Appendix J

Nonoperational Area Evaluation

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J1 Introduction

This appendix presents information that supports the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) Remedial Investigation/Feasibility Study (RI/FS) conducted for 100-F/IU Operable Unit (OU) (*Remedial Investigation/Feasibility Study for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* [DOE/RL-2010-98]). Most of the waste sites in the 100-F/IU OU are located close to former industrial facilities. There are large land areas (beyond the industrial areas and their associated facilities and waste sites) that have little or no subsurface infrastructure or indication of past or present releases of hazardous constituents. This land is referred to as nonoperational property (NPE). This appendix presents an evaluation of the NPE specific to 100-F/IU OU.

J1.1 Scope of the Nonoperational Property Evaluation

This NPE is not directly part of the CERCLA RI/FS process, in that it has no role in determining the basis for remedial action or in evaluating remedial alternatives for contaminated soils or groundwater. "National Oil and Hazardous Substances Pollution Contingency Plan" (40 CFR 300) requires that the nature and extent of contamination is evaluated and that appropriate remedial actions are taken. Two important outputs from the NPE are evidence that effort has been taken to identify where waste may be present outside of operational areas and, where appropriate, the inclusion of NPE waste sites that may warrant further consideration as part of the RI/FS. The NPE also documents nonoperational conditions for use in risk communication and for informing stakeholders.

There are fate and transport mechanisms that could potentially distribute contaminants to nonoperational areas. The most credible are human disposal, wind-blown dust dispersion, air emissions from stacks during active operations, overland flow, and biological vectors (intrusion by plants and animals). Multiple lines of evidence have been developed to assess these fate and transport mechanisms and the potential for contamination to exist outside known operational areas. Areas of focus in developing the lines of evidence include the following:

- **Review of existing programs, data, and information with a nonoperational area focus:** Decades of environmental monitoring and surveillance have been conducted and reported at the Hanford Site. In addition to general (routine) monitoring that has included nonoperational areas, special studies have been commissioned and conducted that assess broad-area evidence of emissions and releases from facilities and waste sites.

- **Results of Orphan Sites Evaluations:** The Orphan Sites Evaluation (OSE) is a program that has been designed primarily to support cleanup and long-term stewardship activities in the River Corridor. It provides a detailed understanding of disturbed areas (contaminated or not). Review of historical records and imagery, combined with on-the-ground walkdowns and field investigations, provide a comprehensive evaluation of current conditions in nonoperational areas.

- **Statistical analyses:** Two statistical analyses were conducted as adjuncts to environmental monitoring, data review, and field investigations. The first was developed and applied to enhance efforts to locate potential waste disposal sites systematically and rigorously. The second evaluated radionuclide distribution (based on available soil concentration data and aerial radiological surveys) in order to quantify and understand relationships with known waste sites and examine the potential for unidentified sites to exist outside operational areas.

J1.2 100-F/IU Description

The 100-F area contains the former F Reactor and supporting facilities. The 100-F area has three OUs: 100-FR-1 and 100-FR-2 encompass source OUs that include liquid and solid waste sites; the 100-FR-3 OU is a groundwater OU encompassing the 100-F area (*Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 4: 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* [DOE/RL-2008-46-ADD4]). The upland environment within the boundary of 100-F contains graveled areas adjacent to buildings and facilities; however, significant portions of 100-F are vegetated. The main vegetation cover type throughout the central and northeastern portions is gray rabbitbrush/cheatgrass. This cover type extends beyond the perimeter fence in the northeastern corner to form a narrow band (approximately 20 to 50 m [65.6 to 164 ft] wide) between the 100-F fenced area and the riparian zone to the northeast. Within the western edge of the 100-F area, Sandberg's bluegrass and cheatgrass compose the dominant vegetation cover with small patches of big sagebrush and gray rabbitbrush occurring within this type in the southwestern corner. The southeastern corner is dominated by big sagebrush/Sandberg's bluegrass-cheatgrass. The area to the south and west beyond the perimeter fence consists primarily of two vegetation cover types: big sagebrush/bunchgrass mosaic and abandoned old agricultural fields (now primarily Sandberg's bluegrass and cheatgrass). From the eastern perimeter fence eastward to the edge of the riparian zone are areas of big sagebrush/Indian ricegrass and bitterbrush/Indian ricegrass. North of the perimeter fence, the upland environment is narrow and consists primarily of abandoned old agricultural fields and the narrow band of gray rabbitbrush/cheatgrass mentioned above (*Literature Review of Environmental Documents in Support of the 100 and 300 Area River Corridor Baseline Risk Assessment* [PNNL-SA-41467]).

The surrounding open large expanses of the River Corridor near 100-F comprise the 100-IU-2 and 100-IU-6 OUs and include scattered support facilities and the former townsites of Hanford and White Bluffs. The vegetation in the upland environment near the White Bluffs and Hanford areas has been subject to disturbances due to farming and traffic. The types of vegetation cover found there are primarily Sandberg's bluegrass-cheatgrass, gray rabbitbrush/Sandberg's bluegrass-cheatgrass vegetation cover types where cheatgrass and other exotic annuals may be the dominant species. The upland habitats surrounding the White Bluffs and Hanford areas are described in the vegetation mapping for the site as "abandoned old fields" (*Literature Review of Environmental Documents in Support of the 100 and 300 Area River Corridor Baseline Risk Assessment* [PNNL-SA-41467]).

J2 Nonoperational Property Evaluation Approach

River Corridor cleanup efforts have focused on known waste sites located within operational areas (often within perimeter fences) and on a limited number of known sites outside these boundaries. Where surveillance monitoring or focused investigative activities have identified previously unknown sites, they have been evaluated for inclusion within the scope of the cleanup efforts. Operational areas comprise a small fraction of the total land surface in the River Corridor. Outside of the operational areas is the NPE area. For purposes of this appendix, the NPE area in the River Corridor is defined as that area beyond the boundaries of waste sites listed in the Waste Information Data System (WIDS) database. The NPE area is considered not directly associated with a Hanford Site process or operational activity known or suspected to contribute CERCLA hazardous constituents to the environment.

The approach to the NPE for the River Corridor is to develop a conceptual model of the fate and transport mechanisms that could distribute contaminants from Hanford operations that would warrant further evaluation in the NPE areas, and then apply multiple lines of evidence to examine the likelihood that such contamination is present. The lines of evidence include the following information:

- Results from long-term surveillance and monitoring programs and other studies.
- Results from a spatial model for predicting the location of fabricated features (including waste sites) based on proximity to fabricated and topographic features.
- A spatial model for predicting where elevated radionuclide concentrations (specifically Cs-137) are present in soil, based on aerial radiological survey results.
- Results from the OSE program.

Section J2.1 presents a brief description of potentially significant contaminant fate and transport pathways. Section J2.2 provides summary descriptions of the key surveillance and monitoring programs and other studies for the NPE area in the 100-F/IU OU. Section J2.3 includes brief descriptions of the statistical analyses, and Section J2.4 contains a brief description of the OSE program.

J2.1 Nonoperational Contaminant Transport Pathways

The NPE area, having no history of releases of hazardous or radioactive substances, is presumed to have a low likelihood of contamination that would require a response action under CERCLA. The principal objective of this evaluation is to examine multiple lines of evidence to confirm that hazardous or radioactive substance releases are not present in the NPE area. An outcome of this evaluation could be the identification of areas where releases, or contaminant transport, may have occurred.

A select set of contaminant release pathways applies when evaluating the potential for contaminant transport into NPE areas:

- **Anthropogenic contaminant sources.** Contaminants from facilities or known waste sites may have been physically transported by human actions to shallow soils outside of waste site boundaries. Several activities and programs at the Hanford Site identify waste sites that have resulted from these types of activities. Section J2.2 presents an overview of these activities and programs.

- **Transport via wind-blown dust.** Hazardous and radioactive substances in surface soils and materials can become suspended into the air, dispersed to downwind locations, and subsequently deposited onto the ground. Approximately 6 percent of the 1,518 km^2 (586 mi^2) Hanford Site (about 83 km^2 [32 mi^2], or 8,909 ha [20,000 ac]) has been actively disturbed or used. Potential fugitive dust emission sources are located in the five operations areas within this actively disturbed area: the 100, 200 East, 200 West, 300 Area, and 400 Area. The potential for fugitive dust emissions from these sources is generally conceived to occur subsequent to disturbance, erosion, or removal of soil covers over waste sites or through plant or animal biointrusion. These events can expose erodible material that contains contamination. Engineering controls (e.g., surface soil stabilization, dust suppression water, work cessation due to wind conditions) can be, and are, applied to mitigate or eliminate this transport pathway. However, contaminated areas posted as Radiologically Controlled Areas or Soil Contamination Areas could contain erodible material that might produce fugitive emissions from resuspension of windblown dust (*Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2009* [DOE/RL-2010-17]). Figure J-1 depicts a conceptual model of wind-blown dust transport.

- **Emissions from facility stacks.** Hazardous and radioactive substances emitted into the air from former and currently operating facility stacks and vents can be dispersed to downwind locations and subsequently deposited onto the ground. Three groups of sources of Hanford Site stack air emissions had the potential to affect the River Corridor by air deposition. The two groups that represent the greatest potential contributors are stack emissions that occurred during active operations between

1944 and 1972. Group one is stack emissions from 200 Area operations that separated plutonium and uranium from irradiated reactor fuel. The second group is stacks in the 100 Area that exhausted ventilation air from the working areas of the nine production reactor facilities. The 100 Area sources were minor compared with those from 200 Area facilities. The third group is nonradionuclide emissions resulting from coal-fired power plants used to generate steam for heating and process operations. Two large power plants operated in the 200 Area until the mid-1990s—284-E Power Plant and 284-W Power Plant (*Facility Effluent Monitoring Plan for the 284-E and 284-W Power Plants* [WHC-EP-0472]). Nonradionuclide toxic air pollutants that could be emitted from coal-fired power plants are principally trace metals, but also include traces of volatile organic compounds such as formaldehyde, and polycyclic organic matter. The polycyclic aromatic organic matter and certain trace metals, in particular arsenic, cadmium, lead and antimony, adhere to the fine particulate matter emitted from a power plant stack. Figure J-2 presents the conceptual model of transport from stack emissions.

- **Overland transport.** Hazardous and radioactive substances in surface materials can be transported away from facilities or known waste sites by surface runoff (overland flow). This could conceivably occur following precipitation events or, as has been documented, from releases (or “spillage”) of process liquid waste that had been discharged to liquid waste disposal sites. Overland flow potentially results in the transport of contaminated sediments or water away from a waste site. Factors that affect overland flow include slope of the ground surface, soil texture, vegetative cover, and frequency of precipitation.

  The Hanford Site is in a semiarid region and precipitation is more than balanced by evaporation and transpiration, such that substantial overland flow from precipitation is an unlikely occurrence. A more likely source for overland flow is spills or releases from liquid waste disposal facilities during historical active operations. In general, these leaks were infrequent and documented through written and photographic records. Most resulted in localized contamination in and around the disposal sites. A number of these sites have been remediated under the Interim Action RODs.

- **Biointrusion.** Hazardous and radioactive substances in shallow soil can be transported to plants at ground surface through their roots or disturbed and transported to the soil surface by burrowing animals or insects. Most of the mass of plant roots is concentrated within the shallow soil; however, some deep-rooted plant species are found at the Hanford Site. Unless actively managed and controlled, deep-rooted vegetation (e.g., tumbleweeds, sagebrush) growing over underground sources of contamination may uptake radionuclides into their tissues. When radionuclides are transported from roots to aerial portions of the plant, surface contamination may result. Desert animals and insects burrow for shelter from the heat, cold, or predators; reproduction; feeding; and water conservation. Most wildlife burrow no more than a few feet; however, some macroinvertebrates (harvester ants) have been reported to burrow to depths of up to 2.4 m (8 ft) in soil at the Hanford Site. Animals that burrow into contaminated soils could disperse them on the soil surface. Figures J-3 and J-4 depict the conceptual model of biointrusion.

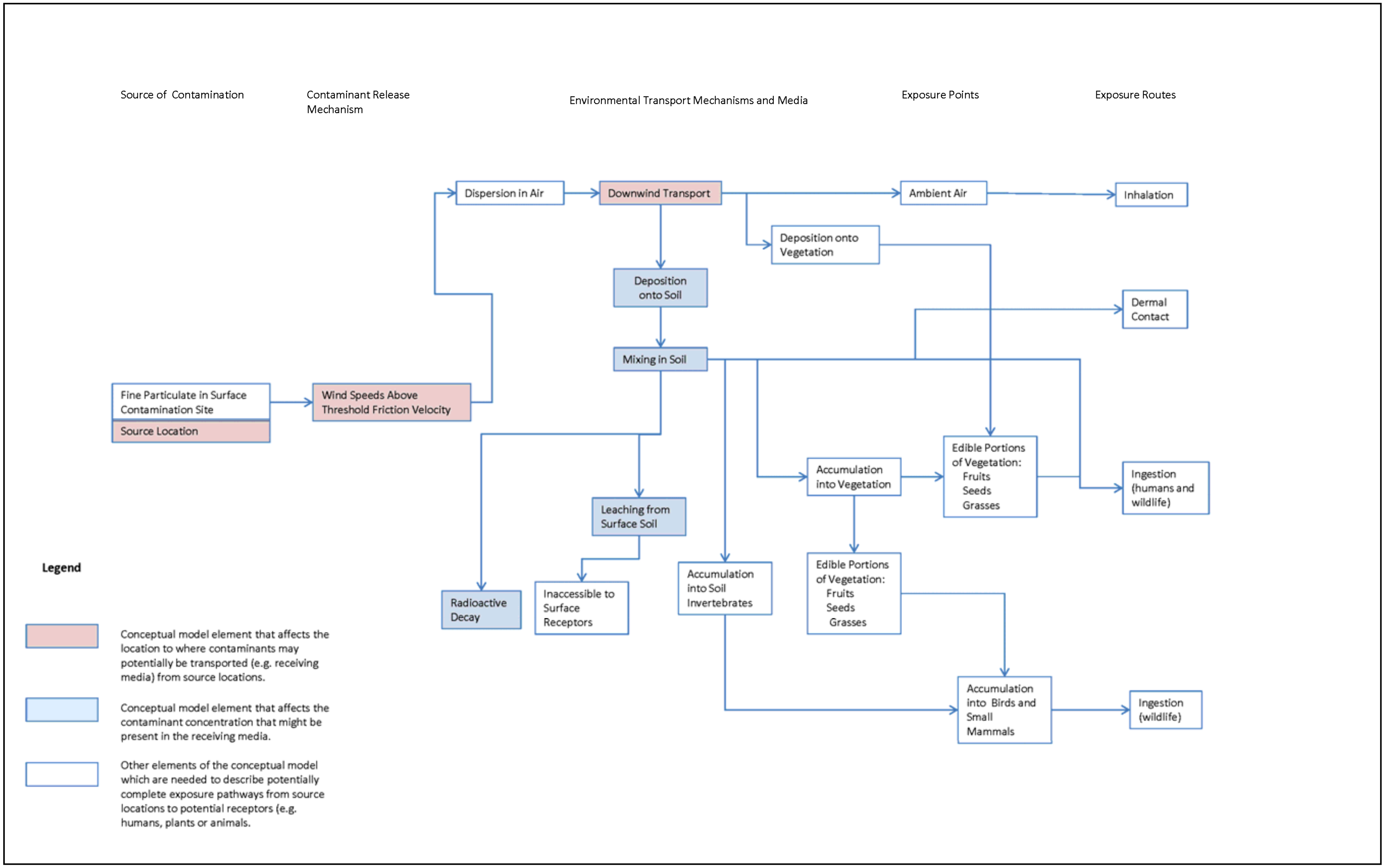


Figure J-1. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport of Windblown Dust

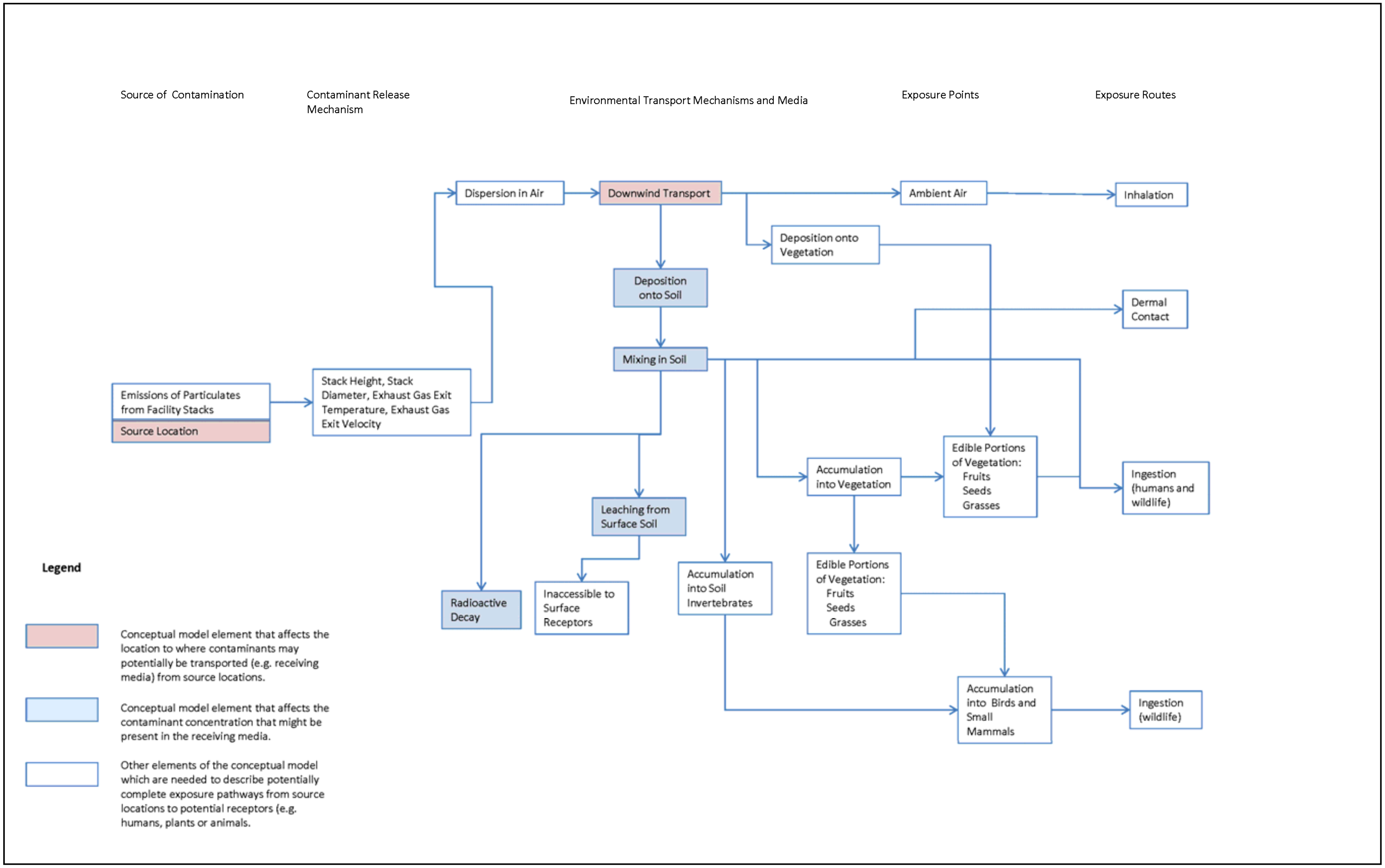


Figure J-2. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport via Emissions from Facility Stacks

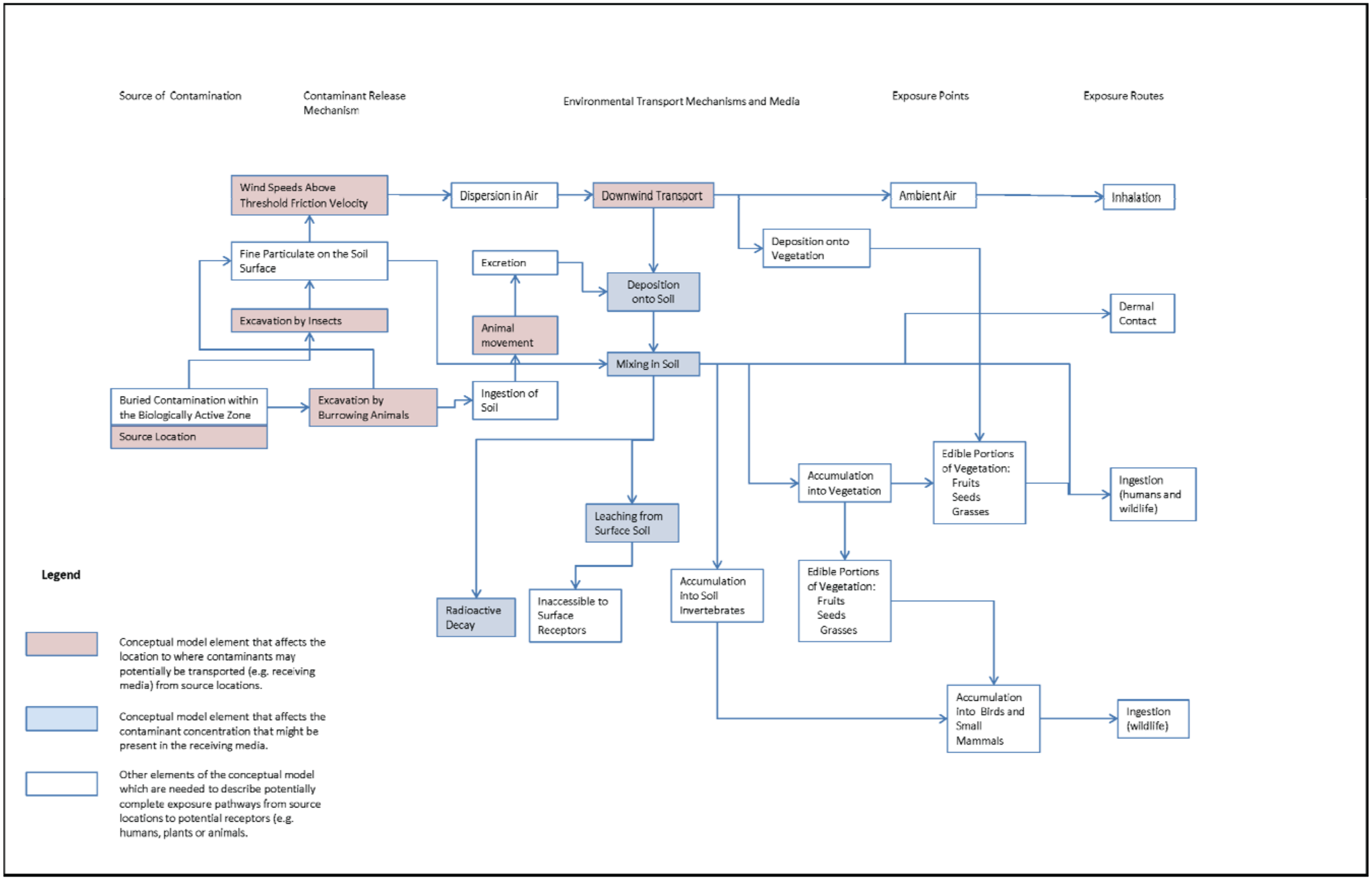


Figure J-3. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport via Animal Intrusion of Buried Contaminants

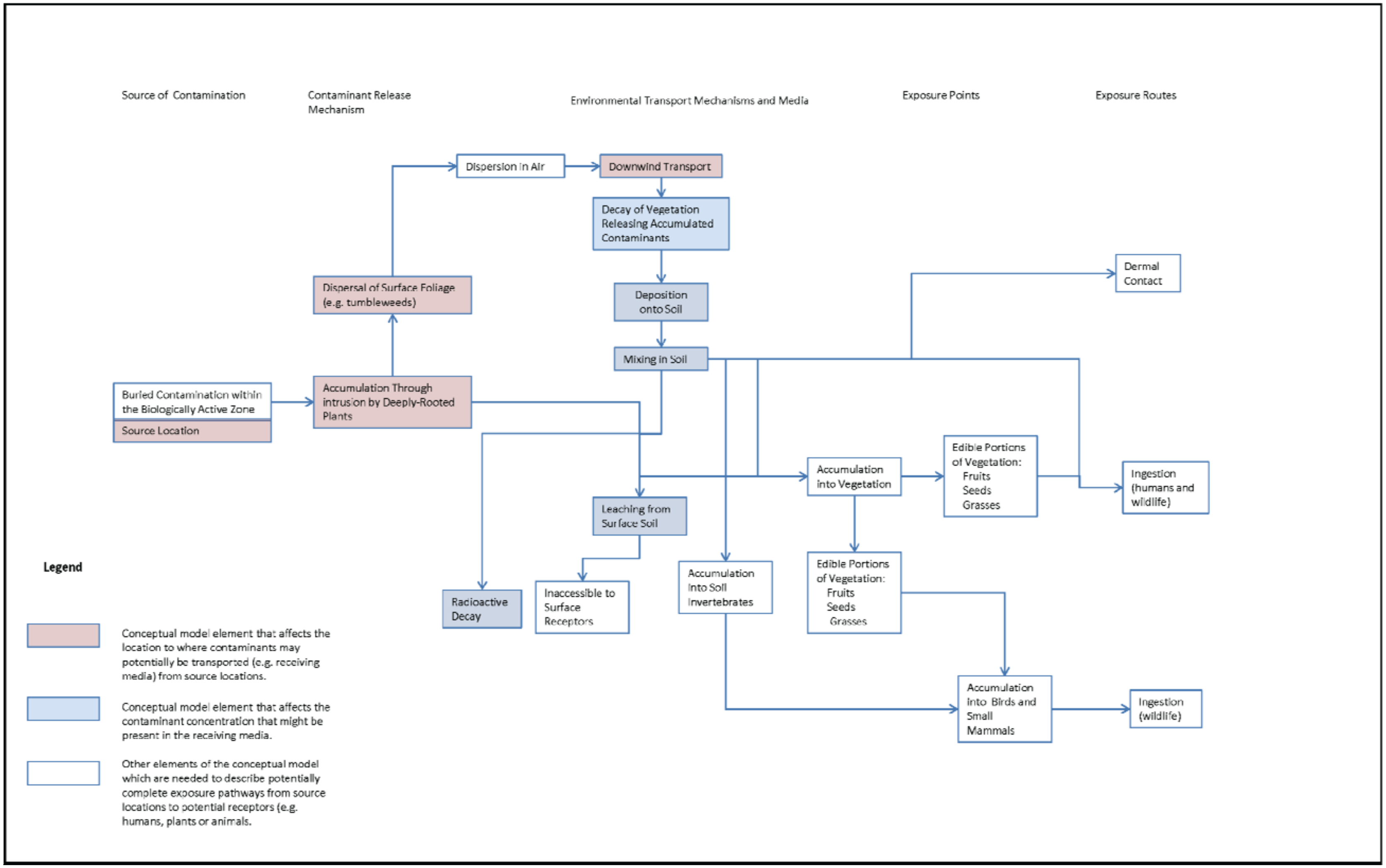


Figure J-4. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport via Intrusion of Deep-Rooted Plants

J2.2 Surveillance and Monitoring Programs

Several programs at the Hanford Site collect environmental surveillance and monitoring data. Many of these programs collect data to address regulatory requirements for emissions, effluent discharges, or DOE Orders regarding radiological control. Other programs perform environmental monitoring of soil, water, air, or vegetation. Most of these programs are summarized in the Annual Environmental Report for the Hanford Site (see *Hanford Site Environmental Report for Calendar Year 2009* [PNNL-19455] for an example of an environmental report).

Table J-1 lists 15 Hanford Site programs that identify waste sites and/or collect environmental monitoring and surveillance data. In addition, Table J-1 identifies five other sources of information and data applicable to a nonoperational area evaluation. Information and data from these programs were evaluated to identify trends in how hazardous substances or radionuclides may have been transported from operational areas or waste sites to nonoperational areas within the River Corridor. Information from the programs involved with soil, air, or vegetation monitoring, or with radiological control, were of most use in the NPE. The evaluation of the results from these programs as they pertain to the 100-F/IU OU is summarized in Section J3.1.

Table J-1. Existing Hanford Site Programs Related to Environmental Data and Monitoring

Ongoing Hanford Site Programs	
Air Emissions Monitoring	Liquid Effluent Monitoring
Ambient Air Monitoring Near Hanford Site Facilities and Operations	Sitewide and Offsite Ambient Air Monitoring
Soil Monitoring Near Hanford Site Facilities and Operations	Sitewide and Offsite Soil Monitoring
Vegetation Monitoring Near Hanford Site Facilities and Operations	Sitewide and Offsite Vegetation Monitoring
Radiological Dose Measurement Near Hanford Site Facilities and Operations	Radiological Surface Surveys Near Hanford Site Facilities and Operations
Groundwater Monitoring	Radiation Area Remedial Action Project
Waste Information Data System	Spill and Release Reporting
Vegetation Control Activities	
Additional Information and Data Sources	
Aerial Radiological Surveys	*River Corridor Baseline Risk Assessment* (DOE/RL-2007-21)
Aerial Photography (includes LiDAR)	Emissions estimation and dose assessments conducted as part of the HEDR Project.
Hanford Site background studies	

HEDR = Hanford Environmental Dose Reconstruction

LiDAR = Light Detection and Ranging

J2.3 Statistical Analyses

The statistical analyses focused on the following tasks:

- Developing and applying a predictive model for waste site locations
- Establishing association between Cs-137 measured directly in soil and high resolution aerial survey results
- Developing a sitewide model of soil Cs-137 using lower resolution sitewide aerial surveys

The results of these analyses were used to model the likelihood of finding previously undiscovered waste sites in the nonoperational areas as a function of fabricated and topographic features, and model the potential for radionuclide concentrations (specifically Cs-137) in surface soil to be higher than selected threshold concentrations.

The following text describes these lines of investigation. Section J3.2 discusses the results from these analyses.

J2.3.1 Predictive Modeling of Waste Site Locations

The predictive model is based on the conceptual model that waste sites are located in proximity to anthropogenic features such as roads or existing operational areas, or flat or low-lying topography. The distributions of these geographic variables, measured at WIDS sites, were compared with the distribution of the same variables calculated at an unbiased set of locations systematically distributed across the Hanford Site. A quantitative model was developed to show the probability of a waste site being located at any unsampled location within the Hanford Site as a function of these geographic measures. Factors considered in developing geographic variables for known waste sites and sources included distance to operational areas; distance to roads, railroad grades, utility rights of way (e.g., power lines); and topography, including slope aspect elevation, and curvature. These models were used to rank areas based on the relative probability that a previously undiscovered waste site might exist.

J2.3.2 Aerial Surveys and Soil Radionuclides

Measurements of the presence of radionuclides were available from direct soil measurements, as well as from laterally extensive aerial radiological surveys. Soil measurements were expressed as activities per unit mass (pCi/g), suitable for estimation of exposure for risk assessment, whereas data obtained from aerial surveys were expressed as gross counts for gamma emitting radionuclides. Aerial survey data could be used to estimate exposure if it could be calibrated with soil Cs-137 activity data. Predictive models and maps of the probability that Cs-137 levels would be expected to exceed screening levels could be prepared based on the statistical relationship between soil activity measurements and aerial survey gross counts.

A detailed investigation in the BC Control Area (BCCA), which included collecting high-resolution aerial survey data and relatively high-density soil sampling, provided data to perform a detailed geostatistical analysis. The analysis of the BCCA data supported development of a sitewide model based on less resolved, but more laterally extensive, aerial surveys of the entire Hanford Site. The results of the sitewide model were used to draw conclusions specific to the River Corridor. The results of both analyses support the utility of aerial radiological surveys for estimating concentrations in soil for unsampled areas.

J2.4 Orphan Sites Evaluation

The OSE is a systematic approach to evaluate land parcels in the River Corridor to ensure that all waste sites or releases requiring characterization and cleanup have been identified. Information collected through these evaluations also supports elements of the CERCLA Section 120(h)(4), "Federal Facilities," "Property Transferred by Federal Agencies," Identification of Uncontaminated Property," requirements for review and identification of uncontaminated property at federal facilities. The OSE supplemented past systematic efforts that identified source waste sites, including the *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14, "Maintenance of the Waste Information Data System (WIDS)" (RL-TPA-90-0001) discovery process for identifying known and potential waste sites, and the CERCLA hazard ranking conducted in 1985 and 1986 to place the Hanford Site on the "National Priorities List" (40 CFR 300, Appendix B), hereinafter called the NPL.

Two of the key elements of an OSE include a historical review and a field investigation. Review of historical information was conducted to identify potential orphan sites and to target areas for further evaluation during the course of conducting the associated field investigation. Historical research focused on identifying specific items or features typically associated with a waste site. The most common features associated with a waste site in reactor areas include drains, cribs, drywells/French drains, burial grounds, pipelines, aboveground and belowground storage tanks, septic systems, drain fields, burn pits, trenches, ditches, pits, spills, sumps, vaults, ash pits, disposal areas, pumps, and buildings and facilities that contain chemicals and radiological contaminants. Information obtained and used in the historical review included the following resource types:

- Maps
- Construction and operations drawings
- Technical and operations documents
- Construction and operations photographs
- Aerial photographs
- Geophysical survey results
- Cleanup verification packages
- Sampling logbooks
- Personnel interviews

Field investigation activities were used to provide another level of assurance by conducting systematic walking surveys to document potential orphan sites and to follow up on potential orphan sites identified from historical review. Three primary tools provided the media to record the information observed in the field—hand-held Trimble GeoXT™ Global Positioning System (GPS) units, digital cameras, and field logbooks. Geophysical survey instrumentation was used to supplement these tools in selected areas of suspect subsurface features identified during the historical review or field investigation.

To ensure a systematic approach for area coverage, standardized 30 × 30 m (98.4 × 98.4 ft) conceptual grids were established over the investigation areas. The grid and existing known features in the areas were loaded onto the GeoXT GPS units, which were used in the field to monitor progress and record information. Walking surveys were typically performed in pairs with approximately 15 m (49 ft) spacing between individuals. Features encountered during this investigation were recorded using the GPS unit, digital camera, and field logbook.

The field investigation for regions of the River Corridor used a graded approach. High resolution, four-band (red, green, blue, and near-infrared) orthophotography imagery and Light Detection and Ranging (LiDAR) topography data were collected for approximately 57,468 ha (142,000 ac) of the River

™Trimble GeoXT is a trademarked product of Trimble Navigation Limited, Sunnyvale, California.

Corridor in April 2008. The data were collected in the early spring when foliage and undergrowth obscuring the ground surface was at a minimum. The orthophotography and LiDAR data were used to conduct “virtual walkdowns” of the areas. Based on results of these “virtual walkdowns,” areas were selected to conduct walking surveys (30 × 30 m [98.4 × 98.4 ft] reference grid system). Vehicle surveys along accessible roads and utility easements were also part of the field investigation. In addition, standard walking surveys were conducted throughout the River Corridor along the Columbia River, based on the level of interest in the shoreline area and its inclusion as part of the Hanford Reach National Monument (“Establishment of the Hanford Reach National Monument” [65 FR 37253]).

J3 Evaluation Results

This section summarizes the results of the NPE in the 100-F/IU OU of the River Corridor based on the approach presented in Section J2. The NPE is based on multiple lines of evidence, including the results from surveillance and monitoring programs and other studies conducted in the River Corridor; the results from statistical analyses performed to identify the potential presence of waste sites and to evaluate the spatial distribution of selected radionuclides in soil; and the results from the OSE.

J3.1 Results from Surveillance and Monitoring Programs

Hanford Site programs, which provided information characterizing conditions in the nonoperational areas in and around the 100-F/IU OU, included the soil, air, and vegetation sampling conducted as part of the Near Facility Monitoring program and the Surface Environmental Surveillance Program (SESP). The radiological control program with emphasis on radiological surveys and activities for identifying and controlling biological vectors (biointrusion from plants and animals), and external radiation monitoring conducted as part of the SESP.

Other activities that contribute to characterizing conditions in the nonoperational areas include the waste site discovery process under *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14, “Maintenance of the Waste Information Data System (WIDS)” (RL-TPA-90-0001), which results in identified waste sites being inventoried in WIDS and, as discussed in Section J3.3, the OSE. Historically, interim actions conducted under the Radiation Area Remedial Action (RARA) project contributed to stabilizing and controlling releases from waste sites. The results from these programs have been discussed using the framework of the conceptual model described in Section J2.1.

J3.1.1 Anthropogenic Disposal Activities

Past and present investigation activities provide confidence that waste site locations within the River Corridor are known. Waste site identification activities in the River Corridor fall into two categories: systematic and observational. Various systematic programs have been conducted at different times since the beginning of Hanford Site transition from production to cleanup in the 1980s, with the most recent being the OSE program that was initiated in 2004 (Section J3.3). An inventory of known and potential waste sites has been maintained in the WIDS database since the early 1980s, and is continually maintained through *Tri-Party Agreement Handbook Management Procedures* Guideline Number TPA-MP-14, “Maintenance of the Waste Information Data System (WIDS)” (RL-TPA-90-0001) discovery process. Between 1985 and 1988, preliminary assessment/site inspection activities were completed to identify waste sites and prioritize the relative hazards. Waste disposal information was collected through exhaustive reviews of literature and maps, employee interviews, and visual inspection of all sites and unplanned releases. Results were organized and sites were ranked with respect to potential environmental impacts in accordance with a slightly modified version of the CERCLA hazard ranking system. The results from this process provided information to support addition of the 100 and 300 Areas to the NPL and subsequent listing of waste sites in Appendix C of the Tri-Party Agreement (*Hanford Federal Facility Agreement and Consent Order* [Ecology et al., 1989]).

A variety of characterization activities conducted as part of the RI/FS process has further characterized potential release and disposal activities in the 100 Area. These historical activities are summarized in *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 4: 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* (DOE/RL-2008-46-ADD4).

J3.1.2 Windblown Dust Emissions

Emission sources, which could release contaminants through wind-blown dust, are described variously as "fugitive," "diffuse," or "nonpoint" emissions sources (*Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2009* [DOE/RL-2010-17]). The Hanford Site consists of 1,518 km^2 (586 mi^2) of semiarid shrub-steppe land, of which approximately 6 percent (about 83 km^2 [32 mi^2], or 8,909 ha [20,000 ac]) has been actively disturbed or actively used. This 6 percent of land is distributed into large operational and support areas where almost all fugitive emissions sources are located: the 100, 200 (which includes 200 East and 200 West), 300, and 400 Areas.

The potential for fugitive dust emissions from waste sites (prior to their cleanup) is generally characterized as occurring subsequent to erosion of soil covers or plant or animal biointrusion, which may expose erodible material containing concentrations of radionuclides. Contaminated areas posted as Radiologically Controlled Areas or Soil Contamination Areas also could contain erodible material that is radiologically contaminated, and that could produce fugitive emissions from resuspension of windblown dust (*Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2009* [DOE/RL-2010-17]).

The RARA program is responsible for the interim stabilization, surveillance, and maintenance of the inactive waste sites at the Hanford Site. Interim stabilization measures to control fugitive dust have historically been performed on inactive waste sites prior to their cleanup. Stabilization measures included consolidation of surface contamination within the waste site from which it originated, then covering the waste with a layer of soil or other material (such as cobbles). Waste sites were then revegetated or treated as needed with a nonselective herbicide. Following stabilization, quarterly surveillance, annual radiological surveys, annual herbicide applications, removal of deep-rooted vegetation, and occasional corrective action for small areas of surface contamination continued. Interim stabilization reduced sources of windblown dust potentially originating from contaminated soils.

The potential magnitude of windblown dust transport can be evaluated from the frequency of restrictions to visibility and ambient air monitoring for particulate matter and radionuclides in air. Dust, blowing dust, and smoke from field burning are described as phenomena causing restrictions to visibility (i.e., visibility less than or equal to 9.6 kg [6 mi]. Reportedly, there are few such days at Hanford (*Hanford Site National Environmental Policy Act (NEPA) Characterization* [PNNL-6415]). Particulate air monitoring shows that annual average PM_{10} (particulate matter finer than 10 μm in diameter) concentrations at the Hanford Meteorological Station are similar to PM_{10} concentrations at the Benton Clean Air Authority station located in Kennewick.

J3.1.3 Stack Emissions

Radionuclide emissions formerly from stacks in the 200 Area and the 100 Area had the potential to affect the River Corridor through deposition from the air. Based on studies conducted as part of the Hanford Environmental Dose Reconstruction (HEDR) project, most of the emissions occurred between 1944 and 1972 from facilities in the 200 Area that separated plutonium and uranium from irradiated reactor fuel (*Radionuclide Releases to the Atmosphere from Hanford Operations, 1944-1972* [PNWD-2222 HEDR]). The largest releases from these facilities occurred in 1945, before effective collection devices were installed ahead of the stacks to prevent the discharge of volatile and particulate radionuclides. Most of the inventory emitted consisted of gaseous and/or short-lived radionuclides, which would be unlikely to result in measurable concentrations in soil in Hanford Site nonoperational areas. The nine production nuclear reactors in the 100 Area had stacks to exhaust ventilation air from the working areas of the reactor facilities. These were minor sources of emissions compared to the 200 Area facilities. No significant stack releases from 100 Area operations were reported in the documents that evaluated soil sampling and monitoring (*RCBRA Stack Air Emissions Deposition Scoping Document* [DOE/RL-2005-49]).

No near-facility soil samples were collected from 100-F in 2007 or 2009. Five near-facility soil samples were collected from 100-F in 2008. The Annual Environmental Report for 2008 concluded that analytical results from each of these locations were comparable to those observed at other near-facility sampling locations at the Hanford Site (*Hanford Site Environmental Report for Calendar Year 2008* [PNNL-18427]).

One long-term soil and vegetation monitoring station maintained as part of the SESP is located near the Hanford Townsite. Cs-137, Co-60, Sr-90, Pu-239/240, U-235, and U-238 were measured in soil at this station starting in 1982. Concentrations of Cs-137 in soil ranged from 0.5 to 2 pCi/g over the next 10 years. Since the mid 1990s, radioactive decay has become more apparent and concentrations in more recent years have declined to less than 0.5 pCi/g. Concentrations of Co-60 in soil ranged from less than 0.02 to 0.1 pCi/g over the next 10 years. Since the mid 1990s, radioactive decay has become more apparent and concentrations in more recent years have declined to less than 0.01 pCi/g. Pu-239/240 concentrations measured between 1982 and 2009 fluctuated between 0.01 and 0.04 pCi/g. Concentrations of Sr-90 in soil ranged from 0.02 to more than 0.7 pCi/g over the next 10 years, with the exception of a peak measurement of 1.8 pCi/g reported in 1983. Since the mid 1990s, radioactive decay has become more apparent and concentrations in more recent years have declined to less than 0.2 pCi/g. U-235 concentrations measured between 1987 and 2009 were 0.15 pCi/g or lower. U-238 concentrations measured in soil between 1987 and 2009 were 0.8 pCi/g or lower. The highest concentration was measured in 1993; concentrations measured since 2003 have ranged from 0.2 to 0.6 pCi/g. Cs-137, Co-60, and Sr-90 were the only radionuclides detected in vegetation; generally the concentrations detected were very low, often 0.01 pCi/g or lower.

J3.1.4 Overland Flow

The Hanford Site is in a semiarid region and thus experiences many dry periods. January, March, and December are the only months that have always received measurable precipitation, reported from 1946 through 2004. Normal annual precipitation at the Hanford Site is 17.7 cm (6.98 in.) (*Hanford Site Climatological Summary 2004 with Historical Data* [PNNL-15160]). In the Hanford semiarid climate, precipitation is balanced by evaporation, transpiration, and vegetative uptake such that substantial overland flow from precipitation is an unlikely occurrence.

A more likely source for overland flow is historical spills or releases from liquid waste disposal facilities during active operational periods. Liquid effluents generated as a direct result of reactor operations consisted primarily of reactor cooling water, fuel storage basin water, and decontamination solutions.

Leaks are more likely to have occurred from the 100-Area liquid waste disposal sites. These resulted in overland flow described in the 1975 sampling event report (*Radiological Characterization of the Retired 100 Areas* [UNI-946]). In general, these leaks were infrequent, well documented, and resulted in localized contamination around the periphery of the disposal sites. The leaks have been characterized historically or as part of the current RI/FS process. The majority of the leaks have been cleaned up and interim closed out in accordance with the interim action RODs. The identification of leaks or spills from waste sites also is incorporated into the procedure for maintaining WIDS in accordance with *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14, “Maintenance of the Waste

Information Data System (WIDS)" (RL-TPA-90-0001). Based on the available information, overland flows from liquid waste disposal facilities are limited in lateral extent, and unplanned liquid release sites are identified through existing programs such as WIDS. The factors considered in this evaluation indicate that contamination in nonoperational areas through overland transport is unlikely to occur.

J3.1.5 Biointrusion

Biointrusion episodes in the 100-F/IU OU have not been described in radiological survey reports for the past three years. Radiological surveillance monitoring or vegetation sampling conducted as part of the Near-Facility Monitoring Program (*Hanford Site Environmental Report for Calendar Year 2009* [PNNL-19455]) has not identified contaminated vegetation episodes around the 100-F/IU OU.

J3.2 Statistical Evaluations

The statistical evaluations provide estimates of the likelihood of finding previously undiscovered waste sites in the nonoperational property areas and the potential for exposure to Cs-137 exceeding selected threshold concentrations in surface soils.

J3.2.1 Relative Probability of Missing an Existing Waste Site

Known waste sites have largely been located in proximity to anthropogenic features and relatively particular topographic conditions. For example, most waste sites found to date tended to be close to roads, in low-lying areas such as ditches or ponds, or proximate to operational areas. The spatial distributions of these geographic variables, measured at known WIDS sites, were compared with the distribution of the same variables calculated at an unbiased set of locations systematically distributed across the Hanford Site. A statistical relationship was established to rank the likelihood that an available location might contain a previously unknown waste site. Logistic regression was used to develop the statistical relationship between waste site locations and geographic variables.

Factors considered in developing geographic variables expected to predict locations of known waste sites and sources included distance to operational areas; distance to roads, railroad grades, lakes, streams, utility rights-of-way (e.g., power lines); and topography.

The geographic characteristics of the known waste sites were investigated to determine if their locations exhibited predictable spatial patterns. The purpose of this analysis was to develop a quantitative predictive model describing relationships so that areas within the River Corridor could be prioritized based on the relative probability that a previously unidentified waste site might be present. This analysis does not provide an absolute probability that a waste site exists, but rather provides a relative probability that allows locations to be ranked to identify the more likely location for a waste site—after all, there may be no additional waste sites in the River Corridor that have not been found. The predictive model provides direction to the most likely places for a waste site to occur if indeed one exists.

The predictive model was developed based on a set of known waste site locations obtained from WIDS (referred to as a "training set"). The results of this model were used to predict the relative probability of encountering a potential waste site at areas that had might not have been investigated in the field. This provided a ranking of locations within the NPE that could then be investigated in the field, compared with previous field or desktop investigation results to determine the potential that additional previously undetected waste sites may remain within the NPE. In the River Corridor area, the modeled predictions were compared with information generated from the OSE. The modeled predictions were compared with miscellaneous remediation points and waste site points observed during observations of aerial photography and LiDAR imagery, field walkdowns, and vehicular road surveys conducted as part of the OSE. These comparisons provided independent validation of the predictive model.

The waste site probability map is plotted in Figure J-5 showing the 100-F area. Near 100-F area, none of the validation waste site points (locations identified during the OSE and used to validate the predictive model) are located in areas with relative probability less than 5 percent and most are within areas with relative probabilities of 20 percent or greater. This means that in the areas where no waste site points were identified through the OSE process, the probability of an undetected waste site requiring enrollment in the TPA MP-14 process is less than approximately 2 percent. The 100 IU-2/6 Area is shown in Figure J-6. The waste site probability shows that relative probabilities range from 5 to 50 percent. All of this area was walked as part of the OSE program and many independent waste site points and miscellaneous remediation (MR) points were identified in the Townsite. Most of these identified items are associated with the use of the area as a work camp when the site was initially constructed.

The relative probability of a waste site is highest within the decision area boundaries and adjacent to smaller local roads. Outside the decision unit boundaries, the relative probabilities are generally less than 2 percent with the exception of areas that are proximate to smaller roads that could afford easy access for discarding fugitive wastes.

All of the River Corridor area and, by extension, the 100-F area specifically, was investigated through the OSE virtual walkdowns including investigation of high-resolution aerial photography, LiDAR, and other sources of information available in electronic form. In addition, the areas within the red-dashed polygons were also investigated exhaustively through field walkdowns. In the 100-F area, the field walkdowns generally captured all areas with 20 percent or greater relative probability of containing a waste site. The field walkdowns provide essentially 100 percent field coverage for identification of potential waste sites. Generally, field walkdowns in the 100-F area coincide with the areas identified statistically to be the most likely to contain waste sites—areas close to operational facilities, known waste sites, and secondary roads that could afford easy access for dumping fugitive waste.

The relative probabilities of identifying waste sites at the Hanford Townsite (100-IU-6) range from 5 to 50 percent. All of this area was walked as part of the OSE program and many independent waste site points and MR points were identified in the Townsite. Most of these identified items are things associated with the use of the area as a work camp when the site was initially constructed.

J3.2.2 Spatial Analysis of Soil Radionuclides and Aerial Surveys

Measurements of the presence of radionuclides were available from direct soil measurements, as well as from laterally extensive radiological aerial surveys. Soil measurements were expressed as activities per unit mass (pCi/g) suitable for estimation of exposure for risk assessment, but provide only limited understanding of the spatial distribution of concentrations. Data obtained from aerial surveys interrogates much larger areas, but expressed as gross counts for gamma emitting radionuclides. The aerial survey data were not directly applicable to estimation of potential exposure without calibration to directly measured soil concentrations.

For purposes of the NPE, aerial survey data were calibrated against measured soil Cs-137 activity data. Geostatistical methods were used in a preliminary study to develop a spatially explicit relationship between soil activity measurements and aerial survey gross counts within the BCCA. Detailed geostatistical analysis was conducted within the BCCA because high-resolution aerial survey data and relatively high-density soil sampling were available for this area. The preliminary analysis of the BCCA data was used as a pilot study to support determination to proceed with development of a more extensive sitewide model based on less resolved, but more laterally extensive aerial surveys of the entire Hanford Site. The results of the sitewide model were used to draw conclusions regarding the distribution of Cs-137 (a contaminant of potential concern related to Hanford Site operations) specific to the nonoperational area.

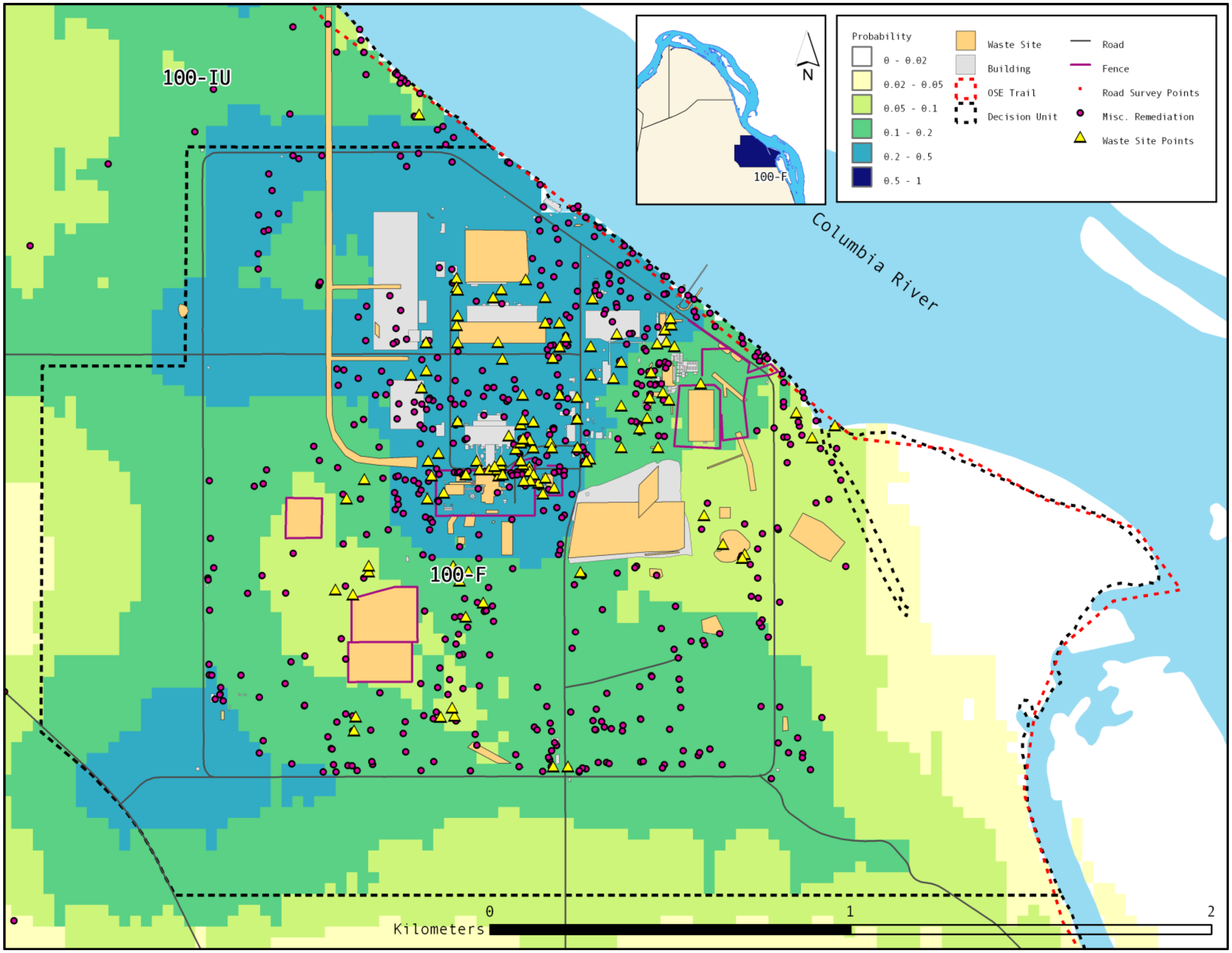
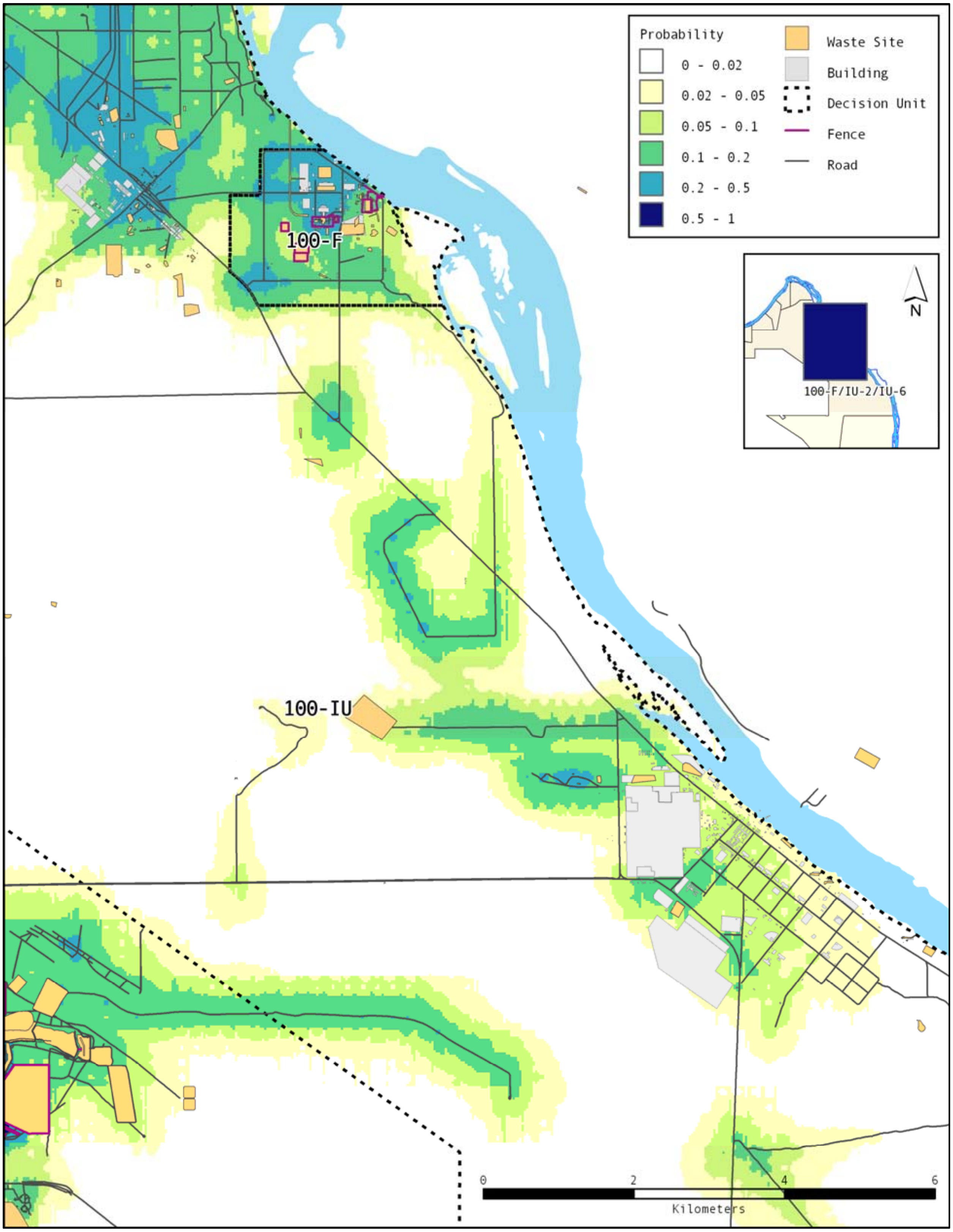


Figure J-5. Relative Probability of Waste Site Locations in the 100-F Area of the River Corridor

1


2 Figure J-6. Relative Probability of Waste Site Locations in the 100-IU Area of the River Corridor

Aerial surveys were conducted in 1996 (*An Aerial Radiological Survey of the Hanford Reservation Richland Washington, Date of Survey: February 29 to March 21, 1996* [DOE-0335]) and 2009 (*An Aerial Radiological Survey of the Hanford BC Controlled Area and West Lake Area* [SGW-45563]) were combined with ground radiological surveys and soil sampling and analytical data for Cs-137 in the BCCA to establish a relationship to the aerial survey results and measured concentrations in soil. A statistical model of the probability that soil Cs-137 levels exceed selected threshold levels (1.05, 1.5, 3.1, and 6.2 pCi/g) was developed as a function of gross counts of gamma emitting radionuclides using sitewide aerial survey results. The statistical model was validated against a set of waste sites in the 200-MG-1 OU, where radiological surveys and soil sampling and analysis had been conducted as part of interim remedial actions.

The logistic regression models provide estimates of the probability of exceeding threshold levels, which can be interpreted as estimates of the proportion of an area that would be expected to exceed those levels if one were to sample them. The probability that Cs-137 activities exceed 1.05 pCi/g near the 100-F/IU OU is shown in context with the Hanford Site in Figure J-7. The modeled probability that concentrations of Cs-137 in soil exceed 1.05 pCi/g is less than 2.5 percent near the 100-F reactor area and the 100-IU-2/6 areas. In general, the spatial analysis of radionuclides indicates that concentrations resemble background levels around the 100-F and 100-IU-2/6 areas.

J3.3 Orphan Sites Evaluation

The results from historical research, field walkdowns, GIS mapping, and geophysical surveys for the 100-IU-2 and 100-IU-6 areas are summarized in *100-IU-2 and 100-IU-6 Areas Orphan Sites Evaluation Report* (OSR-2008-0001). A field walkdown was conducted over 801 ha (1,980 ac) in the 100-IU-2 area and 2,751 ha (6,797 ac) in the 100-IU-6 area. A total of 43 new orphan sites were identified through the OSE in the 100-IU-2 and 100-IU-6 areas. Each of these sites was accepted into WIDS. There were 17 locations with non-CERCLA debris consistent with the miscellaneous restoration criteria. The results from the statistical analysis of waste site locations versus fabricated and topographical features are shown in Figures J-5 and J-6.

The following sections summarize the results from the OSE for each of the 100-F/IU-2/6 segments. The Segment Areas are part of the 100-F/IU-2/IU-6 geographical area within the River Corridor that do not contain any historical reactor/operational areas. The five segments consist of more than 47,774 ha (118,000 ac).

Segment 1. The OSE for Segment 1 is presented in *100-F/IU-2/IU-6 Area – Segment 1 Orphan Sites Evaluation Report* (OSR-2009-0002). Segment 1 includes approximately 7,349 ha (18,161 ac), while the 100-BC Buffer Area includes 671 ha (1,659 ac). Six new discovery sites were identified during the Segment 1 OSE and were accepted into WIDS. There were 18 non-CERCLA features that were consistent with the miscellaneous restoration criteria that were identified through the investigation.

Segment 2. The OSE for Segment 1 is presented in *100-F/IU-2/IU-6 Area – Segment 2 Orphan Sites Evaluation Report* (OSR-2010-0001). The coverage for the Segment 2 orphan sites evaluation includes an area of approximately 8,172 ha (20,195 ac). No features were identified as orphan sites during investigation of Segment 2. One feature was categorized as a miscellaneous restoration item and documented as part of the Segment 2 orphan sites evaluation.

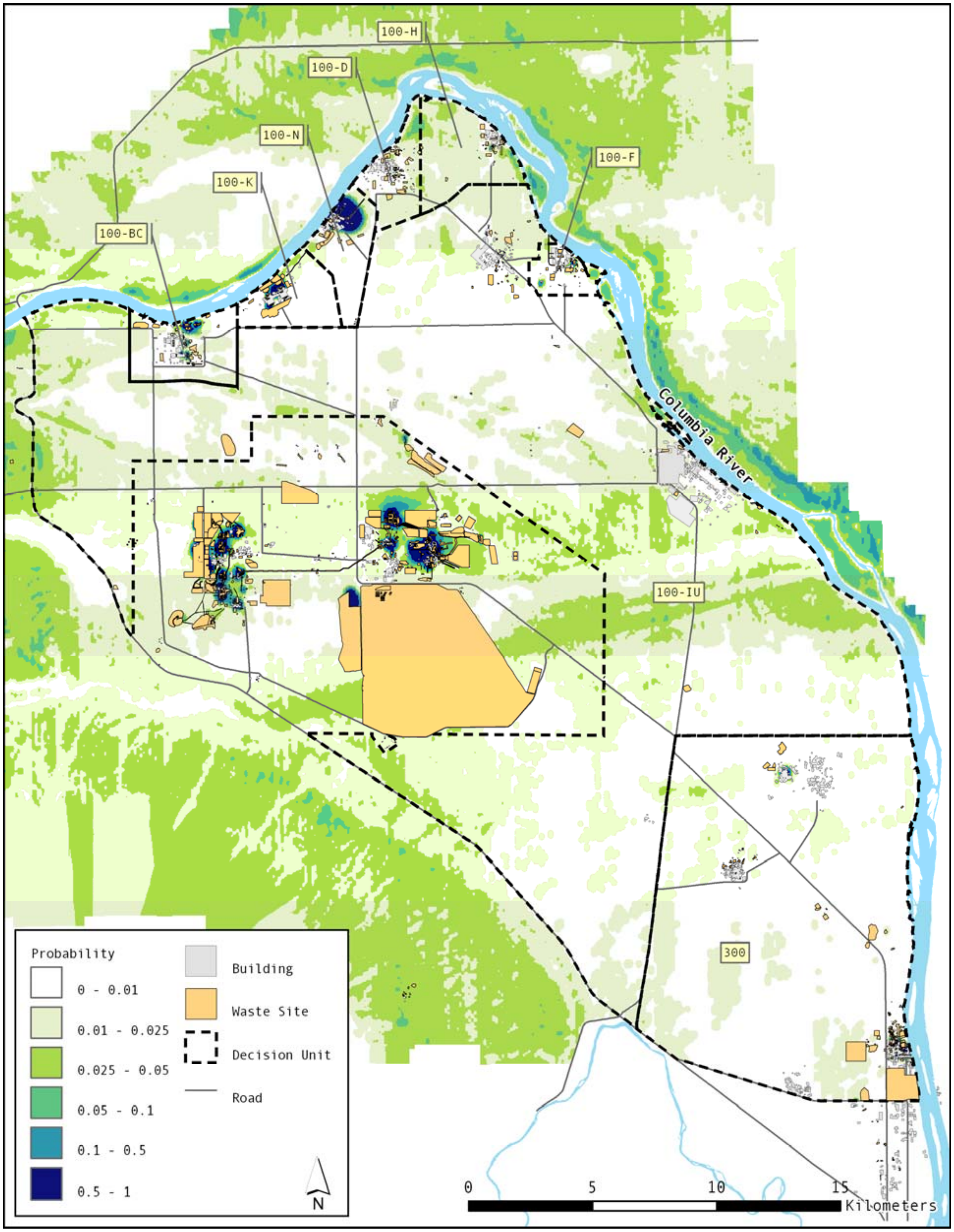


Figure J-7. Modeled Probability that Soil Cs-137 Exceeds 1.05 pCi/g in at Hanford Site

Segment 3. The OSE for Segment 3 is presented in *100-F/IU-2/IU-6 Area – Segment 3 Orphan Sites Evaluation Report* (OSR-2010-0004). The coverage for the Segment 3 orphan sites evaluation includes an area of approximately 12,003 ha (29,660 ac). No features were identified as orphan sites during investigation of Segment 3. There were 17 features categorized as a miscellaneous restoration item and documented as part of the Segment 3 orphan sites evaluation.

Segment 4. The OSE for Segment 4 is presented in *100-F/IU-2/IU-6 Area – Segment 4 Orphan Sites Evaluation Report* (OSR-2011-0001). The coverage for the Segment 4 orphan sites evaluation includes four subareas: Segment 4 - 9,546 ha (23,588 ac); Segment 4 (100-D/H) - 2,030 ha (5,017 ac); Segment 4 (100-K) - 898 ha (2,218 ac); Segment 4 (100-N) - 889 ha (2,197 ac); Segment 4 (100-F) - 220 ha (544 ac). Nineteen new discovery sites were identified during the OSE of Segment 4. There were 69 features categorized as a miscellaneous restoration item and documented as part of the Segment 4 orphan sites evaluation.

Segment 5. The OSE for Segment 5 is presented in *100-F/IU-2/IU-6 Area – Segment 5 Orphan Sites Evaluation Report* (OSR-2011-0002). Historical activities that occurred within this area prior to 1943 (pre-Hanford) consisted of farm/homesteads that were mainly confined to the south end of Segment 5 and near the 300 Area. The remaining portion of Segment 5 consists of mainly dune formations. One orphan site and 17 miscellaneous restoration features were identified in the OSE for Segment 5.

J3.4 Historic Orchard Lands

Prior to 1943, farming occurred primarily on land between 100-D/DR and 100-H Areas, as well as land surrounding the 100-F Area and the former town of White Bluffs (100-IU-2). Settlement projects sponsored by the Federal government following World War I brought veterans to the area to farm, which included raising orchard crops such as pears, peaches, apples and plums (*100-IU-2 and 100-IU-6 Areas Orphan Sites Evaluation Report* [OSR-2008-0001]; *100-F/IU-2/IU-6 Area – Segment 4 Orphan Sites Evaluation Report* [OSR-2011-0001]). From the turn of the 20th Century until 1948, lead arsenate was used in orchard crops for the control of codling moth infesting pears and apples. The use of lead arsenate ceased after 1948 with the introduction of DDT ("Historical Use of Lead Arsenate Insecticides, Resulting Soil Contamination and Implications for Remediation" [Peryea, 1998]).

In Washington, lead and arsenic contamination in areas downwind from former smelter operations, and soil in orchard formerly treated with lead arsenate pesticide, pose concerns for site cleanup. These are referred to as "area-wide soil contamination." Area-wide soil contamination refers to low to moderate level soil contamination that is dispersed over a large geographic area covering several hundred acres to many square miles. For schools, childcare centers, and residential land uses, Ecology considers total arsenic concentrations up to 100 mg/kg to be within the low-to-moderate range. For properties where exposures of children are less likely or less frequent, such as commercial properties, parks, and camps, Ecology considers total arsenic concentrations up to 200 mg/kg to be within the low-to-moderate range (*Area-Wide Soil Contamination Task Force Report* [Area-Wide Soil Contamination Task Force, 2003]). The area-wide concentrations of arsenic in soil are above background, and often above the Method A cleanup level of 20 mg/kg. The Task Force recommended to Ecology that a consistent and predictable approach be applied to area-wide soil contamination. In numerous remedial actions completed in former orchard lands across Washington State, Ecology has accepted a cleanup level of 20 mg/kg for arsenic in soil; in some cases, this cleanup level is combined with institutional controls.

J4 Conclusions

Multiple lines of evidence were reviewed to evaluate conditions in the 100-F/IU OU nonoperational area (and the River Corridor more generally) based on potential release and transport mechanisms.

Surveillance and monitoring programs, in combination with the OSE, have comprehensively identified all waste sites within the 100-F/IU OU. In addition, the surveillance and monitoring programs, in combination with studies conducted as part of the HEDR, have demonstrated that emissions to the air-either from windblown dust or from stack emissions—have not affected nonoperational area soils with radionuclides. The surveillance and monitoring programs also have verified that biointrusion has not resulted in a spread of contamination into the nonoperational areas.

Statistical analysis of the geographical distribution of waste sites based on fabricated features and topography describes the likely locations of waste sites near the 100-F/IU OU. The results from this analysis reinforce the findings from the OSE, which has systematically identified the remaining waste sites within 100-F/IU OU. Statistical analysis of the distribution of radionuclide concentrations observable from aerial surveys has confirmed that the probability of detecting elevated radionuclide concentrations in nonoperational area soils is very small.

Based on the evaluation of these multiple lines of evidence, the probability of identifying waste sites or contaminant dispersal from Hanford Site operations in 100-F/IU OU nonoperational areas is considered negligible.

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