2.4E-03§	2.4E-03 ± 4.1E-03‡	4	1	2.6E-02 ± 7.3E-02	8.9E-02 ± 1.1E-01‡
	600	14	6	4.1E-03 ± 3.3E-03	8.4E-03 ± 4.4E-03	46	4	-7.0E-04 ± 5.7E-02	5.8E-02 ± 1.0E-01‡
Uranium-238	100	2	1	3.3E-03 ± 7.0E-04	3.7E-03 ± 2.7E-03	13	9	2.8E-02 ± 5.9E-02	1.0E-01 ± 1.2E-01‡
	200-East	9	8	8.0E-03 ± 3.6E-03	1.1E-02 ± 4.9E-03	39	21	2.6E-02 ± 7.6E-02	1.4E-01 ± 1.3E-01‡
	200-West	17	14	1.1E-02 ± 7.8E-03	2.0E-02 ± 7.1E-03	71	49	1.7E-02 ± 7.1E-02	1.4E-01 ± 1.1E-01
	300	1	1	2.7E-02§	2.7E-02 ± 9.2E-03	36	34	3.0E-02 ± 5.6E-02	1.2E-01 ± 1.1E-01
	400	1	1	6.9E-03§	6.9E-03 ± 4.4E-03	4	3	1.1E-02 ± 9.4E-03	1.8E-02 ± 7.9E-02‡
	600	14	12	7.8E-03 ± 4.4E-03	1.2E-02 ± 4.9E-03	47	33	1.2E-02 ± 9.8E-02	1.6E-01 ± 2.5E-01‡

*Average ± two standard deviations; †Maximum ± analytical uncertainty; ‡Maximum value reported is a non-detect; §Standard deviation cannot be calculated for one sample.

10.3.1.2 Vegetation Sampling at Hanford Off-site Locations

Vegetation samples were collected at six off-site locations around the Hanford Site in 2015. Off-site samples were collected around the perimeter of the Hanford Site, Sunnyside, George, and Wanapum, WA.

Vegetation samples consisted of the current year's growth of leaves, stems, and new branches from sagebrush and rabbitbrush. Samples were dried before analyses, and analytical results were reported on a dry weight basis. Shoreline samples were usually taken from a predominant species at the sampling location. A contaminant was detected if the analytical result was greater than the minimum detectable activity and was larger than the total analytical error. All six samples collected in 2015 were analyzed for gamma-emitting radionuclides, strontium-90, uranium isotopes (uranium-234, uranium-235, and uranium-238), and plutonium isotopes (plutonium-238 and plutonium-239/-40).

10.3.1.3 Analytical Results for Vegetation Samples Collected at Hanford Off-site Locations

Vegetation sampling results in 2015 generally confirmed observations from past sampling efforts. Strontium-90, cesium-137, plutonium-238, and plutonium-239/-240 concentrations were generally below nominal detection limits at off-site locations (Table 10.7). Uranium-238 was detected in two vegetation samples collected off site in 2015, and plutonium-239/-240 was detected in two of the off-site samples. The maximum uranium-238 concentration measured in vegetation during 2015 was collected at Sunnyside (0.036 ± 0.038 pCi/g [1.3 ± 1.4 mBq/g]). This result was higher than the maximum uranium-238 concentration measured at Hanford off-site locations between 1998 and 2008. The highest measured plutonium-239/-240 concentration (0.00075 ± 0.00042 pCi/g [0.028 ± 0.016 mBq/g]) was from a vegetation sample collected at Sunnyside. This concentration was higher than the maximum plutonium-239/-240 concentration measured at Hanford off-site locations between 1998 and 2008.

Table 10.7. Hanford Site Concentrations of Select Radionuclides in Off-site Soil Samples*

	2015				1998, 2001, 2004, and 2008			
Isotope	Number of Samples	Number of Detects	Average† (pCi/gm)	Maximum‡ (pCi/gm)	Number of Samples	Number of Detects	Average† (pCi/gm)	Maximum‡ (pCi/gm)
Cobalt-60	6	0	-1.4E-02 ± 6.3E-02	9.0E-03 ± 2.3E-02§	0	0	N/A	N/A
Cesium-137	6	0	-3.9E-03 ± 2.5E-02	8.3E-03 ± 2.0E-04§	12	0	7.4E-03 ± 2.4E-02	3.0E-02 ± 1.4E-02
Plutonium-238	6	2	2.2E-04 ± 3.1E-04	5.0E-04 ± 2.8E-04	12	0	2.6E-05 ± 1.1E-04	1.1E-04 ± 2.3E-04
Plutonium-239/-240	6	2	4.5E-04 ± 4.8E-04	7.5E-04 ± 4.2E-04	12	5	6.0E-04 ± 2.0E-03	3.1E-03 ± 7.3E-04
Strontium-90	6	1	2.8E-02 ± 1.5E-01	2.0E-01 ± 4.4E-02	12	2	2.5E-02 ± 2.9E-02	8.7E-02 ± 1.0E-01
Uranium-234	5	2	3.6E-02 ± 5.9E-02	8.9E-02 ± 5.6E-02	0	0	N/A	N/A
Uranium-235	5	1	1.5E-02 ± 3.7E-02	5.1E-02 ± 4.8E-02§	0	0	N/A	N/A
Uranium-238	6	2	1.6E-02 ± 2.3E-02	3.6E-02 ± 3.8E-02§	12	3	1.8E-02 ± 1.5E-02	2.6E-02 ± 1.3E-02

*2015 compared with select previous years; pCi/g dry weight, where 1 pCi = 0.037 Bp; †Average ± two standard deviations; ‡Maximum ± analytical uncertainty; §Maximum value reported is a non-detect

10.3.2 Radiological Contamination

JW Wilde, RC Roos

Investigations of radioactive contamination in vegetation were conducted in and near operational areas to monitor the presence or movement of radioactive materials around areas of known or suspected contamination or to verify radiological conditions at specific project sites. All samples collected during investigations were field-surveyed for alpha- and beta-gamma radiation.

Radiological contamination was found in 48 vegetation samples surveyed during the 2015 investigations. Forty-seven of the samples were Russian thistle (*Salsola tragus*) or fragments, and one sample was

unidentified. No samples were analyzed for specific radionuclides. Tumbleweed surveys resulted in 8 locations posted as contamination areas; 40 samples were disposed at a licensed facility.

Section 10.3.1 provided a discussion of the vegetation control on the Hanford Site. Table 10.8 summarizes the number and general locations of vegetation contamination incidents investigated from 2000 to 2015.

Table 10.8. Hanford Site Vegetation Contamination Incidents Investigated

Location	2015 Incidents
100 Area	1
200-East Area	
Tank farms	8
Burial grounds	4
Cribs, ponds, and ditches	3
Fence lines	2
Roads and railroads	1
Unplanned release sites	0
Underground pipelines	0
LERF/ETF	4
Miscellaneous	5
200-West Area	
Tank farms	5
Burial grounds	1
Cribs, ponds, and ditches	7
Fence lines	4
Roads and railroads	0
Unplanned release sites	0
Underground pipelines	0
Miscellaneous	0
Cross-site transfer line	0
600 Area burial grounds	1
200-North Area	0
300 Area	0
400 Area	0
600 Area	1
1100 Area	1
Total	**48**

Year	Incidents
2000	66
2001	20
2002	16
2003	32
2004	60
2005	66
2006	75
2007	62
2008	127
2009	109
2010	36
2011	10
2012	18
2013	35
2014	50
2015	**48**

10.3.3 Vegetation Control

JM Rodriguez, RC Roos

The purpose of vegetation control at the Hanford Site is effective control and minimization of noxious weeds, industrial weeds, and other vegetation to ensure protection of Hanford Site workers, the public, facilities, property, and the site's cultural and environmental (including biological) resources. Risks that are mitigated through effective vegetation control are the spread of contamination, wildfire fuel loading, harborage of vermin and insect pests around facilities, damage and destruction of native plant communities, damage to facilities and interference with work and transportation.

Approximately 5,164 ac (2,090 ha) were treated with herbicides in 2015 on radiological waste sites, around operations areas, and along roadways to keep areas free of deep-rooted vegetation (e.g., Russian thistle, also known as tumbleweed). Follow-up treatments are included in the total treated acres; several areas received more than one herbicide application.

Noxious Weeds

Noxious weeds are controlled at the Hanford Site to prevent their spread and eliminate populations. A noxious weed is a legal and administrative category designated by federal or state regulatory agencies (e.g., the U.S. Department of Agriculture or Washington State Department of Agriculture). Noxious weeds are non-native, aggressively invasive, and hard to control. Noxious weed plant communities degrade ecosystems unless control measures are taken. Control measures can be mechanical, chemical, cultural, or biological. Approximately 94 ac (38 ha) of noxious weeds on the Hanford Site were treated with herbicides in 2015 along roadways. The *Environmental Assessment: Integrated Vegetation Management on the Hanford Site, Richland, Washington* (DOE/EA-1728-F) was completed in 2012. The FONSI clears the way to develop an appropriate process for NEPA clearance of noxious weed control.

Ten plant species are on a high-priority list for control at the Hanford Site. These species are described in the following paragraphs, along with a summary of 2015 control activities.

Yellow Starthistle (*Centaurea solstitialis*). Yellow starthistle represents the most rapidly expanding weed infestation in the western United States. Since 1995, yellow starthistle has been the highest priority weed for the Hanford Site noxious-weed control program because it has the potential to invade the entire site and have a dramatic impact on the ecology of the site and neighboring lands.

Control measures for yellow starthistle have included spot treatments and broadcast applications by ground equipment and aerial sprayers, biological control, and hand weeding in critical locations. Major populations near the Hanford Townsite have been reduced to scattered individual plants, mostly near live trees where aerial herbicide applications were not made. Control of yellow starthistle in 2015 consisted of hand pulling individual plants as they were identified and spot treatment with herbicides on roadways and in areas of the Hanford Townsite.

Yellow starthistle seeds are known to remain viable for 10 years in the soil. The small number of seedlings found over much of the area of infestation indicates the seed bank is being exhausted. Careful control efforts over the next few years should result in the yellow starthistle changing from a major infestation to a monitoring and eradication effort.

Biological control agents for yellow starthistle are widely distributed across the infested area and have been highly effective during the early part of the flowering season. However, the adult phase of the control agent's annual lifecycle is completed before the end of the flowering season. Consequently, flowers opening late in the season are largely spared the effects of insect predation.

Successful control of yellow starthistle in the past has substantially reduced populations in both area and density. The biological control organisms require yellow starthistle in order to complete their lifecycle. The reduced plant population can no longer sustain a robust population of biological control organisms. As the population of bio controls fails, greater emphasis needs to be placed on effective monitoring and control of the plants to continue toward eradication of yellow starthistle at Hanford.

Rush Skeletonweed (*Chondrilla juncea*). Rush skeletonweed is a challenging species to control because their seeds are spread by the wind, allowing seedlings to germinate and begin new populations miles away from other plants. The deep and extensive root system of rush skeletonweed makes it extremely difficult to control using herbicides. Herbicide application may kill the main plant, but roots deep in the soil or far from the green portion of the plant often avoid the effects of herbicide. Those roots can remain living in

the soil for several years, eventually sending sprouts to the surface to begin new plants long after the effects of herbicide application have ended.

Rush skeletonweed is scattered over large areas of the Hanford Site. Areas of dense rush skeletonweed infestation north of the Wye Barricade largely have been eliminated. Nevertheless, considerable rush skeletonweed remains as scattered individual plants. Populations of rush skeletonweed have increased in some areas burned by past wildfires. Reduction in active control efforts over the past few years, while NEPA requirements have been evaluated, has allowed populations of skeletonweed to increase in both aerial extent and density. Rush skeletonweed has become the most challenging noxious weed to control on the Hanford Site due to the large aerial extent of infestation, density of infestation, and sustained effort required to eliminate individual plants and populations.

Biological control agents commonly applied to rush skeletonweed at the Hanford Site have not significantly reduced plant populations or seed production.

Babysbreath (*Gypsophila paniculata*). Babysbreath is generally resistant to control by herbicides; however, the above-ground portion of the plant can be destroyed by some herbicides that can prevent flowering and seed production. The plants should be eradicated by continually removing the top portions through herbicide use. By removing the green portions of the plants, the energy reserves in the roots will eventually be depleted, killing the plant. Mainly found in the Hanford Townsite, babysbreath was aggressively controlled in 2015 using herbicide and hand pulling in sensitive areas.

Dalmatian Toadflax (*Linaria genistifolia* ssp. *dalmatica*). A small population of dalmatian toadflax is found near Energy Northwest on the Hanford Site. Sprouts and seedlings of the long-lived perennial plant will be eliminated as they are identified. The current population consists of plants widely scattered across the area of infestation. The low density population is not conducive to successful establishment of predatory species. Consequently, no biological controls have been released at the Hanford Site for dalmatian toadflax. Toadflax growing along road shoulders were controlled using herbicides.

Diffuse Knapweed (*Centaurea diffusa*). In 2015, control of diffuse knapweed was limited to herbicide application on roadways and hand pulling in critical areas. The population of this species near the Columbia River high watermark has not been actively controlled by herbicides because of the biological sensitivity of the area. Established biological controls assist staff members with monitoring and observing effectiveness in controlling the weed.

Tackweed (*Tribulus terrestris*). Tackweed has become increasingly common on the Hanford Site over the past several years. In 2015, a large population found at the Hanford Townsite was controlled aggressively using a combination of herbicide application and hand pulling. Other tackweed found across the Hanford Site as individual plants or small populations were also controlled.

Purple Loosestrife (*Lythrum salicaria*). The banks of the Columbia River bank and islands along the Hanford Site are monitored for purple loosestrife, as these locations in these areas are appropriate for this weed. Individual plants and small populations are found along the south and west bank of the river.

Under good ecological conditions, biological measures for controlling purple loosestrife are effective; however, widely fluctuating levels along the Columbia River destroy the biological control organisms as they attempt to over-winter soil at the plant bases. Winter mortality prevents effective population control agents from developing. No control measures were applied in 2015 for purple loosestrife.

Russian Knapweed (*Acroptilon repens*). Biological controls for Russian knapweed are limited, and their success has been poor in the semi-arid climate of the Hanford Site. Chemicals and other control techniques are being developed that promise to be effective with this difficult-to-control species.

Saltcedar (*Tamarix* spp.). Several individual plants of saltcedar were found at the Hanford Site in years past. Most are the remainders from ornamental plantings near homes in the early part of the previous century. A few populations are the result of natural seed dispersal. Most individual plants south and west of the Columbia River have been eliminated. Those remaining continue to be treated with herbicide and will be monitored until they are eradicated.

Saltcedar roots are very deep and store a great deal of energy, making control of the species difficult. A few trees that were treated with herbicide in 2014 began to show new green growth in 2015. Effective control of weeds often depends on the plant having sufficient green-leaf area for herbicide to enter the plant. The small amount of green growth found in 2015 was not sufficient for effective herbicide application. It is expected that these trees will be sprayed with herbicide in 2016.

Spotted Knapweed (*Centaurea maculosa*). Spotted knapweed at the Hanford Site has been controlled so that sprouts or seedlings are rare. In 2015, no sprouts or seedlings were found. The Hanford Site will continue to be monitored for several years to ensure that viable seeds and roots have been eliminated from the soil. Cooperative efforts with neighboring landowners continue to eliminate spotted knapweed near the Hanford Site. The root-feeding weevil *Cyphocleonus achates* has been released specifically to help eradicate spotted knapweed at Hanford, but it is expected that the population is too small and scattered to sustain a biological control population. *Cyphocleonus* is known to use diffuse knapweed, however, and it is hoped that this weevil will establish in diffuse knapweed and cross over to control spotted knapweed when it appears. Most biological controls for diffuse knapweed also are effective for spotted knapweed.

10.3.4 Mulberry Sampling at the 100N Shoreline

CJ Perkins, SE Johnson

In late May/early June 2015, leaf, bark, and fruit samples were collected from mulberry trees growing along the 100N Area shoreline (Figure 10.6) in an exploratory sampling effort to attain qualitative radio-inventory information. Three groups of 2 to 4 trees were collected to create composite samples, the most upstream (UR) of which was intentionally sited in a known strontium-90 groundwater/spring plume near outfall 100N-79.

Two additional groups of trees located approximately 60 m and 130 m downstream from the first group comprised a midriver and downriver composite sample, respectively. Reference samples of leaf, bark, and fruit were collected upstream of the Hanford Site near the Vernita Bridge rest area.

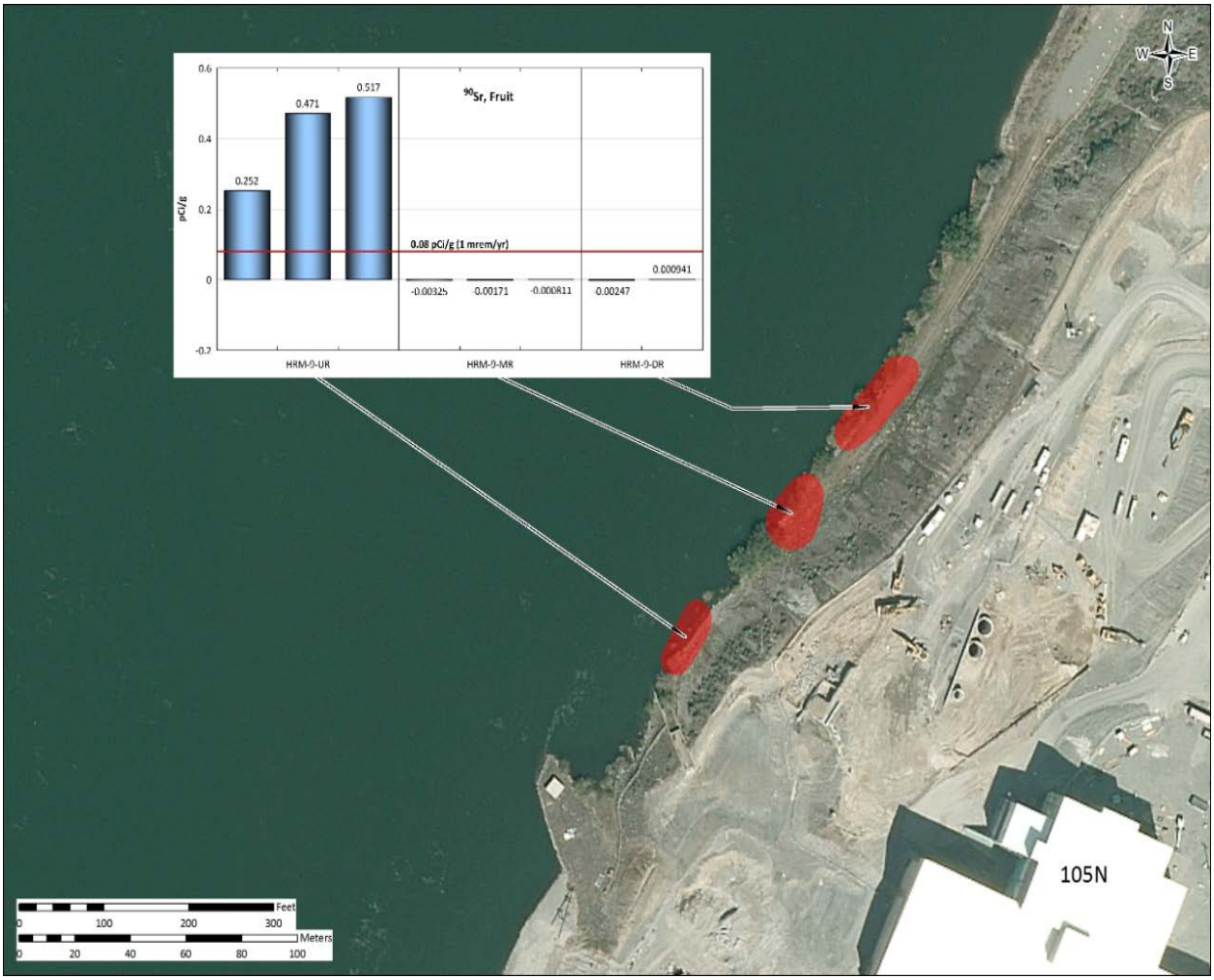


Figure 10.6. Mulberry Tree Sample Locations and Strontium-90 Concentrations (pCi/g) in Fruit Samples

Analytical data indicate that the strontium-90 concentration in fruit samples collected from the upriver group of trees were above the DOE 1 mrem/yr dose reporting threshold. The EPA's Ingestion Model assumes that a 170-lb (80-kg) individual would have to consume approximately 11 oz (311 g) of fruit with a strontium-90 concentration at 0.08 pCi/g every day for a year to receive the 1 mrem dose. The highest strontium-90 levels measured in 100N fruit at the UR location was approximately 0.52 pCi/g, about 6 times higher than the 0.08 pCi/g value, theoretically resulting in an annual dose of approximately 6 mrem to the mulberry consumer. This is an unlikely scenario, as the available quantity of fruit would limit the consumer's intake and therefore the dose. A person would ultimately need to ingest approximately 240 lbs of the fruit per year to receive a 1 mrem dose, while the typical fruit yield for this species of tree (white mulberry) ranges from 5–25 lbs/yr.

Strontium-90 was not detected in the fruit samples in any of the other locations, and no other radionuclides were detected above the 1 mrem/year dose-based reporting value (Table 10.9).

Table 10.9. Concentrations (pCi/g)* of Select Radionuclides in 100N Shoreline Mulberry Tree Samples

Radionuclide	Sample Type	Number of Samples	Number of Detections†	Average‡	Maximum§	Maximum Location
Tritium	Fruit	6	4	7.8E-01 ± 2.4E+00	2.7E+00 ± 4.9E-01	HRM-9-UR
	Leaves	6	3	8.5E-01 ± 2.7E+00	3.5E+00 ± 4.9E-01	HRM-9-UR
	Bark	6	0	3.9E+00 ± 1.1E+01	1.3E+01 ± 1.0E+01	HRM-9-UR
Strontium-90	Fruit	10	3	1.2E-01 ± 4.2E-01	5.2E-01 ± 9.8E-02	HRM-9-UR
	Leaves	11	9	7.2E-01 ± 2.1E+00	3.2E+00 ± 6.0E-01	HRM-9-UR
	Bark	8	7	1.2E-01 ± 8.4E-01	3.2E+00 ± 6.0E-01	HRM-9-UR
Technetium-99	Fruit	6	0	-1.9E-02 ± 5.0E-01	3.9E-01 ± 4.4E-01	HRM-9-MR
	Leaves	6	0	3.5E-01 ± 8.2E-01	7.5E-01 ± 7.8E-01	HRM-9-MR
	Bark	6	0	-6.3E-02 ± 7.5E-01	3.2E-01 ± 8.2E-01	HRM-9-DR
Cesium-137	Fruit	6	0	1.2E-01 ± 1.7E+00	9.2E-03 ± 1.1E-02	HRM-9-UR
	Leaves	5	0	4.1E-03 ± 1.0E-02	1.1E-02 ± 1.3E-02	HRM-9-UR
	Bark	0				
Uranium-234	Fruit	6	5	7.2E-03 ± 8.4E-03	1.3E-02 ± 5.6E-03	HRM-9-MR
	Leaves	6	5	7.2E-03 ± 5.4E-03	1.0E-02 ± 3.8E-03	HRM-9-DR
	Bark	6	5	1.1E-02 ± 9.0E-03	1.9E-02 ± 6.0E-03	HRM-9-UR
Uranium-238	Fruit	6	5	5.3E-03 ± 4.8E-03	9.4E-03 ± 4.3E-03	HRM-9-MR
	Leaves	6	5	5.3E-03 ± 3.6E-03	7.6E-03 ± 3.2E-03	HRM-9-UR
	Bark	6	3	8.5E-03 ± 9.9E-03	1.4E-02 ± 5.1E-03	HRM-9-UR

*1 pCi = 0.037 Bq
†Number of samples with measurable concentrations of contaminant.
‡Average ± two standard deviations of all samples analyzed.
§Maximum ± analytical uncertainty.

10.4 Waste Site Remediation and Revegetation

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In 2015, 46 ac (18.6 ha) were planted with grass seed to stabilize areas where traffic and erosion had damaged the grass cover on waste sites. Waste sites in the 200 East and 200 West areas were designed and constructed with a cap of perennial grass essential to performance of engineered waste sites. However, soil used as backfill and cover on waste sites was often sandy, which provides a poor medium for growth of the grass. Over the years, poor soil combined with lack of maintenance has resulted in degradation and decreased function of the vegetative caps on many waste sites. Integrated Biological Control has been actively restoring vegetative caps on other waste sites.

Vegetative caps on waste sites perform three primary functions:

1. **Prevent Erosion**. A well-designed and maintained grass cap stabilizes soil on waste sites by physically covering the soil surface and serves as a windbreak, reducing wind velocity at the soil surface.

2. **Exclude Tumbleweed Growth**. Tumbleweeds are the main biological vector of contamination spread on the Hanford Site. They are deep-rooted annual plants that quickly invade and establish on disturbed soil. The deep roots readily absorb radionuclides buried in the soil and transport them to the aboveground portions of the plant. At the end of the 1-year lifecycle, dead tumbleweeds detach from the roots and become mobile, transporting radioactive contamination from posted and monitored disposal areas.

A well-designed and maintained grass cap excludes tumbleweeds by direct competition for space and nutrients (primarily water). Stabilized soil forms a crypto-biotic crust composed of moss, lichen, algae, and other organisms that provide a poor surface for germination of tumbleweed seeds. The combination of competition for resources and prevention of germination effectively excludes tumbleweeds from establishing on waste sites.

3. **Prevent Water Percolation through the Soil Column**. Waste sites were designed with vegetative caps to prevent natural precipitation moving through the soil column and washing radioactive or hazardous materials downward toward groundwater.

   The 6- to 7-in (15- to 18-cm) average precipitation received at the Hanford Site typically percolates 2–4 ft (0.6–1.2 m) into the soil during the winter. Evaporation during summer months removes some moisture from the soil. However, as surface soil dries, it acts as a mulch, which inhibits further evaporation. Evaporation alone does not remove all the natural precipitation from the soil. Water remaining in the soil from the previous year has an additive effect during the subsequent wet season, allowing water to percolate to increasing depth.

   Vegetative caps on waste sites were designed so that in addition to evaporation from the soil surface, plant roots would mine water from deeper in the soil profile, transporting it to leaves where it is lost through evaporation. The process of water moving from soil into plant roots, through the plant and out the leaves to the atmosphere is transpiration. The combination of evaporation and transpiration removes sufficient moisture from the soil so that precipitation during subsequent wet seasons falls on dry soil, yielding no net increase in depth of percolation. Effective containment of waste in burial grounds depends on the combination of evaporation and transpiration drying the soil, preventing additive percolation and transport of contaminants to groundwater.