



Public Health Assessment for

THE HANFORD SITE
(a/k/a HANFORD 100-Area (USDOE), HANFORD 200-Area
(USDOE), and HANFORD 300-Area (US DOE))
RICHLAND, BENTON COUNTY, WASHINGTON
EPA FACILITY ID: WA3890090076, WA1890090078,
WA2890090077
OCTOBER 16, 2006

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

Comment Period Ends:

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THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i) (6) (H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them to ATSDR. This revised document has now been released for a 30-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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PUBLIC HEALTH ASSESSMENT

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Prepared by:

Site and Radiological Assessment Branch
Division of Health Assessment and Consultation
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Conclusions

1.1 Health Implications

1.1.1 Health Implications from Past Exposures

Although there have been past releases and exposures, substantial controversy remains over the actual doses individuals received and the potential health effects at those doses. Given the uncertainties, ATSDR could not determine conclusively whether exposures to radioactive substances occurred off the Hanford property at levels sufficient to cause harmful health effects.

ATSDR uses an ***indeterminate public health hazard*** category when a professional judgment about the level of health hazard cannot be made because data critical to such a decision is lacking.

To assess possible health implications of exposure to radioactive materials, primarily radioactive iodine (I-131), ATSDR reviewed the medical, epidemiologic, and radiologic literature. Most recent data include studies in thyroid-induced diseases from the Chernobyl reactor accident in 1986 and other reports describing the cancerous and noncancerous impacts on the thyroid. From these studies, ATSDR found enough evidence to conclude that individuals who were at least 21 years of age during the I-131 releases were probably not exposed to harmful levels of radioactive iodines that would induce thyroid disease or cancer. A review of these studies, however, indicates that younger individuals (under the age of 18) were more sensitive to the potential adverse health effects associated with the uptake of radioactive iodines by the thyroid. Because of the wide range of potential exposures and the uncertainties associated with historical reconstruction of the dose estimates, ATSDR cannot identify specific population groups of younger individuals who may have been impacted by past releases from the site.

ATSDR believes that individuals who were under the age of 18 during the I-131 releases and who also received a thyroid dose in excess of 10 rads (0.1 Gy) should be considered the critical, sensitive population. ATSDR recommends continued health education to inform those who lived in the Hanford region during the period of the I-131 releases — and their health care providers — about the potential health risks of exposure to I-131.

Latency Period

Health effects do not always appear immediately after exposure. A latency period — a time between the exposure and onset of health effects — can be 3 to 30 years or more. The most significant Hanford releases leading to off-site population

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incidence of thyroid diseases among the group studied was about the same as the expected incidence of thyroid disease in a similar group of children who were not exposed to I-131. Study results showed no correlation between the estimated dose to the thyroid from I-131 and the amount of thyroid disease in the study population, and that greater exposures to I-131 did not lead to a greater incidence of thyroid disease.

The findings did not prove healthy people living in the Hanford area during the 1940s and 1950s were not exposed to I-131 and other radionuclides, or that these exposures had no effect on their health. Rather, the study findings showed that if there were an increased risk of thyroid disease from exposure to Hanford's I-131, it was likely too small in number to identify using the best epidemiologic methods available, because thyroid disease occurs at low frequency in all populations, regardless of I-131 exposure. There may be individuals in the overall population who were exposed to Hanford radiation and who did develop thyroid disease because of their exposure.

Migrant Farm Workers

During the period 1942–1947, approximately 16,000 migrant workers harvested crops annually in the six-county area surrounding Hanford. In a study of the migrant workers and their families, Duffie and Willard (1997) concluded that migrant workers may have experienced an increased *daily* exposure to radiation through the air and water pathway as a result of

- time spent out-of-doors,
- exposure to soil and dust in the fields,
- drinking and swimming in local surface waters, and
- consuming locally grown food products.

Migrant workers' *annual* exposure, however, was less than the permanent population because they were only in the area from April 1 to November 1 each year.

Fish Consumption

Radionuclide releases into the Columbia River and subsequent radiation doses to people were greatest from 1956 through 1965, peaking in 1960. Most of the radioactivity was highly diluted by the high volumes of water in the Columbia River. However, some radionuclide concentration occurred in Columbia River fish consumed by local populations. Depending on scenario, this could have led to varying radiation doses to consumers of Columbia River fish. The radiation doses to people during the period 1956 to 1965 may be compared to current recommendations of national and international scientific committees (such as the NCRP and the ICRP), or compared to U.S. federal regulations for limiting exposure of the general public (10 CFR 20) to 500 mrem for any 5-year period,

Conclusions

Columbia River

Hanford Site discharges or releases to the Columbia River are negligible compared to earlier times when the single-pass cooling systems were used on plutonium-production reactors at the North end of the Site. Therefore, people are not currently being exposed to contaminants in river water — including water used for drinking supplies — at levels expected to cause adverse health effects. The River and all public water supplies are monitored to ensure public safety. People may be occasionally exposed to residual radioactivity along the shoreline and in river- bottom sediments when the sediments are stirred up through boating, dredging or other activities. However, most of the activity released during earlier reactor operations has decayed away or has been collected for safe disposal. Therefore, the Columbia River does not currently represent a source of significant radiation exposure to members of the public.

Plants and Animals

Sr-90 and chromium levels have been identified as possible concerns regarding the health of young salmon redds in the Columbia River near the 100-Area. Although contaminants have also been found above screening comparison levels in tumbleweed, in yarrow, in mulberries, and in mice, current consumption of contaminated plants and animals through subsistence or other uses (e.g., in traditional medicines) is infrequent. Accordingly, such infrequent consumption is not expected to cause adverse health effects.

Soil

A number of contaminants exceeded levels of possible health concern in Hanford soils in the early 1990s. Two of these, Sr-90 and Ce-137, were found at low levels (near detection limits) in on-site soil in 1998. Contaminants in soil in the early 1990s have either since been removed and replaced with clean soil, or the levels of contaminants were of minimal concern for public exposure. Concerns have been expressed about the potential effects of children playing in contaminated soil, but no children have access to these areas. Standards for Hanford Site cleanup determine the actions being taken for Site-wide removal and disposal of contaminated soils. Future access to soils with residual contamination may be restricted.

1.1.3 Health Implications from Future Exposures

ATSDR identified four potential future exposures that could constitute public health hazards. At present, institutional controls limit public access and therefore no exposure takes place. Future exposures could only occur if institutional controls were removed and members of the general public were allowed to be exposed to residual contaminants at the Site.

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1.2.1 Health Education

Hanford Community Health Project

The Hanford Community Health Project (HCHP) is an outreach and education initiative sponsored by ATSDR since 1999. The project provided educational information and materials about potential health risks to individuals who were exposed as young children to past releases of I-131 between 1944 and 1951. Through its Web-page, www.hanfordhealth.info, and other outreach efforts, the HCHP worked to make information and educational materials about health risks of exposure to I-131 available to people who lived in the Hanford region during the period of the I-131 releases. The Web site makes available materials that have been developed by several government agencies including, the Agency for Toxic Substances and Disease Registry (ATSDR), the Hanford Health Information Network, Centers for Disease Control and Prevention (CDC), and the National Cancer Institute (NCI).

Radioactive I-131 from Fallout

Hanford was not the only source of I-131 releases that affected populations in Washington State. The largest releases of I-131 in the United States were from the Nevada Test Site. People living downwind of Hanford received radiation doses from both the Hanford Site and the Nevada Test Site. The National Cancer Institute (NCI) has developed a Web site, <http://i131.nci.nih.gov/>, to provide information on releases from the Nevada Test Site.

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1.2.4 Actions Planned by the U.S. Department of Energy (DOE)

The Department of Energy will continue clean-up of the Hanford Site in accordance with the Hanford Federal Facility Agreement and Consent Order (May 15, 1989) between DOE, the U.S. Environmental Protection Agency (EPA) and the Washington Department of Ecology (WDOE). The Agreement sets forth the Site remedial action provisions and schedule for compliance with the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) and with the Resource Conservation and Recovery Act (RCRA). These provisions define the treatment, storage, and disposal, and other corrective actions for Site remediation. The Tri-Party Agreement defines and ranks the CERCLA and RCRA cleanup commitments, establishes organizational responsibilities, sets the budget, and sets forth enforceable milestones. Annual Tri-Party goals and accomplishments can be found at the Hanford Web site <http://www.hanford.gov/>

Remediation cleanup levels are set for future use as “industrial,” rather than residential. The following institutional controls are planned to ensure industrial use:

- Placement of written notification of the remedial action in the facility land use master plan,
- DOE prohibition of activities that could interfere with remedial activity,
- EPA review of measures necessary to ensure continued restrictions before property transfer or lease,
- Notification to prospective property recipient before transfer or lease, and
- Provision of written verification to EPA that restrictions are in place.

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Introduction

2.0 Chapter Summary

Site History

On February 9, 1943, the U.S. Undersecretary of War approved a plan to acquire more than 400,000 acres of South-eastern Washington State to the south and west of the Columbia River between today's Vernita Bridge and the Yakima River delta. On February 23, 1943, the U.S. District Court of Washington State, Southern Division, issued an order of possession. The first tract of land was acquired on March 10, 1943. The acquisition of this land, under eminent domain, affected grazing land for 18,000 to 20,000 sheep and 49,000 acres of farmland (Jones, 1985, pp 331–343).

The Hanford Site lies within lands ceded to the U. S. by the Confederated Tribes of the Umatilla Indian Reservation (Umatilla, Cayuse, and Walla Walla) and the Confederated Tribes and Bands of the Yakama Indian Nation. The Wanapums were removed from the Hanford area in 1943 and relocated to an area north of the Site near the current Priest Rapids Dams. Designation of the Hanford Site for the war effort removed it from tribal uses. Native Americans could no longer hunt, fish, or gather herbs in the area (DOE 1997b Section 3). Native Americans want re-access this land in the future.

For approximately 40 years, the 560 (originally 640) square-mile DOE Hanford Site in southeastern Washington was used to produce plutonium for atomic weapons. It also processed spent nuclear fuel and extracted plutonium and uranium for national defense. Because of wartime secrecy, few people knew the purpose of the Hanford Site or knew about its releases of radioactive and nonradioactive materials. These releases contaminated groundwater, the Columbia River, ambient air, and soil (HHIN1997).

Freedom of Information Act Request

In February 1986, the DOE responded to a request under the Freedom of Information Act for detailed information on past Hanford operations. DOE released 19,000 pages of previously classified or unavailable documents. The documents detailed Hanford's operating history and demonstrated its off-site releases of radioactive material, primarily iodine-131 to the atmosphere. The documents revealed that some of the releases of radioactive materials from Hanford were planned as part of scientific study, and that these and other releases had contaminated the Columbia River, ambient air, soil, and groundwater at levels higher than had been previously known by the public (HHIN1997).

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(Tatham et al. 2002). ATSDR is currently conducting a Birth Cohort Study on autoimmune disease and cardiovascular diseases. Since 1999, ATSDR has funded the Hanford Community Health Project to inform and educate regarding potential exposures and health effects, and regarding healthcare options.

Community Health Concerns

The community surrounding the Hanford Site show a high level of interest on issues associated with radiation releases. Before it closed in May 2000, the Hanford Health Information Network responded to information requests from approximately 40,000 households. Downwinders expressed concern about health problems possibly resulting from exposure to both past and current Hanford releases of radiation and toxic chemicals. Concerns regarding past exposures include

- exposure as children,
- substances other than I-131,
- cumulative and synergistic effects,
- incorrect dose estimates,
- inadequate knowledge by the medical community,
- need for a government apology, and
- lack of medical monitoring and health care.

Concerns about current conditions include contaminants in sediment, groundwater contamination, and potential accidents or leaks. Some of the health problems most frequently mentioned include thyroid diseases, cancer, cardiovascular diseases, and autoimmune diseases (including allergies and fibromyalgia).

Hanford Contamination

ATSDR has identified contaminants of concern at or near the Hanford Site by comparing the highest concentrations of all contaminants detected at the site to health-based screening comparison values. Comparison values provide a means of selecting contaminants for further evaluation (and are not used to predict adverse health effects). Certain contaminants found at or near Hanford exceeded their comparison values in soil and sediment, groundwater, surface water, and plants, animals, or their products. A total of 35 contaminants exceeded their comparison values, indicating a need for further investigation of these substances.

2.1 Site History

The DOE Hanford Site in southeastern Washington borders the Columbia River and the City of Richland. About 94% of its 560 square miles is vacant sagebrush

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2.1.2 Tribal Lands

The Hanford Site lies within lands ceded to the United States by the Confederated Tribes of the Umatilla Indian Reservation (Umatilla, Cayuse, and Walla Walla) and the Confederated Tribes and Bands of the Yakama Indian Nation. The Wanapums were removed from the Hanford area in 1943 and relocated to the Priest Dams area north of the Hanford Site. Creation of the Hanford Site eliminated tribal access — Native Americans could no longer hunt, fish, or gather herbs within the boundaries of the Hanford Site (DOE 1997b).

The Hanford Site is now managed by the Department of Energy (DOE). The Site is located about 170 miles southeast of Seattle and 120 miles southwest of Spokane. The Columbia River borders the Site on the north and east. The City of Richland forms the southern border, and the Rattlesnake Hills form the Site's western border. Of the 560 square-mile Hanford Site, much of which contains buildings and open land, about 6% (32 square miles) is in active use (Westinghouse 1995c). The remaining 94% (528 square miles) was acquired as a buffer and security zone. The Hanford Site currently includes portions of Benton, Grant, Franklin, and Adams counties (DOE1990a).

2.1.3 Hanford Mission

In 1943, the Hanford Site was acquired by the U.S. War Department for the Manhattan Project of the Army Corps of Engineers as the location for a highly classified mission: to produce plutonium for atomic weapons as a major component of the nuclear weapons complex. Until recently, the mission of the site was operating reactors for producing plutonium and electricity using the N-Reactor generating station¹, processing spent nuclear fuel, and extracting plutonium and uranium for national defense (DOE, undated).

From the mid-1940s until 1990, the primary mission of the Hanford Site was plutonium production in support of national military defense programs.

¹During 1965–1966, the PUREX facility processed 664 tons of powered thorium oxide fuel targets that had been irradiated in the K reactors for producing uranium-233. In 1970, 820 kilograms of pelletized thorium targets were processed. Shortly afterward, thorium oxide fuel was ruled out for large scale development at Hanford.

Table 2-1. Description of Hanford Areas	
Hanford Area	Description of Area
100-Area	North side of the Site along the banks of the Columbia River. Nine production reactors (B, C, KE, KW, N, D, DR, H, F); K-basins 1301-N Trench N-Springs
200-Area	Near the center of the Site. Contains plutonium and uranium separations and nuclear waste reprocessing and storage areas; PUREX plant REDOX plant Tank Farm Plutonium Finishing Plant
300-Area	Southeast part of the Site, just north of Richland. Fuel assembly fabrication areas
400-Area	Southeast part of the Site, between 200- and 300-Areas. Fast Flux Test Facility (FFTF) Fuels and Materials Examination Facility (FMEF);
700-Area	The Richland Village Contains housing and administrative offices;
1100-Area	North of Richland. Construction, transportation, and supply facilities

Current activities at the Hanford Site focus on environmental management and restoration, including pumping and treating contaminated groundwater, stabilizing underground storage tanks, stabilizing plutonium wastes at the Plutonium Finishing Plant, and treating high-level waste by evaporation. Engineering studies and scientific research and development are also conducted at Hanford in such areas as technology development, environmental management, new materials development, computational systems, and national security (DOE, undated). Additional information about ongoing activities can be found at the DOE Hanford Web site: <http://www.hanford.gov/>

2.1.4 Radioactive Wastes Released to the Environment

Nine plutonium-producing reactors were built and operated on the Hanford Site near the Columbia River. Eight of these reactors (B, C, D, DR, F, H, KE, and KW) used river water for cooling the reactors; the ninth reactor (N) was a closed-

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- elevated radionuclide levels (e.g., strontium-90) in the Columbia River, and were in
- close proximity to the Richland drinking water supply and/or fishing areas.

In the late 1990s, the 1100-Area and parts of the 100-Area were removed from the NPL. The EPA and the State of Washington determined that these areas did not pose a threat to public health or to the environment (EPA1989a, b, c, 1992).

In 1989, ATSDR conducted a site visit to Hanford and released initial public health assessments (PHAs) for the 100-, 200-, 300-, and 1100-Areas. Since that time, additional studies have been conducted and more information has become available, including dose estimates provided by the Hanford Environmental Dose Reconstruction (HEDR) Project.

The Hanford Health Effects Subcommittee, an advisory committee to ATSDR, recommended that the public health assessments for each of the Hanford areas be combined into a single document (i.e., this document) and be made available for public comment. The subcommittee membership considered it more appropriate to address contaminants by pathways, given that contaminants do not stop at the fence line of the various NPL sites. On the contrary, they migrate — often through several NPL sites and into the Columbia River. Also, to enhance credibility of this public health assessment, the subcommittee recommended inclusion of a range of perspectives on public issues.

2.2.1 EPA's Hazard Ranking System

In 1989, because of their “hazard ranking” scores as described below, these four Hanford areas were placed on the NPL. EPA uses a Hazard Ranking System to determine which sites should receive priority attention and, consequently, placement on the NPL (EPA 1990). EPA assigns numerical values to three categories that relate to risk conditions at a site, including:

- The likelihood that a site has released or has the potential to release hazardous substances into the environment.
- The relative amount and toxicity of the waste.
- The number of humans and other life forms in the affected environment.

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- The disposal locations and plumes of contaminated ground water cover approximately 11 square miles.
- An estimated 4.3 billion cubic yards of solid and dilute liquid waste comprised of radioactive, mixed, and hazardous constituents were disposed in cribs, trenches, and burial grounds in the 100-Area.
- The DOE has detected hexavalent chromium and strontium-90 in ground water beneath the area; ground water is not used within 3 miles of the 100-Area, but it is known to seep into the Columbia River in the 100-Area.
- DOE detected strontium-90 in the Columbia River at levels significantly above background.
- Intakes on the Columbia River within 3 miles of the 100-Area supply drinking water to over 3,000 workers in the 100- and 200 Areas.

EPA cited the following reasons for listing the Hanford 200-Area on the NPL (EPA 1989b):

- Over 230 waste disposal locations have been identified in the 200 Area.
- The disposal locations and plumes of contaminated groundwater cover approximately 215 square miles.
- An estimated 1 billion cubic yards of solid and dilute liquid wastes comprised of radioactive, mixed, and hazardous constituents were disposed of in trenches, ditches, and landfills in the 200-Area.
- DOE has detected tritium, iodine-129, uranium, cyanide, and carbon tetrachloride at levels significantly above background in groundwater beneath the area.
- Over 2,500 persons obtain drinking water from wells within 3 miles of the 200-Area.
- Tritium has been detected in Richland's surface water intakes at levels above background.
- Surface water within 3 miles of [where groundwater from] the 200-Area [discharges into the Columbia River and] provides drinking water to 70,000 people and irrigates over 1,000 acres.

2.2.3 Removal of the 1100-Area from the NPL

In 1996, the EPA removed the Hanford 1100-Area from the NPL. The EPA and the State of Washington determined that this area posed no significant threat to public health or to the environment (EPA 1996). This determination was based on the 1100-Area being limited to non-residential uses. On October 1, 1998, the Port of Benton acquired the Hanford 1100-Area as part of the Horn Rapids Industrial Park. On June 10, 1999, ATSDR wrote to the president of the Port of Benton Commission, to advise that the ATSDR public health assessment for the 1100-Area recommended that, "If portions of the 1100-Area are transferred from DOE to the public, the transfer should include sufficient safeguards (e.g., institutional controls should be considered to protect public health) to protect the public from exposure to unremediated sites and to guard against the breaching of barriers created in the course of remediation (e.g., caps)." Because DOE's remediation was to industrial standards, a less restricted use such as residential or agricultural, may not be protective of public health. ATSDR recommended that future development of the former 1100-Area be limited to industrial or commercial use, and never developed for residential or agricultural purposes.

In 1998, parts of the 100-Area to the north (on the other side of the Columbia River) were removed from the NPL. Clean up activities had removed contaminants from certain waste areas to established residential use levels under the Washington State Model Toxic Control Act (EPA 1998b).

2.3 ATSDR Involvement

The ATSDR conducts public health assessments for each of the sites listed or proposed for listing on the above-referenced NPL. ATSDR is a federal public health agency in the U.S. Department of Health and Human Services. In 1980, Congress established ATSDR in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, also known as the Superfund Act. Through public health assessments and health consultations, ATSDR can identify follow-up health actions that should be taken at NPL sites.

2.3.1 Purpose of a Public Health Assessment

Public health assessments (PHAs) evaluate available information to determine whether people have been, are, or will be exposed to hazardous substances and, if so, whether such exposure is harmful and should be stopped or reduced. PHAs also serve as mechanisms for determining whether a need exists for additional public health activities.

2.3.3 Other ATSDR Activities

Infant Mortality and Fetal Death Analysis

The ATSDR Infant Mortality and Fetal Death Analysis, finalized in November 2000, investigated the association between estimated I-131 exposure and infant mortality, fetal death, and preterm birth. The study focused on the years 1940–1952, and included the eight Washington counties in the HEDR project: Adams, Benton, Franklin, Grant, Kittitas, Klickitat, Walla Walla, and Yakima. The study used the HEDR project's 1945 exposure estimates for I-131, and found a 70% higher rate of pre-term birth and a 30% higher rate of infant mortality in the areas with the highest estimates of I-131 exposures compared with areas having the lowest estimates of exposure. No association was found for fetal death. The study was published in the *International Journal of Hygiene and Environmental Health* (Tatham et al. 2002).

Birth Cohort Study

ATSDR is currently conducting a birth cohort study. This study of adverse autoimmune function and cardiovascular disease will 1) explore the potential relationship of radioactive releases, mainly I-131, into the environment and the prevalence of autoimmune diseases; 2) explore the potential relationship of radioactive releases, mainly I-131, into the environment and the prevalence of cardiovascular diseases; and 3) conduct a comparative analysis.

Hanford Community Health Project

In the fall of 1999, ATSDR initiated the Hanford Community Health Project (HCHP). Its purpose was to inform and educate individuals exposed to off-site releases of I-131 about associated health effects and healthcare options. By engaging the exposed population and their healthcare providers in an information-sharing dialogue, the HCHP will help them make informed risk-benefit decisions about their healthcare choices. In 2001, the HCHP conducted a survey of exposed individuals to ascertain their level of knowledge and plan an educational campaign.

Hanford Health Effects Subcommittee

In 1998, ATSDR revised the Hanford Public Health Assessments by including information made available since 1989. The Hanford Health Effects Subcommittee, a federally chartered advisory committee to ATSDR, recommended that the public health assessments for the Hanford 100-, 200-, and 300-Areas be combined into a single document, and that the document be made available for public comment. HHES made this recommendation to combine the NPL-site PHAs into one document so as to logically present exposure pathways which crossed NPL sites and which did not stop at site borders. Also, the consensus of the HHES public health assessment working group was to present a

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- substances in addition to radioiodine (on which research thus far has primarily focused),
- cumulative and synergistic effects,
- the accuracy of dose estimates,
- knowledge of the local health official and the medical community about exposures to Hanford releases, and
- the lack of medical monitoring and health care.

Some have also said that it is important for the federal government to accept responsibility for secretly exposing people to Hanford releases, apologize for its errors, and acknowledge peoples' health problems.

People have also expressed concern about current and potential future involuntary exposures to Hanford releases, including contaminants in Columbia River sediments, possible future accidents or leaks, and groundwater contamination.

The most common health problems reported include thyroid disease, cancer, allergies, cardiovascular disease, and auto-immune diseases. Other health problems have also been suggested as possibly associated with exposure to radiation and to chemicals from Hanford.

2.4.1 Sources Used to Identify Community Concerns

The information in this section is summarized from several sources, including

A survey by the ATSDR Hanford Community Health Project (HCHP)

The HCHP survey was conducted to learn more about the Hanford community's knowledge of Hanford I-131 releases, about health care utilization, access to care issues related to thyroid disease, health education needs, and any interest in receiving a free medical examination. Interviews were completed with 501 survey participants who were born between 1940 and 1951 in Adams, Benton, and Franklin counties. Notable findings from the survey include

- 54% reported one or more of the seven thyroid dysfunction-related symptoms.
- 18% reported that they had been diagnosed with a thyroid condition.
- 54% felt poorly informed about health problems related to the thyroid.
- 84% would use a free thyroid examination service.

Information published by the Hanford Health Information Network (HHIN) and the Hanford Health Information Archives (HHIA).

The HHIN, which closed in May 2000, was a collaboration among three states (Oregon, Idaho, and Washington) and nine Indian Nations to provide educational

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Wash., 1998; cited by Merwin, et al., “Application of the Supreme Court’s *Daubert* Criteria in Radiation Litigation,” *Health Phys.* 81(6):670-677; 2001).

Northwest Radiation Health Alliance (NWRHA) Survey

The NWRHA survey was conducted by the Northwest Radiation Health Alliance. The Alliance includes Hanford Downwinders, concerned citizens, and physicians and scientists who are members of the Oregon chapter of Physicians for Social Responsibility (PSR). (NWRHA can be contacted through the PSR-Portland, Oregon office listed later in this section.) The NWRHA survey, which relied primarily on Downwinders’ own networks for collecting data, sought to identify suspected patterns of disease, especially those possibly related to radioactive environmental contamination from Hanford.

2.4.2 General Health Concerns

Many people have expressed concerns about whether their current health problems could be associated with Hanford’s releases of radioactive materials and hazardous chemicals to the environment, and also about possible future health problems from exposure to Hanford releases. Some people have also expressed concern about their own or their family’s health, while others were concerned about their children or their neighbors’ children.

Downwinders were concerned about health problems possibly resulting from exposure to both past and current releases of radiation and toxic chemicals from Hanford. Contrary views were expressed by people living in communities near Hanford who believed that no association exists between health problems and Hanford radiation and chemical releases.

2.4.3 Past Releases from Hanford

People have expressed concern about the possible health effects associated with exposure to past releases of radioactive materials and hazardous chemicals through

- breathing contaminated air,
- drinking contaminated water or milk,
- eating contaminated local foods (e.g., vegetables, meat, fish), including food irrigated with contaminated water or grown in/raised on contaminated soil, and
- swimming or boating in the Columbia River.

Other community health concerns regarding past releases from Hanford include

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Some individuals who might have had hypothyroidism may not have been identified. They may have suffered depression or experienced a variety of other illnesses ranging from musculoskeletal disorders to gastrointestinal and reproductive dysfunction which may have been related to hypothyroidism.

Need for government apology

Some have said that the government should accept responsibility for secretly exposing people to radioactive and chemical releases from Hanford, should apologize for its past errors, and should acknowledge the grief and despair suffered.

Lack of medical monitoring and health care

Many people who believed that they received the highest radiation exposures from Hanford emissions are concerned that funding has not been provided for medical monitoring, and that outreach and education only (without medical testing) is insufficient. In addition, those living in rural areas have expressed a need for vans to come to their areas to perform medical monitoring rather than being required to travel into the cities to receive this service. Others expressed concern that former residents of the Hanford areas who now live outside the Pacific Northwest will need proper screening from trained physicians and other health care professionals no matter where they live.

Those with no health concerns

Others who live in the Hanford area believe no association exists between health problems and Hanford radiation and chemical releases; they believe exposure occurred at doses too low to cause adverse health effects. Some who express these views have lived in the Hanford area for many years, with no health problems themselves or to their families. Some in this group believe that continued government public health studies and medical monitoring associated with Hanford only serve to raise public anxiety and take resources away from other important public health concerns.

2.4.4 Current and Potential Future Releases from Hanford

Several concerns are voiced regarding current or potential future releases of radiation and hazardous chemicals from Hanford, including

Contaminants in sediments

Some people are concerned that sediments in the Columbia River which store contaminants may release these contaminants downriver (e.g., during flooding or if dredging occurred). Some of the radioactive and hazardous chemicals of concern include arsenic, cesium, manganese, and strontium, especially in

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generations, resulting in health problems in the children and grandchildren of individuals who were exposed to radiation and to other chemicals from Hanford.

People have raised the issue of the psychological and emotional effects of involuntarily exposure or potential exposure to Hanford releases. People have reported depression or suicide in their families or communities that they believe may be associated with Hanford emissions and the rejection or ridicule they have encountered by government agencies or by physicians. In some cases, people believed that their symptoms were a result of physical illnesses, but that the symptoms had been incorrectly attributed to psychological or emotional problems. For example, one of the commonly listed symptoms of thyroid disease (hypothyroidism) is clinical depression.

Table 2-3 summarizes some of the illnesses of concern to people who currently live or previously resided in communities in the vicinity or downwind of the Hanford site, and the number of people who reported having a specific health concern. The information in Table 2-3 came from three surveys: the “R-11 Survey,” the Northwest Radiation Health Alliance (NWRHA) survey, and an ATSDR survey of community concerns; these surveys are described in the beginning of this section.

Table 2-3. Three Surveys of Community Health Concerns			
Health Problem	R-11 Survey*	NWRHA Survey†	ATSDR HCHP Survey
Thyroid disease	6%	56%	18%
Thyroid cancer	0.3%	4%	0%
Other cancers	2%	42%	NA
Immune system	NA	50%	NA
Reproductive and genetic effects	NA	3%	NA
Nervous system	NA	15%	NA
Cardiovascular system	NA	18%	NA
Gastrointestinal system	NA	11%	NA
Psychological/behavioral	NA	9%	NA

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[Hanford Watch](#)

[Heart of America Northwest](#)--Contact: Heart of America NW, Suite 208, Seattle, WA 98101, (206) 382-1014 (office), e-mail: office@heartofamericanorthwest.org.

[Northwest Environmental Advocates \(NWEA\)](#)--Contact: [Eugene Rosolie](#), Northwest Environmental Advocates, 133 SW 2nd Ave., Ste 302, Portland, OR 97204, (503) 295-0490, e-mail: nwea@igc.apc.org

[Sierra Club Cascade Chapter](#) 8511- 15th Ave. NE, #201, Seattle, WA 98115-3101
Phone: (206) 523-2147, e-mail: cascade.chapter@sierraclub.org.

[Washington Physicians for Social Responsibility \(WPSR\)](#)--Contact: [Martin Fleck](#), WPSR, 4534-12th Ave. NE, Seattle, WA 98105, (206) 547-2630, e-mail: psrwase@igc.apc.org

2.5 Known Contaminants

Contaminants at the Hanford Site include various radioactive materials and non-radioactive chemical wastes. This section summarizes the information that is presently available on the current levels of radioactive and chemical contaminants for the three priority areas at the Hanford Site. The section also explains how ATSDR uses screening values to help determine public health risks from contaminants associated with the Site.

The information provided in this section was obtained from several sources, including the Department of Energy, the City of Richland, and the Washington State Department of Health. DOE provided Hanford Site data and some of the Columbia River data. The Environmental Protection Agency (EPA), the Washington State Department of Ecology, and by the Washington State Department of Health reviewed this information to ensure that it is both accurate and complete.

The highest concentrations of on-site contaminants identified in soil, sediment, water, and plants, animals, or their products in the 100-, 200-, and 300-Areas are shown in Tables 4A to 4D (DOE 1992a, b, 1993a, b, c, 1995b, 1997a; WADOH 1993; Westinghouse 1987, 1992b, 1995a, c). Abbreviations used in these tables are identified in the table footnotes and defined in Appendix A, Glossary. The tables also list current ATSDR “screening comparison values” for each contaminant in each environmental medium.

2.5.1 Comparison Values

ATSDR chose to adopt a practice similar to that of the EPA’s Reference Dose (RfD) and Reference Concentration (RfC) for deriving substance-specific health guidance levels for non-neoplastic endpoints. An MRL is an estimate of the daily

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contaminant of concern. It is important to note that regardless of a contaminant's concentration, a public health hazard exists only if people are exposed to harmful levels of contaminated media. Health effects associated with exposure to specific contaminants of concern are discussed in Chapter 8, in the section on *Toxicological Evaluation*.

2.5.2 How Screening Comparison Values are Developed

Comparison values contain both 1) a toxicity or cancer component and 2) an exposure component. Chronic exposure is most often evaluated, although acute exposure can be evaluated if more appropriate to site-specific circumstances. ATSDR selects comparison values that are calculated using very conservative exposure assumptions to protect the most sensitive segment of the population.

Examples of comparison values used for the Hanford site include: Cancer Risk Evaluation Guides (CREGs), Reference dose Media Evaluation Guides (RMEGs), Environmental Media Evaluation Guides (EMEGs), and Maximum Contaminant Levels (MCLs). The CREG represents a concentration at which no more than one excess cancer case could develop in a million people exposed over a lifetime. The RMEG and EMEG represent the concentrations at which daily exposure for a lifetime is unlikely to result in adverse noncancerous effects. The MCL represents a concentration in drinking water that is unlikely to be associated with adverse (non-cancer) effects over a lifetime at an assumed water intake rate (e.g., 2 liters per day for an adult).

ATSDR uses the no-observed-adverse-effect-level/uncertainty factor (NOAEL/UF) approach to derive MRLs for hazardous substances. They are set below levels which, based on current information, might cause adverse health effects in the people most sensitive to such substance-induced effects. MRLs are derived for acute (1–14 days), intermediate (>14–364 days), and chronic (365 days and longer) exposure durations, and for the oral and inhalation routes of exposure. Currently MRLs for the dermal route of exposure are not derived because ATSDR has not yet identified a method suitable for this route of exposure. MRLs are generally based on the most sensitive substance-induced end point considered to be of relevance to humans. ATSDR does not use serious health effects (e.g., irreparable damage to the liver or kidneys, or birth defects) as a basis for establishing MRLs. *Again, exposure to a level above the MRL does not mean that adverse health effects will occur.*

MRLs are intended to serve as a screening tool to help public health professionals decide where to look more closely. They may also be viewed as a mechanism to identify those hazardous waste sites that are not expected to cause adverse health

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databases, such as IARC and IRIS) indicate that a change in a comparison value is appropriate. (The EPA IRIS database is updated monthly.)

2.5.4 On-Site Contaminants that Exceeded Screening Comparison Values

A total of 31 substances detected at Hanford exceeded screening comparison values established for these chemicals, as indicated in Tables 4A-4D. As discussed below, comparison values were exceeded in soil and sediment, groundwater, and surface water, as well as in plants, animals, or their products. Some substances exceeded comparison values in more than one environmental medium (in some cases in two or three media).

Soil and Sediment

Of the 35 substances found in soil and sediment onsite at Hanford, 13 were above the established comparison values, including: americium-241, cesium-137, cobalt-60, lead, neptunium-237, plutonium-239 and -240, polychlorinated biphenyls, silver, strontium-90, uranium-234, -235, and -238.

Groundwater

Of the 33 substances found in groundwater onsite at Hanford, 23 were found to be at or above the comparison values, including: antimony, arsenic, carbon-14, carbon tetrachloride, cesium-137, chloroform, cobalt-60, copper, cyanide, europium-154, fluoride, iodine-129, lead, nickel, nitrate, strontium-90, technetium-99, trichloroethylene, tritium, uranium-234 and -238, vanadium, and zinc.

Surface Water

Of the 14 substances found in surface water on site, two (lead and nickel) were found to be above the comparison values.

Plants, Animals, or their Products

Fifteen contaminants were found in fourteen types of plants, animals, or their products. In eight cases, the contaminants were found to be above the comparison values.

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Sources of Contamination

3.0 Chapter Summary

DOE produced plutonium at the Hanford Site in Eastern Washington State from the 1944 until the late 1980s when the need for plutonium diminished. The Hanford Site comprised fuel fabrication, nuclear production reactors, irradiated fuel reprocessing, and waste disposal activities. The Hanford Site also received radioactive materials from other Department of Energy sites. As the result of incomplete containment, the Site was contaminated by both radioactive materials and chemicals. Released materials have impacted the ,the local soil, groundwater, water, and sediments in the nearby Columbia River. Airborne releases from the Hanford Site have mainly affected residents of Washington, Idaho, and Montana. Until 1986, the DOE did not release details about Hanford operations because they were classified for military and security reasons. Prompted by public interest groups and a Freedom of Information request, DOE in 1986 released thousands of previously classified or unavailable documents. These documents showed that substantial amounts of radioactive material had been released to the environment during prior years of Site operations.

Consequently, the Department of Energy initiated a dose reconstruction project which was later managed by the Centers for Disease Control and Prevention (CDC). In April 1994, CDC released the first estimated doses. Since 1994, CDC researchers have done additional work to more fully characterize public exposures to short-lived radionuclides and to improve on base assumptions used in the Columbia River dose reconstruction model.

Environmental Monitoring

Prior to 1987, DOE and its contractors conducted extensive environmental monitoring of Hanford soils, groundwater, subsurface waters, plant life, animal life, and airborne emissions from its facilities and operations for both radionuclides and chemicals. Since 1987, monitoring programs have expanded. Annual environmental reports, available for public review, document both the extent of Hanford Site contamination and the results of ongoing monitoring efforts. Even though the EPA and state agencies oversee the monitoring program, some public interest groups question the results of the DOE monitoring program.

Four contaminated areas at Hanford (the 100-Area, 200-Area, 300-Area and 1100-Area) are listed on EPA's National Priorities List — a list of the country's most contaminated hazardous waste sites. ATSDR evaluated the 1100-Area in a separate public health assessment (ATSDR 1995a).

Sources of Contamination

The 200-Area annually discharges almost 100 million gallons of process wastewater, including sanitary sewage, chemical wastes, and laundry wastes. The effluents include measureable levels of Cs-137, Ru-106, Sr-90, tritium, and various uranium radioisotopes (Westinghouse 1992b).

The 200-Area includes several landfills that accept radioactive wastes. Records show that the 200-Area received about 883,000 cubic feet of solid radioactive wastes in a typical year (Anderson and Hagel 1992).

300-Area

The 300-Area was used to fabricate uranium fuel elements for Hanford's production reactors. This process generated uranium-contaminated waste solvents and acids (nitric and sulfuric). Disposal of these wastes has resulted in soil and groundwater contamination. Contaminants in the 300-Area groundwater include arsenic, cadmium, cobalt-60, chromium, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and uranium isotopes. These contaminants are migrating to the Columbia River.

Although the Fast Flux Test Facility is in the 400-Area, it is included in Operable Unit 300. The Fast Flux Test Facility operated for about 10 years as a test reactor for breeder reactor components. The FFTF is currently being decommissioned and dismantled.

3.1 Overview of Contamination and Environmental Monitoring

The Hanford Site is located in southeastern Washington State, about 170 miles southeast of Seattle and 120 miles southwest of Spokane. The Columbia River borders the Hanford Site on the north and east. The City of Richland forms the south border, and the Rattlesnake Hills form the west border of the Site. The total land area of the Hanford Site is presently about 560 square miles. Of this area, about 6 percent (32 square miles) is in active use (Westinghouse 1995c). The remaining 94 percent (528 square miles) is barren, sagebrush-covered desert.

Operational Areas

The Hanford Site is divided into operational areas, including: the 100, 200, 300, 400, 700, 1100, and 300 Areas (see Figure 1). In 1989, EPA added the 100, 200, 300, and 1100 Areas to the National Priorities List (NPL). In 1999, the 1100-Area was removed from the NPL because remediation activities had been completed and the EPA and State of Washington determined that the 1100-Area posed no significant threat to public health or the environment if it continued to be used as an industrial, not residential, area (EPA 1996).

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effects to the thyroid from that exposure. The panel's recommendations evolved into what are known today as the Hanford Environmental Dose Reconstruction Project (HEDR) and the Hanford Thyroid Disease Study (HTDS).

Hanford Environmental Dose Reconstruction Project (HEDR)

The purpose of the HEDR dose reconstruction project was to develop environmental pathway models for radioactive materials and to calculate estimated doses received by "representative" persons who lived in the surrounding areas and along the Columbia River during Hanford production years. CDC first became involved in the HEDR Project in 1992, when responsibility for the project was transferred from the DOE to the Department of Health and Human Services.

CDC released the first estimated dose results in April 1994. Since then, CDC researchers have been using the mathematical computer model developed during the HEDR project to address remaining community and scientific concerns. The additional work focused on 1) exposures to radioactive particles and short-lived radionuclides, and (2) the doses people may have received from Hanford's radioactive-material releases to the Columbia River.

Hanford Thyroid Disease Study (HTDS)

In 1988, Congress mandated the CDC to evaluate the thyroid morbidity rates among persons who lived near the Hanford Nuclear Site between 1944 and 1957. CDC contracted with the Fred Hutchinson Cancer Research Center in Seattle to conduct the HTDS research. The HTDS thyroid disease study evaluated whether the rates of incidence of thyroid disease were related to different levels of estimated I-131 radiation dose (TSP 1994).

Because health effects resulting from exposure to radioactive iodine would most likely have affected those who were children at the time of exposure, the study focused on those who were children during the time of highest releases. Researchers studies all types of thyroid disease, as well as a disease of the parathyroid glands called hyperparathyroidism.

The study results did not show a link between the estimated I-131 dose and the amount of thyroid disease in the study population. The findings mean that if there is an increased risk of thyroid disease from exposure to Hanford's iodine-131, it is probably too small to observe using the epidemiological methods available. Although no relationship was found, the study does not prove that a link between I-131 and thyroid disease does not exist.

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characteristics. These groups of locations are known as “operable units”. Each of the 1,605 waste locations and the four groundwater contamination plumes were assigned to one of the 78 designated operable units. In 1989, the 78 operable units were further combined into 17 major groups (DOE 1995c).

Also in 1989, DOE organized “tiger teams” to assess environment, health, and safety at each of its sites in the United States. A tiger team audited the Hanford Site during May to July 1990 (DOE 1990c). Some of the findings of the audit concerned the storage of radioactive wastes in the underground tanks, low-level waste sites, and transuranic waste sites. The audit team found deficiencies in the containment of wastes and was concerned about the contamination of groundwater. The audit team also found deficiencies in several environmental monitoring programs (DOE 1990c).

3.2 100-Area

The 100-Area includes nine plutonium-producing reactors along the shoreline of the Columbia River in the northern part of the Hanford Site. Eight of these reactors were constructed between 1943 and 1955. The ninth (N-Reactor) was constructed during the early 1960s as a dual-purpose reactor (for producing both plutonium for nuclear weapons and steam for electrical power generation). DOE no longer operates the reactors in the 100-Area, which have been decommissioned and are being dismantled or cocooned. The first reactor at Hanford, the B reactor, was listed on the National Register of Historic Places and is now a museum. The B reactor is occasionally open for public tours.

While in operation, the 100-Area reactors contaminated the local environment in the following ways:

River water

Columbia River water was used to cool eight of the nine reactors in operation from 1944–1971. The water was pumped through the reactors, where it came in contact with fuel elements. Some amounts of radioactive material contaminated the cooling water. The cooling water was then held in ponds for decay of short-lived contaminants, and was later released back into the Columbia River. Some amounts of longer-lived contaminants were carried into the Columbia River.

Groundwater

The groundwater under the 100-Area is contaminated by materials that seeped out from retention basins and from spent fuel stored in the K-basins. Groundwater contaminants, including nitrate, chromium, benzene, tritium, and strontium, are seeping into the Columbia River.

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The main part of the Hanford radioactive waste inventory consists of about 2,300 tons of irradiated N-Reactor fuel stored in the 105-K East and 105-K West Fuel Storage Basins. The fuel storage basins (K-Basins) are located in the reactor buildings to the left of the circular structures, shown in Figure 2, 100-K Area Aerial Photograph (DOE 1995c).

The unprocessed spent nuclear fuels in storage at the Hanford Site constitute about 80% of the total inventory of defense reactor spent fuels currently stored throughout the DOE complex.

The K-Basins are a potential source of strontium-90, technetium-99, and tritium contamination. As contamination migrates from the basins, it enters the groundwater and then seeps into the Columbia River (DOE 1995c). Sediment samples at the N-Springs had measurably high levels of strontium-90 (Sr-90) (DOE 1997a). Radioactivity has also been measured in groundwater in the 100-Area. The K-Basin remediation and cleanup, with complete removal of radioactivity and associated contamination are scheduled for completion by the year 2009.

Contaminants that leaked from the single-shell, high-level waste tanks in the 200-Area have also reached and contributed to contamination of the 100-Area groundwater. Some of these contaminants include benzene, chromium, nitrate, tritium (H-3), and Sr-90. A waste vitrification plant is being constructed for permanent storage of these wastes.

3.3 200-Area

When the Hanford Site was first developed, the 200-Area was established to separate radioactive materials — including uranium and plutonium — from reactor fuels and to manage liquids, solids, and used equipment waste. On a plateau in the approximate center of the Site, the 200-Area consists of the 200-West and 200-East Areas. The individual components of 200-Area are described in Appendix C and shown in Figure 3.

Fuel assemblies were transported to the 200-Area chemical plants, dissolved in acid, and subjected to solvent extraction processes to separate out plutonium, uranium, and waste materials. The recovered plutonium was converted into metal for nuclear weapons. The uranium was recovered for recycling, and mixed

The major source of 200-Area contamination is radioactive and chemical waste from reactor fuel reprocessing.

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Groundwater

Groundwater in the 200-Area is contaminated and groundwater flow is towards the Columbia River. On-site groundwater exceeds EPA drinking water standards for chromium, iron, manganese, total organic carbon, and tritium.

3.3.1 Past Radioiodine Air Releases from the 200-Area

Fuel processing at the 200-Area facilities routinely discharged radioactive materials into the atmosphere. Some of these releases were accidental, but others were planned. It is estimated that the time period between 1944 to 1947 accounts for 90% of the iodine-131 released. Current estimates are that from 1944 to 1947, a total of 740,000 curies of I-131 were released (Heeb 1992).

In 1949, a classified test was conducted to determine how radioactive materials were transported through the air (Technical Steering Panel, 1992). During this test, known as “the Green Run,” about 7,800 Ci of I-131 and 20,000 Ci of xenon-133 were released to the atmosphere.

3.3.2 Air Releases from the 200-Area

The 200-Area had 69 potential atmospheric discharge points (or stacks) in 1990 for radioactive material. All stacks were equipped with high-efficiency filters to remove particles larger than 0.3 microns (Westinghouse 1992a). Measured air releases during 1990 included 5,700 Ci of krypton-85 (an inert gas) and less than one pCi of U-235.

Under the Clean Air Act, Department of Energy operations may not expose members of the public to a radiation dose greater than 10 millirem per year (40 CFR 61 [1989]). The maximum annual dose to a member of the public since 1990 from Hanford Site airborne releases of radioactive materials has been consistently less than 0.1% of the applicable federal limits.

Table 3-1 shows airborne releases of radionuclides from 200-Area facilities in 1990. Air emissions sampling in 1991 (Table 3-2) showed that tritium (H-3) was the most prevalent of the radionuclides released to the atmosphere. Others included Cs-137 and I-129 (Westinghouse 1992b). Table 3-3 shows radionuclide emissions for 1994.

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Table 3-2. 1991 Air Releases from 200-East Area		
Radionuclide	Activity* (pCi)	Average Concentration† (pCi/L)
H-3	1.4 x 10 ⁹	0.0010
Sr-90	1.1 x 10 ⁶	8.1 x 10 ⁻⁷
Ru-106	3.85 x 10 ⁶	2.9 x 10 ⁻⁶
I-129	6.7 x 10 ⁷	4.8 x 10 ⁻⁵
I-131	ND‡	<2.5 x 10 ⁻⁷
Cs-137	4.1 x 10 ⁶	3.01 x 10 ⁻⁶
Pu-239/240	5.2 x 10 ⁴	3.85 x 10 ⁻⁸
Pu-241	4.1 x 10 ⁵	3.01 x 10 ⁻⁷
Am-241	4.8 x 10 ⁵	3.56 x 10 ⁻⁷

Data from reference (Westinghouse 1992b).
 * Values are in picocuries (pCi).
 † Average concentration released from the 291-A-1 stack in the 200 East Area. Values are in pCi per liter.
 ‡ Not detected.

Table 3-3. 1994 Air Releases from 200-East Area		
Radionuclide	Activity* (pCi)	Average Concentration† (pCi/L)
Sr-90	4.8 x 10 ⁴	3.15 x 10 ⁻⁸
I-129	1.78 x 10 ⁷	1.19 x 10 ⁻⁵
Cs-137	8.1 x 10 ⁴	5.33 x 10 ⁻⁸
Pu-239/240	3.85 x 10 ⁴	2.60 x 10 ⁻⁸
Pu-241	2.5 x 10 ⁵	1.6 x 10 ⁻⁷
Am-241	1.5 x 10 ⁴	1.0 x 10 ⁻⁸

Data from reference (Westinghouse 1995b).
 * Values are in picocuries (pCi).
 † Average concentration released from the 291-A-1 stack in the 200 East Area. Values are in pCi per liter.

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20,000 pounds of nonradioactive salts and chemical sludges (Kaiser 1995). The last fuel reprocessing discharge to the tanks occurred in 1990. The estimated total volume of wastes in the tanks is approximately 37 million gallons of liquid, sludge, and salt cake.

In April 1996, DOE and the Washington State Department of Ecology released an environmental impact statement (EIS). The EIS described nine alternatives for managing the high-level radioactive wastes stored tanks and the more than 1,500 strontium-90 and cesium-137 capsules stored separate from the tank waste. The EIS identified a preferred method for remediating the tank waste and capsules (DOE 1996d). The strontium-90 and cesium-137 capsules have potential commercial value as radiation sources. The plan for stabilizing the tank waste was contained in a 1997 Record of Decision published in the Federal Register, Volume 62, page 8693 (DOE 1997c).

DOE has chemically neutralized and stabilized all of the single-shell tanks, and work continues on pumping radioactive waste from the single-shell tanks to double-shell tanks. The General Accounting Office has conducted audits of spending on waste storage, tank maintenance, and restoration programs (GAO 1994).

Explosion Hazard

Potential explosions from hydrogen gas buildup in several tanks was a hazard, but systems have been added to remove excess heat and hydrogen that accumulate in the tanks. DOE has determined that organic substances in the tanks are of insufficient amounts and concentrations to support explosive chemical reactions. In December 1998, 18 tanks were removed from this category (DOE 1998). Of the 25 tanks in the hydrogen-concern category, the 241-SY-101 tank was of foremost concern for hydrogen build-up. DOE installed a mixing pump to increase the release rate of hydrogen from this tank. Six double-shell tanks are of concern for hydrogen build-up (PNNL 1995).

Monitoring of 54 tanks was conducted for: ferrocyanide, flammable gas, high-heat, organic-containing wastes, and radionuclides. Concerns include radiological contaminants that have leaked from the 200-Area storage tanks, including an estimated 20,000 Ci of radioactive cesium (Anderson 1990).

Tanks containing ferrocyanide can react with nitrate or nitrite under conditions of elevated temperature, and an explosion can result. Of the initial 24 tanks being monitored, six have been downgraded because analyses have verified that the

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described in Appendix C. The PUREX Plant was also used for the THOREX operation in 1966 and again in 1971. THOREX recovered U-233 with thorium.

Separated plutonium from reprocessing was converted into metal at the Plutonium Finishing Plant in the 200-West Area. This facility is no longer used to process plutonium. The area is still used to store plutonium.

A chemical explosion occurred in this area in 1997 in one of the nonradioactive chemical storage tanks. A 400-gallon tank containing hydroxylamine nitrate and nitric acid exploded and eight workers were evaluated for potential radioactive contamination. No workers were injured (Tri-City Herald 1997). A follow-up investigation team determined that the accident did not release radioactive material into the environment or result in the contamination of any of the workers involved (DOE 1997d).

3.3.5 200-Area Liquid Effluents

Effluent discharges in the 200-Area included sanitary sewage, chemical wastes, and laundry wastes. In 1987, the 200-Area discharged about 39,600 lbs of nitrates and about 24,200 lbs of total organic carbon. In 1991, almost 7,700 lbs of nitrates and about 31,460 lbs of total organic carbon were discharged. In 1990, unless radiation monitors reported conditions that might exceed discharge permit levels, liquid effluents from the 200-Area were discharged to the ground by way of unlined subsurface engineered structures such as cribs, ditches, French drains, and reverse wells. Definitions and descriptions of engineered structures are provided in Appendix D.

In 1991, the 200-West Area discharged 67 million gallons of process wastewater and 13.5 million gallons of sanitary sewage to the soils. The 200-East Area discharged 23 million gallons of wastewater and sewage (Westinghouse 1992b).

Radionuclides released in 1990 included Cs-137, Ru-106, Sr-90, tritium, and various uranium radioisotopes. With 20 discharge points reported, the average liquid discharge was 291 million gallons. The average activity of individual radionuclides exceeded the maximum concentration levels (MCLs) for drinking water. This discharge water did not, however, serve as a supply of drinking water in the 200-Area or in any areas outside the Hanford Site that obtain drinking water from the Columbia River (Westinghouse 1992b).

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Table 3-4. Radionuclide Inventory in 200-BP-1 Cribs *		
Radionuclide	April 1, 1986 (curies)	April 1, 1995 (curies)
H-3	2,500	1,505
Sr-90	6,054	4,892
Cs-137	2,092	1,700
Co-60	0.449	0.14
Ru-106	0.000090	<0.000001
U-238	0.18	Not substantially reduced [†]
Pu-239	4.1	Not substantially reduced [†]
Pu-240	1.09	Not substantially reduced [†]

Data from reference (DOE 1990b).

* The 1995 values are based on a physical half-life; no adjustment is made for washout or weathering.

† Not substantially decayed: the half-life of these radionuclides is greater than 5,000 years and the change in total decay is less than 0.1% of the initial 1986 concentration in the cribs.

Table 3-5. Chemicals Discharged in 200-BP-1 Cribs in 1987	
Chemical	amount (kg)
Sodium	2,650,500
Nitrate	6,501,500
Sulfate	469,000
Phosphate	332,000
Ferrocyanide	18,900
Ammonium nitrate	10,000
Ammonium carbonate	21,000

Data from reference (DOE, 1990b).

Sources of Contamination

The 216-S-10 pond and ditch received liquid wastes from the S-Plant in the 200-West Area, creating a perched water zone. The last discharge occurred in October 1991 and consisted of 50 million gallons and the perched zone is diminishing. Wastes included aluminum nitrate, sodium nitrate, sodium phosphate, sodium hydroxide, sodium fluoride, sodium chloride, and potassium dichromate, as well as associated low-level radioactive wastes. By mid-1994, the concentration of uranium¹ was at or less than the maximum concentration limit of 20 micrograms per liter ($\mu\text{g/L}$). Volatile organics, tritium, and technetium-99 have not been detected in groundwater beneath the 200-West Area (DOE 1995b).

The 216-U-12 Crib south of the U-Plant in the 200 West Area received wastes from 1960–1988. The average annual volume of liquid discharges was 35 million gallons. Radioactive wastes contained uranium, mixed fission products², and plutonium. Nonradioactive contaminants included nitric acid, CCl_4 , chromates, and iron. Contamination was detected to depths of 140 feet in 1983. By 1993, the depth of contamination decreased to 64.5 feet because of crib inactivity. Detectable technetium-99, tritium, and other fission products are well below EPA drinking water standards. From 1991 to 1994, the nitrate concentrations in monitoring wells near the crib 216-U-12 Crib ranged from about 100,000 to 500,000 ppb. Carbon tetrachloride exceeded the EPA's drinking water standard (DOE 1995b).

3.3.7 200-Area Solid Waste Disposal

The 200-Area was designated as the central storage location for solid wastes from the entire Hanford Site. It received mixed wastes, transuranic wastes, contaminated materials, and other types of wastes. These solid wastes contained about 1 million curies (Ci) of uranium, plutonium, strontium-90, cesium-137, ruthenium-106, and other radionuclides. These wastes were placed in the many burial grounds in the 200-East and 200-West areas (Anderson and Hagel 1992).

Records show that the 200-Area received about 883,000 cubic feet of solid radioactive wastes from other sites in a typical year (1992).

¹Natural uranium consists of three radioisotopes: uranium-234 (U-234), uranium-235 (U-235), and uranium-238 (U-238).

²Mixed fission products consist of many different radioisotopes produced in uranium fission. The most prominent fission products include isotopes of cesium, strontium, and iodine.

Sources of Contamination

disposal trenches were closed when migration of uranium from the soil to area groundwater was observed.

Groundwater

Contaminants in the 300-Area groundwater include arsenic, cadmium, cobalt-60, chromium, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and uranium isotopes. Contaminated groundwater from other areas of the Hanford site has contributed nitrate, trichloroethylene, and tritium contamination to groundwater under the 300-Area.

River water

The 300-Area process ponds, retention basins, and trenches are 300–1,000 feet from the Columbia River. Wastes delivered through the 300-Area sewers to these disposal areas included isotopes of cesium, cobalt, plutonium, and uranium, as well as copper and chromium. These contaminants are migrating to the groundwater and then into the Columbia River.

Air

Between 1945–1962, some solid wastes were burned above ground.

3.4.1 300-Area Operable Units

The 300-Area was consolidated into three operable units (OUs): 300-FF-1, 300-FF-2, and 300-FF-5 (DOE 1995d). The boundaries of the operable units are shown in Figure 5. Waste sites and facilities are shown in Figure 6.

Operable Unit 300-FF-1 includes the major liquid (as well as several solid) waste disposal units of the 300-Area. It includes soil contaminated by waste disposal (DOE, 1995d). Operable Unit 300-FF-5 includes contaminated soil below the water table, groundwater, and Columbia River water and sediment contaminants from the 300-Area (DOE 1995d [p. 1-1]).

Operable Unit 300-FF-2 includes identified waste sources in the 300-Area outside of 300-FF-1 and groundwater contaminant plumes outside of 300-FF-5 (DOE 1994, [p. 2-1]). In addition, Operable Unit 300-FF-2 includes the Fast Flux Test Facility (FFTF) and waste sites in the 600-Area (DOE 1994 [p. 2-1, 2-2]).

3.4.2 Fast Flux Test Facility (FFTF)

Although the Fast Flux Test Facility is in the 400-Area, it is included in Operable Unit 300-FF-2. The FFTF is DOE's relatively new 400-megawatt thermal sodium-cooled nuclear test reactor, located about 15 miles north of the City of

Sources of Contamination

(i.e., DOE, EPA, and Washington State Department of Ecology) signed an agreement defining the deactivation milestones currently underway.

3.4.3 300-Area Contamination Sources

Most of the contamination in the 300-Area occupies about 2.5 square miles. The Columbia River forms the east border of the site, and northern part of the City of Richland lies about 1.5 miles to the south (DOE 1994 [p. 1F-2]; DOE 1995d [p. 2-1]). The 300-Area elevation is 390 feet above mean sea level and about 40 feet above the Columbia River (DOE 1995f [p. 2-8]). Waste sites and facilities in the 300-Area are shown in Figure 6.

Environmental contamination resulted from the disposal of both liquid and solid wastes, as well as from unplanned releases of materials during production, transportation between facilities, and waste management. Liquid wastes were fed from generating facilities through sewer lines into holding tanks for specialized disposal or into trenches and ponds for evaporation and seepage into the soil. Solid wastes were buried in pits and trenches. From 1945–1962, some solid wastes were burned aboveground.

Sources of groundwater contamination include plumes from other waste sites, such as the nitrate and trichloroethylene plumes from the 1100-Area, and the tritium and nitrate plumes from the 200-Area.

Operable Unit 300-FF-2 contains a sanitary sewer, a process sewer, a former radioactive liquid waste sewer, a new active radioactive liquid waste sewer, and a retention process sewer. The currently inactive process and retired waste sewers may have leaked at some of the joints (DOE 1992b [p. 3-2]; DOE 1994 [p. 2-4]). The process sewers delivered most of the liquid wastes from the generating facilities in 300-FF-2 to the process ponds and trenches in 300-FF-1 (DOE 1995d [p. 2-2]). Wastes included isotopes of uranium, cesium, cobalt, plutonium, promethium, and acids and solvents (DOE 1992b [p. 4-4]).

3.4.4 307-Area Retention Basins and Trenches

The 307-Area retention basins and trench system was constructed in 1953 to separate liquid wastes by level of radioactive contamination. Liquid wastes from laboratories in the 300-FF-2 area fed into four concrete retention basins about 350 feet southwest of the South Process Pond. Waste in the basins was monitored for radioactivity. When radioactivity exceeded 5 picocuries per liter (pCi/L), it was diverted into holding tanks below- and above-ground in the 340-building for transport to the 200-Area for disposal.

3.4.7 300-Area Burial Grounds and Landfills

Six solid waste sites (two burial grounds and four landfills) were located in Operational Unit 300-FF-1. These burial grounds contain miscellaneous materials contaminated with uranium. In 1995, the burial grounds contained mostly uranium soil contamination, metal objects, uranium-contaminated materials, solid wastes, and small amounts of the solvents perchloroethylene and trichloroethylene (DOE 1995e [p.6]).

Burial Ground 5 (618-5) was a trash burning pit from 1945 through 1962. Uranium metal on the surface was removed in 1988 (DOE, 1992b [p. 4-7]). Further information on 300 Area burial grounds and trenches is available in Appendix D, Operable Unit 300-FF-2 Burial Grounds (Gerber 1992, 1993; DOE 1995a).

3.4.8 Uranium Fuel Assembly and Research Facilities

The uranium fuel for production reactors was manufactured in the 313-building, the 314-press building, the 306-metal fabrication development building, and the 333-uranium fuels finishing building (DOE 1996c [p. 1-4]). The most important technology and research facilities in the 300-Area included the 321-separations research building, the 3706-building, the 325-radiochemical processing laboratory, the 327- radiometallurgy building, the 329-physical sciences and radioanalytical laboratory, the 309-plutonium recycling test reactor, the 324-chemical engineering laboratory, and the 331-life sciences laboratory (Gerber 1992, 1993; DOE 1996c [p. 1-4]).

4

Past Exposures

4.0 Chapter Summary

An exposure pathway is the route by which a contaminant travels from its source of origin, through the environment, to people. To determine Hanford exposure pathways, scientists first estimated the amounts of radioactive materials released from the Hanford Site to the Columbia River (from 1944 to 1971) and to the atmosphere (from 1944 to 1972). Scientists then estimated the amounts of radioactive materials transported from the river or air to soil, plants, animals, animal products, and people. Much of this information was developed during the Hanford Environmental Dose Reconstruction (HEDR) project, which involved the DOE and its contractors, an independent Technical Steering Panel of scientists, the Centers for Disease Control and Prevention (CDC). Congress mandated the HEDR project after the public learned in 1986 of the releases of radioactive materials.

The major exposure pathway through which people received radiation doses involved drinking milk from cows and goats that grazed on grass contaminated with airborne radionuclides. Other exposure pathways included drinking water from cisterns, drinking treated or untreated water from the Columbia River, eating food irrigated with contaminated river water, eating contaminated fish from the river, breathing contaminated air, swimming or boating in the Columbia River, eating contaminated vegetables, eating contaminated waterfowl from the river, contact with contaminated soil, and pica behavior (i.e, children eating contaminated soil). Individual risk factors, such as age at time of exposure and sensitivity to radiation, influence how a person is affected by radiation.

The major sources of air releases were the chemical processing and separation plants of the 200-Area. Persons living in the Columbia Basin and other areas of eastern Washington, northeastern Oregon, and western Idaho, as well as those who ate food products produced in the fallout area, were exposed to radioactive releases, primarily radioiodine (I-131). HEDR estimated the *maximum* radiation dose to an off-site person's thyroid from airborne I-131 during the period 1944 to 1957 to be between 54 to 850 rads. However, HEDR estimated the *average* thyroid dose to be 2 to 10 rads.

Sources of radioactive releases to the Columbia River included river water used as cooling water for the plutonium reactors, leaks from underground storage facilities, fuel assembly ruptures, and film and corrosion in pipes. Persons in the Tri-Cities area who consumed large amounts of fish or waterfowl from the Columbia River would be among the most exposed. According to HEDR estimates, a person could have received an effective dose of up to 1,500 millirem

Past Exposures

factors and characteristics determine the health effects that may occur as a result of exposure to a contaminant in the environment.

The most probable exposure pathways were evaluated. For example, if contaminated groundwater was the source of drinking water, it was evaluated for possible human exposure. Similar approaches were taken for ingestion pathways involving wild game and other food.

4.1.1 Estimating Past Releases: The HEDR Project

In September 1986, the Hanford Health Effects Review Panel, representing concerned populations in Washington and Oregon including several Native American tribes, recommended that studies on dosimetry — radiation doses received by people — and thyroid disease studies be initiated to assess the potential impacts of the releases on human health (TSP 1994). The DOE responded by directing one of its contractors, the Pacific Northwest Laboratory in Richland, Washington, to reconstruct the radiation dosimetry for affected populations. This project was called the Hanford Environmental Dose Reconstruction (HEDR) project. The purpose of this project was to determine the amounts of radioactive material that were released, the exposure pathways to people, and the radiation doses that may have been received.

Requests made under the Freedom of Information Action resulted in widespread public knowledge of and concern about radioactive releases.

When members of the public expressed mistrust of the government and its national laboratory in conducting these studies, an independent Technical Steering Panel of scientific experts and representatives of neighboring states was formed to direct the Dose Reconstruction Project (TSP 1994). In 1992, the responsibility for directing this research was transferred from the DOE to the Centers for Disease Control and Prevention (CDC). The Technical Steering Panel provided technical oversight of the HEDR study by evaluating all

Factors Contributing to the Radiation Dose that Persons Received from Hanford Included

- Where a person lived.
- When and how long the person lived there.
- The amount of contact the person had with radioactive substances.

Past Exposures

Table 4-1. Completed Past Exposure Pathways (Primarily from 1944 to 1971)					
Pathway Name	EXPOSURE PATHWAY ELEMENTS				
	Contamina- tion Sources	Environ- mental Media	Points of Exposure	Routes of Exposure	Estimated Exposed Population
Air-Milk 1944–72 (major releases 1944–51)	200-Area separations plants, air, pastureland	Backyard cow and goat milk	Consuming local dairy products (e.g., fresh milk, cheese, ice cream)	Ingestion	Residents of Washington, Oregon, Idaho, neighboring states and provinces
Air - Produce 1944–72 (major releases 1944–51)	200-Area separations plants, air	Backyard produce	Eating home- grown fruits, vegetables	Ingestion	Residents of Washington, Oregon, Idaho, neighboring states, and provinces
Air 1944–72 (major releases 1944–51)	200-Area separations plants	Air	Breathing, im- mersion in contaminated air, irradiation from air-con- taminated sur- faces, soil	Inhalation, dermal contact, external irradiation	Residents of Washington, Oregon, Idaho, neighboring states, and provinces
Surface Water – Columbia River 1944–71	100-Area Reactors along the river	Surface water, irrigation water, river sediment	Swimming, boating, fishing, drinking river water	Ingestion, dermal (skin) contact, and/or inhalation	Tri-Cities residents, consumers of locally grown food, occupa- tional and recreational river users
River Plants and Animals 1944–71	100-Area Reactors along the river; river water	Fish, shellfish, waterfowl	Eating anadromous fish and shellfish, their predators, and waterfowl	Ingestion	Recreational and subsistence fish- ers, sportsmen and their famil- ies, Tribal con- sumers of fish and waterfowl

Past Exposures

Persons exposed to airborne releases of radioactive materials from Hanford include those living in the Columbia Basin and other areas of eastern Washington, northeastern Oregon, and western Idaho, and those who ate food products produced in the fallout area. Most airborne radioactive releases from Hanford occurred during the first three years of Hanford operations, 1944 to 1947. Persons living downwind from Hanford also received radiation doses between 1950 to 1957 from Hanford and other sources, including nuclear weapons testing from the Nevada Test Site, which contributed to this population's radiation dose.

Estimating Past Releases

HEDR scientists and the Technical Steering Panel evaluated environmental monitoring and processing records to determine the amounts of radioactive materials that were released into air at the Hanford Site, beginning in 1944. The emissions were estimated from data on production, air filters, stack measurements, and air-monitoring stations at various locations (TSP 1994).

Climate studies at Hanford started before the reactors were operating. These studies included weather measurements, such as wind direction and speed, rainfall, and temperature. Such meteorological data are essential for predicting the behavior and paths of radioactive materials and chemicals that are released into the air (TSP 1994).

Environmental studies at and near the Hanford Site were later expanded to include measurements of radioactive materials in the air, soil, vegetation, food-crops, wildlife, Columbia River water, river sediments, fish, animals, and animal products. However, the exposure pathway of airborne I-131 to persons drinking contaminated milk — involving I-131 in air deposited on grass consumed by cows and goats, and milk from these animals then consumed by people— was not recognized by scientists until about 1957. Therefore, from 1944 to 1957 — the period during which the major I-131 releases took place — pasture grass and cows' milk from farms in Eastern Washington were not monitored for radioiodine (TSP 1994).

Project scientists developed several computer programs to reconstruct the missing information needed to estimate radiation doses and uncertainties. The full set of computer programs (i.e., the Hanford Environmental Dose Reconstruction Integrated Codes, or HEDRIC) consisted of four components including 1) a source-term model, 2) an atmospheric transport model, 3) an environmental pathways model, and 4) a radiation dose model (TSP 1994).

Past Exposures

that was conducted to test airborne monitoring equipment and to correlate measurements with the amount of spent fuel in process. The regular air filter and containment systems were bypassed to ensure that the release carried enough radioactive material for atmospheric measurements by aircraft. The Green Run accounted for about 7,000 curies of I-131 released to the air. It represented the largest single release of I-131 from Hanford (TSP 1994).

HEDR scientists estimated the airborne releases of strontium-90 (Sr-90), ruthenium-103 (Ru-103), ruthenium-106 (Ru-106), I-131, cerium-144 (Ce-144), and plutonium-239 (Pu-239) for eight locations for the years 1944 through 1972. These radionuclides accounted for more than 99% of the off-site radiation dose from the atmospheric pathways. The major contributor to radiation dose was I-131, most of which was released during the first 3 years of Hanford operations. I-131 releases continued to occur after the first three years, with another peak release in 1951. Lesser contributors to radiation dose were Ru-103 and Ru-106, followed by Ce-144, Sr-90, and Pu-239. Releases of tritium, carbon-14, and argon-41 from reactor stack gas systems and reactor effluent cooling water were negligible contributors to radiation dose.

Additional, Non-Hanford Sources

Radioactivity in the atmosphere has many sources, including naturally occurring cosmic radiation, releases from radionuclides naturally present in all rocks and soils, nuclear weapons testing — including the Nevada Test Site — and releases from nuclear power plants. The U.S. Department of Health and Human Services and the National Cancer Institute have conducted studies to gather air monitoring data from across the U.S. and estimated radiation doses by county from airborne radioactivity. These studies showed that the Hanford Site was not the sole contributor to radiation doses to the thyroids of persons living downwind from the Hanford Site.

A major contributor to public radiation exposure was the atmospheric testing of nuclear weapons between 1945 and 1963. According to the National Cancer Institute studies, the highest thyroid doses from NTS fallout occurred to persons born between January 1950 and December 1963 — when the Limited Test Ban treaty was signed, ending atmospheric testing of nuclear weapons¹. This was a second major exposure period, in addition to the time period when most of the Hanford releases took place between 1944 and 1947. The dose reconstruction scientists estimated that the theoretical maximum thyroid radiation dose to an

¹More information about releases from the Nevada Test Site, including individual dose calculations, can be found at the National Cancer Institute's web page: <http://i131.nci.nih.gov/>.

4.2.2 Air Pathway and Transport Modeling

The atmospheric transport of radionuclides released from the Hanford Site were tracked using the computer program RATCHET (Regional Atmospheric Transport Code for Hanford Emission Tracking). This program combined the data on radioactive materials released with the measured meteorological data. Dose-reconstruction project scientists used RATCHET to estimate the daily air concentrations and levels of surface-contamination from fallout in the study region. Calculations were made for over 2,000 locations within the study area on a daily basis. The program accounted for the 8-day physical half-life of I-131 and the cumulative effect of ongoing daily releases (TSP 1994).

4.2.3 Plants and Animals

The third part of the dose-reconstruction program package — DESCARTES or Dynamic Estimates of Concentrations and Radionuclides in Terrestrial Environments — was used to estimate concentrations of radioactive materials in soil and plants in the food chain from airborne releases. The DESCARTES program accounted for weathering and removal of contamination from plant surfaces by wind, rain, and irrigation water (Shindle et al. 1992). During the growing season, dairy cows and goats could have ingested radioiodine deposited on pasture lands. DESCARTES used the daily input values from RATCHET to estimate the concentrations of radioactive materials in several types of vegetation, crops, and animal products. This calculation required data on agricultural production and distribution systems for the affected regions during the period 1944 to 1951 (TSP 1994).

Research on radionuclide migration provided information on the transport of radionuclides from air to vegetables, grains, and fruits eaten by people, and to plants used in animal feed such as grass, alfalfa, silage and grain. Scientists used these concentration factors to estimate radionuclide concentrations in animal products such as beef, venison, poultry, eggs, milk. Radiation doses to people were then estimated using this data. Figure 9 shows the total cumulative deposition of I-131 across the study area for the year 1945 (TSP 1994). Figure 9 also shows that the I-131 depositions occurred mainly to the northeast of the Hanford Site, consistent with the prevailing wind directions in the region. On average, an estimated 55% of the I-131 released from Hanford was deposited within the HEDR Project study area. About 10% of the releases decayed during atmospheric transport, 35% was transported beyond the study area, and the remainder decayed during transport beyond the study area (TSP 1994).

4.2.4 Activities Resulting in Exposure

Past Exposures

The Columbia River received contamination from several Hanford areas. Eight of Hanford's nine plutonium production reactors used Columbia River water to cool the reactors. This cooling water, which washed small amounts of radioactive materials from the reactor and which accumulated radioactivity by neutron activation of natural water impurities, was then held in ponds before it was discharged back into the River. Contaminated water was released to the ground from leakages from subsurface storage facilities located near the River, from cracks in failed fuel assemblies, and from films and corrosion in piping.

The HEDR project initially studied 19 radionuclides identified in the Columbia River in the HEDR project, and estimated concentrations in River water of five of these radionuclides considered to be the most important because they contributed about 94 percent of the estimated doses to people

- sodium-24 (Na-24),
- phosphorus-32 (P-32),
- zinc-65 (Zn-65),
- arsenic-76 (As-76), and
- neptunium-239 (Np-239).

CDC funded additional work on the Columbia River dose reconstruction model that evaluated additional radionuclides — including iodine-131, cobalt-60, and strontium-90 — as contributors to the river pathway. The additional work did not support the suggestion that the original HEDR Project should have included dose calculations for I-131 and Sr-90 in the Columbia River (RAC 2002).

HEDR scientists found 0 to 13 pCi/g of radioactivity in Columbia River fish based on measurements of fish caught in the Hanford Reach at the time of the greatest releases to the river. A higher radiation concentration was estimated using a model that assumed all the fish spent their entire life in the Hanford Reach. Using this model, an “upper limit” on the concentrations ranged from about 1 pCi/g to 100 pCi/g.

The HEDR project identified several activities that could have resulted in persons receiving radiation doses from the Columbia River, including

- drinking water from the River,
- using River water for irrigation,
- swimming, boating, or walking along the banks of the River, and
- eating fish, shellfish, or waterfowl from the River.

Past Exposures

A review of the dose reconstruction work by SENES, Oak Ridge, under contract to ATSDR, recommended that three more radionuclides — iodine-131, cobalt-60, and strontium-90 — be evaluated by HEDR for their contribution to dose.

NCEH funded additional work on the Columbia River dose reconstruction model. Native Americans and others whose diets included fish from the Columbia River between 1956 and 1965 were interested in new parameters to estimate radiation doses. The model included the 11 radionuclides for which HEDR had source term estimates, plus others, including cobalt-60 and strontium-90 for which HEDR did not estimate source terms (RAC 2002).

The follow-up NCEH results did not support the suggestion that the HEDR Project should have made dose calculations for I-131 and Sr-90. Although I-131 and Sr-90 were not eliminated in the initial screening, they were identified as low priority contributors to dose in all three exposure scenarios. The scientists accounted for the consumption of whole fish including the bones by Native Americans; however [their] research indicated it was unrealistic to assume whole fish were consumed year round in large quantities. For this reason the dose and risk for Sr-90 and Sr-89 were not significant. Iodine-131 screening values ranked consistently low for the three representative scenarios. On an absolute level, I-131 risk for the local resident (i.e., River user) scenario at Richland was about a factor of 20 less than the estimated risk from the atmospheric releases of I-131 at Ringold. Therefore, I-131 did not appear to warrant further investigation. If further evaluation of risks from radionuclides released into the Columbia River is undertaken, the following four radionuclides are important for the analysis — As-76, Np-239, P-32, and Zn-65; the following four of moderate priority — Na-24, Zr-95, Co-60, and Cs-137. Fallout from atmospheric weapons testing may have exaggerated the significance of Cs-137 in this study. And I-131, I-133, Sr-90, Sr-89, Ga-72, Sc-46, and Y-90 were of low priority and probably could be dismissed. Over the years 1952 to 1964, fish ingestion was the dominant exposure pathway for releases to the Columbia River. The significance of fish ingestion for Native American users of the river was greater than that for non-Native American users by a factor of 10. (RAC 2002).

Radioactive contamination of river water also resulted from fuel assembly failures when ruptures in the fuel cladding occurred. When failures were detected, the reactors were shut down to replace the failed fuel elements. Other contamination resulted from the chemical purges to reduce build-up of films and corrosion products in the piping.

Hanford scientists conducted radiological monitoring of river water. Drinking water was sampled in the nearby towns of Richland, Pasco, and Kennewick.

Past Exposures

has a half-life of 5.3 years, and Zn-65, which has a half-life of 245 days, were less influenced by the presence of the Columbia River dams.

4.3.3 Plants and Animals

Some of the contaminants that were released into the Columbia River were first taken up by smaller fish and aquatic organisms such as algae, then larger fish and shellfish. These organisms were then consumed by species higher in the food chain such as waterfowl and humans. The dose-reconstruction project estimated the levels of contaminants in these animals using Hanford monitoring data from samples collected by other scientists, federal agencies, and universities. The correlations between the concentrations of radionuclides in river water, fish, and waterfowl, and concentration factors were used to estimate radiation doses to persons who consumed the fish and waterfowl (TSP 1994).

The HEDR Project considered fish species that are *anadromous* such as steelhead trout, and chinook, sockeye, and coho salmon. Anadromous means that they live part of their lives in freshwater and part in ocean water and travel up the Columbia River to spawn. Adult sockeye and other Pacific salmon species do not feed once they enter fresh water and head upstream to spawn; instead, they rely on reserves of fat and protein stored up during their ocean feeding to reach their spawning area. Therefore, measured concentrations of radioactive materials in anadromous species were from radioactivity present in ocean waters. Juvenile salmon and steelhead trout, however, feed on river plants and animals during their 3- to 24-month downstream migration to the ocean.

Very little radioactivity was found in Columbia River anadromous fish. Measurements of samples of salmon caught in the Columbia River showed that 37 of 47 samples were below the minimum detection limit, 0.1 pCi/g for Zn-65. The other 10 samples varied from just above the detection limit to a maximum of 13 pCi/g. The median value for Zn-65 was 0.6 pCi/g (TSP 1994).

Based on input from tribal representatives, the Technical Steering Panel recommended that radiation doses to people from ingestion of salmon and steelhead trout be estimated by two different approaches. The first approach used the measurement data discussed above. The second approach used the assumption that fish spent their entire lives in the Columbia River, which would provide an upper limit on the dose estimates. The latter approach yielded Zn-65 concentrations in salmon ranging from about 1 pCi/g to 100 pCi/g (TSP 1994).

Radionuclide concentrations were measured in shellfish in the Pacific Ocean near the mouth of the Columbia River. Data were compiled on P-32 and Zn-65 in

Past Exposures

- drinking water from the Columbia River,
- swimming, boating, or walking along the shoreline,
- showering with water from the river, and
- eating fish, shellfish, and waterfowl from the river (TSP 1994).

In addition to river water, the river sediment also contained contamination. The greatest contribution to radiation dose to people from activities related to the Columbia River was eating fish caught in the river.

4.3.5 Exposed Populations

The communities of Richland, Kennewick, and Pasco — the Tri-Cities — used treated Columbia River water as drinking water (PNNL 1991b). The HEDR scientists and the Technical Steering Panel estimated the total radiation exposures to residents of these communities for the years 1944 through 1971 from drinking river water, eating fish and waterfowl, and from recreational activities such as boating and swimming. They estimated that a hypothetical “maximally exposed individual” could have received an effective radiation dose over this time period of up to 1,500 millirem (approximately 1.5 rad whole body). More than 90% of this dose would have occurred between 1950 and 1970 (TSP 1994). The average population of the Tri-Cities from 1950 to 1970 was 37,741 (Beck et al. 1992). The number of residents who drank treated river water ranged from 27,000 and 68,000. The number of persons who consumed substantial amounts of fish or waterfowl from the River could have been as high as 2,000 persons.

The initial HEDR exposure pathways determined dose for a “representative” person. The estimated doses did not reflect lifestyles and cultural habits of unique populations, such as Native American, Japanese Americans, and Hispanic Americans.

5

Current Exposures

5.0 Chapter Summary

Current exposure pathways are the routes by which contaminants travel at the present time — rather than in the past or potentially in the future — from their source of origin, through the environment, to people. Table 5-1 summarizes the current potential pathways, Hanford sources, environmental media, points and routes of exposure, and potentially affected populations.

Groundwater

Nine public water systems on the Hanford Site provide potable water for facilities and workers. Each of these systems is monitored for radioactive contaminants. Very low levels of natural radionuclides — tritium, radium, thorium, uranium — are normally present in all public water systems. The public water systems are monitored for both naturally occurring and man-made radionuclides from Hanford Site operations. All radionuclide concentrations measured in 2004 met the safe drinking water requirements of the Washington State Department of Health and the Safe Drinking Water Act.

Groundwaters at certain locations monitored by test wells showed up to 18 different contaminants that exceeded current drinking water standards. This groundwater, however, is not used for drinking.

Seeps and Springs

The pathway of most concern is exposure to contaminants in seeps and springs along the Columbia River such as the H-, K- and N-Springs in the 100-Area. Warning signs labeled “Danger: Radioactive” are posted in these areas; however, it is possible for people to ignore the signs and access the seeps and springs by boat. If people drank the water in these seeps and springs, or their skin touched these sediments, they could be exposed to groundwater contaminants above health screening levels. That said, however, because these areas are isolated, exposure through this pathway is expected to be infrequent.

Columbia River

Levels of contaminants in Columbia River water — including water used for drinking supplies — are below levels expected to cause adverse health effects in the local population. Although it is possible that persons are exposed to shoreline and river bottom sediments when the sediments are stirred up through boating and dredging activities, such exposures would not cause adverse health effects because the amounts of contaminants present are small and exposure times are short.

Current Exposures

Table 5-1. Current Exposure Pathways					
Exposure Pathways	Exposure Pathway Elements				
	Sources	Environmental Media	Points of Exposure	Routes of Exposure	Potentially Affected Population
Seeps and Springs	Contaminated groundwater	Seeps and springs	Drinking or body contact near shoreline seeps and springs	Ingestion, skin contact	Non expected. Access to contaminated seeps and springs is restricted.
Columbia River Water and Sediments	Contaminated groundwater including seeps and springs, process wastes	Sediments	Found hot particles	Skin contact with hot particles	None known.
Plants and Animals	Process wastes, contaminated soil	Plants, Fish, Other animals, Milk, Wine	Eating game, bone-enriched stews and soups ; burning tumbleweed	Ingestion, inhalation	Subsistence and tribal gatherers who consume contaminated plants and animals or burn tumbleweed as a heat source
Soil	Process wastes	Soil	Handling or moving soil	Skin contact or whole-body exposure	On-site workers having direct contact with waste materials in the soil
Air	Process wastes; fires	Air		Inhalation	Persons working or living near Hanford
External Radiation	Radiation sources	All		External contact	Radiation workers at the Hanford Site.

5.1 Groundwater – Current Exposure Pathways

Since the 1940s, large amounts of contaminated wastes from Hanford were released—either intentionally or accidentally—into soil beneath the site. Contaminants migrating in the soil have contaminated area groundwater. Today, contaminants move with the groundwater from their source toward the Columbia River. In 1989, the volume of Hanford wastewater discharges decreased significantly and the spread of contaminants slowed.

Current Exposures

At one time, the Hanford Site groundwater flow was influenced by discharge of contaminated wastes from reactors and chemical reprocessing. Large volumes of contaminated and uncontaminated water seeped into the ground from drainage, water hold-up cribs, trenches, French drains, and leaking storage tanks.

Wastewater discharges from Hanford have accounted for about two to three times the volume of naturally occurring water in the groundwater system under the Hanford Site, causing groundwater levels to rise, most notably in the 200-Area. As a result, groundwater and any contaminants present in the groundwater extended further under a larger portion of the Site, increasing the movement of groundwater and contaminant plumes eastward, toward the Columbia River, and increasing riverbank seepage. This pattern changed in 1989, when wastewater discharges from disposal facilities at Hanford near the N-Reactor were decreased significantly, resulting in a lowering of local groundwater by about 20 feet, and in groundwater contaminants moving in smaller amounts and more slowly toward the Columbia River (PNNL 1999b).

When water discharging ended, groundwater levels over most of the Hanford Site declined. Some of the active monitoring wells went dry. In the eastern portion of the Hanford Site, water levels increased in 1999, presumably because of large-scale, off-site irrigation activities. In part of the 200-East Area, it appeared that groundwater moved upwards rather than in a typically downward movement. The depth of contaminant plumes was not well understood, and was estimated to be between 16.5 and 66 feet in different areas of the site. Carbon tetrachloride and tritium have been detected in the deepest areas.

5.1.2 Contaminants in the Groundwater

Table 5-2 lists some of the contaminants found in Hanford Site groundwater. Table 5-2 lists contaminants whose concentrations were above EPA drinking water standards. At the point where groundwater enters the Columbia River, it carries tritium, iodine-129, uranium, strontium-90, and nitrates (PNNL 1999b).

Current Exposures

directly north of Richland. The highest concentrations of tritium, 155,000 pCi/L, were found at the Hanford Townsite area. The drinking water standard for tritium is 20,000 pCi/L. Near the 300-Area, tritium was detected at 6,580 pCi/L. The highest levels of I-129 found in 1999 were 47 pCi/L; the drinking water standard for I-129 is 21,000 pCi/L. Technetium-99 levels have increased in wells near the 200-West area (PNNL 1999b).

Nonradiological Contaminants in Groundwater

Nitrate, carbon tetrachloride, and trichloroethylene were the most notable nonradiological, chemical groundwater contaminants measured at the Hanford Site. Several metals also exceeded standards, but these metals were from natural sources that existed prior to the Hanford operations (PNNL 1999b).

While nitrate was detected above drinking water standards in groundwater at all areas of the Hanford Site, concentrations near the Columbia River at the old Hanford Townsite were below drinking water standards and have not increased in the last ten years.

5.1.3 Sources of Contamination

Most of the groundwater contamination from Hanford resulted from the discharge of liquid wastes into cribs, ponds, and ditches. New areas of groundwater contamination may result if some previously immobile contaminants have begun to move. Also, potential new sources of contamination include additional single-shell tanks, K basins, and disposal facilities.

100-Area Sources

The reactor sites in the 100-Area are the major sources of groundwater contamination along the Columbia River shoreline. The N-reactor hold-up ponds percolated Sr-90, which contaminated nearby groundwater and then entered the Columbia River at the N-Area Spring. Other sources of Sr-90 in the 100-Area included leaks from underground pipelines and retention basins; fuel element ruptures; and Sr-90 in effluent from coolant systems and fuel storage basins (PNNL 1999b).

Tritium leaks at the K-basins have been detected (PNNL 1999b). Also at the K-reactor site, Cs-137 from the K-basins entered the groundwater and was discharged to the river at K-Area Spring. The 100-Area process trenches have contaminated groundwater with cis-1,2-dichloroethylene, trichloroethylene, and uranium at elevated levels. The 100-H-Area basins have contaminated the groundwater with chromium, nitrate, technetium-99, and uranium above regulatory standards.

Current Exposures

West Area, with the largest plume associated with the U-Plant. Technetium-99 was also found at the single-shell tank farms in the 200-West Area and near cribs in the 200-East Area. Cribs in the 200-West Area were probably the source of uranium concentrations measured in groundwater.

Strontium-90 was present in large amounts in waste streams associated with fuel element processing in the 200-Area. These wastes were then piped to underground tanks or diverted to the soil via cribs, trenches, and ponds. Only a small portion of Sr-90 appears to have reached the groundwater, except for one injection well, and no Sr-90 from the 200-Area is known to have reached the Columbia River via groundwater (Peterson and Poston 2000).

One nitrate plume originated from the PUREX plant in the 200-East Area; two other nitrate plumes began near the U- and T- plants of the 200-West Area (PNNL 1999b). ATSDR believes that the nitrate in the 100-Area monitoring well — and possibly also the tritium and technetium-99 — concentrations were too high to reflect only 100-Area activities.

Carbon tetrachloride contamination in the 200-West Area originated from waste disposal operations associated with the Plutonium Finishing Plant. Carbon tetrachloride has been found in monitoring wells far below the groundwater table; further study is needed to determine its depth.

High levels of trichloroethylene were found near the T- and U- plants in the 200-West Area (PNNL 1999b).

The groundwater concentrations of these substances near the 100-Area facilities and the Columbia River may have resulted from 200-Area leaks, which have migrated toward the River. The number of monitoring wells between the 200-Area sources and the 100-Area monitoring wells may be too few to determine the plume characteristics. Process liquids that were released into the vadose zone beneath cribs, ditches, French drains, ponds, reverse wells, settling tanks, and trenches may have been part of the source.

300-Area

In the 300-Area, sources of groundwater contamination were the liquid process effluents that were discharged to trenches and ponds. See Figures 4, 5, and 6 in Appendix F.

The contaminant most frequently found in 300-Area monitoring wells is uranium-238. Deep-aquifer monitoring in the 300-Area shows the uranium plume resulted from seepage into the soil and groundwater from fuel assembly

Current Exposures

systems found the systems to be in compliance with Washington State and EPA drinking water standards (PNNL 1999a).

Tritium in Groundwater Wells

A water system supplies the FFTF. This system draws from three wells, all of which are contaminated with tritium. Well 499-S1-8 (P-16) is the primary supply well and has contamination ranging from 3,990 – 4,150 pCi/L tritium. Well 499-S0-8 (P-14) is a back-up well for the system. Tritium in well P-14 was detected at 33,800 pCi/L. In 1999, well P-14 was used in February, March, April, May, and August for 36 hours. The third well, 499-S0-7 (P-15), is available for emergencies. Its tritium concentration ranged from 15,100 to 20,600 pCi/L (PNNL 2000b). For that year, ATSDR estimated that the average system tritium concentration was 4,173 pCi/L — similar to DOE's estimate of 4,275 pCi/L tritium and well below the state standard for tritium, which is an annual average of 20,000 pCi/year (PNNL 2000b).

Municipal Water Supplies

Municipal groundwater drinking systems and private wells that use groundwater as their water source could potentially be affected by contaminated groundwater flowing from Hanford toward the river. Monitoring thus far has consistently found that concentrations of contaminants reaching municipal well fields or private wells are below drinking water standards and that most of the wells are not in the path of contaminant plumes.

Most of the water used by the City of Richland for its municipal water supply is obtained from a pumping station on the Columbia River south of the Hanford Site (DOE 1993b). Columbia River water is also pumped into an aquifer recharge pond at the North Richland Wellfield, which is 2.5 miles south of the nearest Hanford 300-Area production facilities. The North Richland facility is located less than a mile from the 1100-Area of Hanford. Two other recharge well fields were previously located within Richland City limits.

The recharge of groundwater by the North Richland well field is a potential exposure pathway, although such exposure probably would not occur because 1) groundwater currently flows away from the well field; 2) no private wells are used in the path of contaminant plumes; 3) groundwater contaminants are unlikely to be at levels of possible health concern.

A groundwater plume near the 1100-Area containing TCE and nitrate originating from the Areva (formerly Siemens Power) Corporation and moving toward the Columbia River should be monitored to ensure that it is reduced to levels below possible public health concern before it reaches the Columbia River. TCE is unlikely to persist in surface water until it reaches a water supply intake. Nitrate

Current Exposures

in seeps along the Hanford Reach in the N-Springs area (Buske and Josephson 1988).

A 1990 DOE study (Dirkes 1990) analyzed samples taken from springs, river water up- and downstream of Hanford, and irrigation return water and spring water from the shoreline opposite the Hanford. Table 5-4 lists contaminants found at levels above drinking water standards in seeps adjacent to the Columbia River. Contaminants included chromium, strontium-90, tritium and gross beta.

Sr-90 was detected at levels as much as 1,000 times its drinking water standard. The highest level of Sr-90 (6,680 pCi/L) was detected in the N-Springs seep. The drinking water standard for Sr-90 is 8 pCi/L.

Contaminant	Location	EPA Drinking Water Standard	Variation over Time*
Chromium	100-H, 100-K, 100-D, 100-B	50 ug/L	Slight increase (100-H, 100-K); Significant increase (100-D) NA† (100-B)
Strontium-90	100-N, 100-H, 100-F	8 pCi/L	Highly elevated (100-N); Slightly elevated (100-H, 100-F)
Tritium	100-B, 100-N	20,000 pCi/L	Increase (100-B); Decrease (100-N)
Gross Beta Emitters	100-H, 100-N	50 pCi/L	Moderate increase (100-H); Great increase (100-N)
*A decrease in concentration from earlier times indicates that the source is no longer contributing and/or that the contaminant is not moving with groundwater flow. An increase indicates that slower moving plumes had not reached the sampling locations in earlier times and/or that recent disposal has occurred. †NA = no data available Source: (Dirkes 1990)			

In 1998, DOE reported that tritium levels (at the old Hanford Townsite and 100-N riverbank springs) and chromium levels (at the 100-B, 100-D, 100-K, and 100-H Area riverbank springs) exceeded Washington State ambient surface water quality criteria. Uranium exceeded a site-specific proposed EPA drinking water standard

Current Exposures

The last of eight Hanford reactors using once-through cooling systems that discharged to the river was deactivated in 1971. Since that time, releases of radionuclides directly to the river were significantly reduced, and the primary sources of contaminants into the river is contaminated groundwater discharging into riverbank seeps and springs, particularly those adjacent to the 100- and 300-Areas of Hanford. The levels discharged, however, are less than detectable levels in river water samples.

A total of about 3,000,000 Ci/yr of radionuclides was released from liquid waste discharge lines from Hanford's reactors directly into the Columbia River between 1944 to the mid-1960s.

5.3.2 Contaminants Present in Columbia River

A 22-year study by the Oregon Health Division (Toombs et al. 1983) found that radioactivity present in the Columbia River downstream of the Hanford Site has continually decreased, and that at no time during the study were levels in excess of national drinking water standards.

DOE annual Environmental Reports from the early 1990s (PNNL 1991c, 1992a, b, c) indicated that generally

- radionuclides present were not at levels of public health concern,
- concentrations of most radionuclides were essentially the same upstream and downstream of the Hanford Site, indicating they were present naturally, and
- contaminant concentrations were relatively constant or decreasing over time.

According to two studies, regardless of the concentrations of contaminants in sediment of seeps, the concentrations in river water immediately downstream has not been found to exceed drinking water standards (Peterson and Johnson 1992; DOE 1992c).

The 1998 DOE annual Environmental Report (PNNL 1999a) stated that while radionuclides associated with Hanford operations could be detected, such levels remained very low at all locations and were well below safe drinking water standards. In 1998, levels of tritium, iodine-129, and uranium were higher at the Richland Pumpouse downstream from the Site than at Priest Rapids upstream of

Current Exposures

The Columbia River flows eastward and then southward near the northern and eastern borders of the Hanford Site (DOE 1993b). Several cities and towns in the area use the Columbia River as a source of drinking water.

Most of the water used by the City of Richland for its municipal water supply is obtained from a pumping station on the Columbia River south of the Hanford Site (DOE 1993b). Columbia River water is also pumped into an aquifer recharge pond at the North Richland Wellfield, which is 2.5 miles south of the nearest Hanford 300-Area production facilities and about 0.5 miles east of the Columbia River. The North Richland water-intake facility is located less than a mile from the 1100-Area of Hanford. Two other recharge wellfields were previously located within city limits. Table 5-3 lists the substances tested for in the Richland drinking water supply in 1998 through 2001.

Table 5-4. Substances Tested for in the Richland Water Supply		
Radionuclides	Nonradionuclides Chemicals	
Alpha emitters (gross)	Ammonia (dissolved, as N)	Nitrate as nitrogen
Antimony-125	Anions	Nitrite + nitrate (dissolved, as N)
Beryllium-7	Calcium	Nitrogen (total Kjeldahl, as N)
Beta/Photon emitters (gross)	Carbon (dissolved organic)	(Dissolved) oxygen
Cesium-134, -137	Chromium (dissolved)	Phosphorus (total)
Cobalt-60	(Total) Coliform bacteria	(Dissolved) solids
Europium-154, -155	Copper	Suspended solids
Gamma emitters	Cryptosporidium	(Total) Trihalomethanes
Iodine-129	Cyanide	Turbidity
Plutonium (238, 239, 240)	Fluoride	
Potassium-40	(Total) hardness (CaCO ₃)	
Ruthenium-106	Iron (dissolved)	
Strontium-90	Lead	
Technetium-99	Manganese	
Tritium	Metals	
Uranium (234, 235, 238, total)		

Source: (City of Richland 2002; PNNL 1999a; Wiggins et al. 1998)

Current Exposures

River Bottom Sediments

Some of the contaminants from Hanford adhered to sediment at the bottom of the Columbia River and remain there today. Smaller amounts of contaminants are also present in Columbia River sediments as the result of fallout from nuclear testing in various locations around the world, including the Nevada Test Site. Generally, levels of radiological contaminants in offshore sediments are low, and have been covered with increasingly less contaminated sediment over time. Contaminants in offshore sediments/seeps in the Columbia River determined to be greater than comparison values in the 1970s and 1980s included cobalt-60 (Co-60), neptunium-237 (Np-237), and strontium-90 (Sr-90).

Stirring up of Columbia River sediments through activities such as boating or dredging could expose people to contaminated sediments.

Generally, Columbia River flow rates and flow volumes are high enough that no major sedimentation of fine-sized material was expected or observed upstream of the McNary Dam pool. Plutonium and americium-241 were found at lower concentrations in the area of the Hanford Ferry (near the old Hanford Townsite) than in the McNary Dam pool. Samples from downstream showed decreasing concentrations from those measured at the McNary Reservoir (Robertson and Fix 1977).

One study of plutonium, americium-241, cesium-137, and cobalt-60 in sediment samples from the lower Columbia River suggested that these substances were not transported in significant amounts to the lower portion of the river or estuary (Robertson and Fix 1977). Another study found the amount of residual radioactivity to be “vanishingly small” and that measurements showed that natural radioactivity of the sediments containing isotopes of K, Th, U, and Ra exceeded that of the artificial radioactivity by nearly an order of magnitude (Beasley and Jennings 1984).

Another study found that, except for plutonium-239, radionuclides in the sediment were consistent with levels expected from global fallout estimates. Hanford-derived plutonium-239 appeared to account for 20 to 25% of the total plutonium found in the McNary sediments. This study also stated that most of the radionuclides that have been transported downstream to the McNary Reservoir were trapped behind the dam and subsequently buried by sedimentation (Beasley et al. 1981).

Current Exposures

was found in reed canary grass samples in the 100-N shoreline area near N Springs (PNNL 1999a).

100 N-Springs Area

Vegetation in the 100 N-Springs area (e.g., such as mulberry, chicory, and water plants) might be an important food source to local animals species; however, humans are not currently using the vegetation for subsistence. Sampling results from 1990 to 1992 indicated that maximum concentrations of tritium (97,000 pCi/L), strontium-90 (440 pCi/g), cobalt (0.34 pCi/g), and possibly uranium-238 in mulberry foliage were elevated compared to samples from upstream locations. The researchers then calculated possible doses to people from eating the edible portions of the vegetation. The highest dose was three orders of magnitude less than the 100-mrem dose limit set by the DOE. The most significant contribution to dose (0.2 mrem for 50 years) resulted from Sr-90 in mulberries (Antonio et al. 1993). One study also reported that levels of strontium-90 in a mulberry leaf sample from a tree at the N-Springs were much higher (202,000 pCi/kg(dry)) than Sr-90 found in a nearby groundwater monitoring well (average of 5,900 pCi/L) (Buske 1999).

Tumbleweeds and Thistle

Contaminated tumbleweed was found, mainly in the 200-Area, when the DOE began to remediate the most contaminated parts of the Hanford Site in 1979 (McKinney and Markes 1994).

Investigations also showed that Russian thistle growing in trenches and in other engineered waste-storage structures in 200-East Area contained Sr-90.

Radionuclide samples in tumbleweed are reported each year.

Thistle and tumbleweed from other parts of the 200-Area, such as the ponds and ditches of the 200-West Area, were less contaminated (Johnson et al. 1994).

Russian thistle continues to grow in the less contaminated areas (United Press International 1998).

When the contamination was identified, tumbleweed was removed from the 100-Area, 200-Area, and other treatment, storage, and disposal areas (Hayward 1997). Public interest groups have expressed concern about the tumbleweeds that blow off-site.

In 1998, strontium-90 levels as high as 7,360,000 pCi/g (or 272,320 Bq/g, compared to the comparison value of 108 Bq/g) and cesium-137 levels as high as 1,410,000 pCi/g (or 52,170 Bq/g, compared to the comparison value of 422 Bq/g) were recorded in tumbleweed (PNNL 1999a).

Current Exposures

5.4.4 Milk and Wine

Sampling of farm products in 1998 found that milk contained iodine-129 at slightly elevated levels in locations downwind of Hanford compared to upwind locations; iodine-129 levels have decreased in milk collected over the past five years and are close to levels at upwind locations. The maximum level of I-129 in milk in 1998 was 0.0007 pCi/L; there is no regulatory standard for I-129 in milk, but the drinking water standard for I-129 is 1 pCi/L.

Strontium-90 was found in milk at the same levels upwind and downwind of the Hanford Site. The maximum level of Sr-90 found in milk in 1998 was 0.95 pCi/L, compared to the drinking water standard for Sr-90 in water is 8 pCi/L. There is no standard for Sr-90 in milk. Sr-90 was also detected in two leafy vegetable samples at a maximum level of 0.021 pCi/L, and in one grape sample at 0.005 pCi/g.

Tritium is a naturally existing radionuclide in all plants. Tritium was found in Columbia Basin wine samples, at a maximum of approximately 86 pCi/L. Tritium was also found in milk samples in 1998, but results have not yet been reported due to sampling analysis problems; additional sampling in 1999 found a maximum concentration of approximately 92 pCi/L of tritium in milk; the drinking water standard for tritium is 20,000 pCi/L. No standard exists for tritium in milk or wine. (PNNL 1999a, 2000b).

5.4.5 Exposure Routes

Off-site hunters could hunt game that could have grazed on Hanford lands; however, monitoring studies have confirmed that levels of radioactivity in elk, deer, and other game on the Hanford Site are the same as levels in game from elsewhere in the Pacific Northwest.

Tumbleweed is not known as a food source. Persons who gather dried brush and tumbleweed for disposal could receive an effective dose of less than 1 mrem from beta exposure to their skin.

Other than the activities discussed above, people who eat or otherwise regularly use plants and animals from the Hanford area are unlikely to be exposed to levels of contaminants at levels of possible public health concern because of the current restricted access to Hanford land and because contaminant levels in farm or animal products in the area appear to be either non-detectable or well below levels that would cause adverse health effects. Potential exposures if land use changes in the future are discussed in Chapter 7.

Current Exposures

zinc, polychlorinated biphenyls (PCBs), and uranium-238 (U-238) exceeded comparison values.

5.5.2 Sources of Contamination

The sources of current soil contamination primary involve past releases from the production reactor operations. Releases included cesium-137 (Cs-137), europium-152 (Eu-152), europium-154 (Eu-154), strontium-90 (Sr-90), and technetium-99 (Tc-99). Soil contaminants in Hanford's 200-Area originated from leaking tanks, cribs, ditches, French drains, process ponds and trenches, and unplanned releases. Soil contaminants in the 100- and 300-Areas originated from cooling water and process wastes discharged to ponds and trenches, or from leaking sewer lines.

5.5.3 Exposure Routes

Comparison values for child ingestion of surface soil were exceeded by arsenic, barium, lead, manganese, mercury, nickel, PCBs, silver, vanadium, and zinc concentrations in on-site soils in the early. However, children would are not ingesting soil and being exposed to these contaminants. The elimination of the soil exposure pathway depends on both the maintenance of present institutional control over Hanford Site and on the public respecting that control. No current examples of the exposure of children to Hanford Site soils is known.

5.6 Air – Current Exposure Pathways

There are not as many air releases as there were in the past and doses to the public are less than 1% of the allowed limit. There is a potential for unplanned releases, such as the brush fire that occurred in 2000. During the fire, levels of plutonium were detectable, but not a health hazard.

5.6.1 Contaminants

In 1998, strontium-90, cesium-137, plutonium-239, 240, and uranium were detected in the air in the 100-K, 100 N, and 200 Areas. Cobalt-60 was detected in the 100 N Area. These radionuclides were detected within about 1,500 feet, primarily downwind, of sites or facilities having the potential for, or a history of, environmental releases. Radiological doses to people through the air pathway were calculated to be 0.13% of the EPA limit of 10 mrem/yr. Gross alpha air concentration in 1998 at the site perimeter was slightly higher than concentrations at a distant community location. Gross beta air concentrations were the same at the Hanford Site perimeter as at distant community locations. Iodine-129 levels

Current Exposures

Only plutonium concentrations increased, while uranium and other radionuclide concentrations were unchanged. Elevated plutonium concentrations were found at similar levels both on and off site, leading to speculation that it was due to resuspension of global fallout.

The fire included parts of the newly designated Hanford Reach National Monument. With monument status comes the policy to use a “light hand on the land”. Therefore, local fire districts were restricted in their ability to bring in and use heavy equipment to fight the fire. The Fish and Wildlife Service is now stating that an incident commander is given full discretion to use heavy equipment when it is essential to protect life and property (FWS 2000).

Hanford Site Contingency Plan

Members of the Hanford Health Effects Subcommittee requested that the public health assessment address the Hanford contingency plan. The Hanford Site Emergency Plan is written and updated in coordination with the States of Oregon and Washington. Specifically the Oregon Department of Energy and the Washington Departments of Health, Environmental Health, Nuclear Planning, Agriculture and Washington State Emergency Management Division review the emergency plans. DOE also receives assistance from the U.S. Nuclear Regulatory Commission, because Energy Northwest's Columbia Generating Station (formerly Washington Public Power Supply System Unit-2 or WPPSS WNP-2) located on land leased from the U.S. Department of Energy (USDOE) on the Hanford Site. The complete plan can be found at the following URL

<http://www.hanford.gov/docs/rl-94-02/rl94-02contents.html>

5.7 External Radiation Doses

Measurements of external radiation include cosmic radiation, naturally occurring radioactivity in air and soil, and fallout from nuclear weapons tests, as well as any contributions from Hanford Site activities. Generally, DOE 1998 average dose rates at various 100-Area Hanford locations were comparable to off-site ambient background levels. At some 100-Area locations, on-site or nearby doses were somewhat higher (e.g., 4% and 9%) than 1997 doses rates, while at other locations 1998 doses had decreased substantially (e.g, 17% and 61%) from 1997 doses. In the 200-, 300-, and 400-Areas, annual dose rates were either comparable to or slightly lower or higher than 1997 measurements.

N-Springs

Dose rates at the N-Springs shoreline were elevated above the 100 mrem/yr DOE annual external dose limit to members of the public, reportedly because of a



Future Pathways

6.0 Chapter Summary

Land Use

Future use plans indicate that after the year 2020, part of the current Hanford Site will be transferred to non-DOE owners. Future uses include tribal, scientific, agricultural, and industrial activities. Some of the residual chemical and radiological contamination will remain. As land use changes, it is conceivable that future populations could be exposed in some places to remaining radionuclide or chemical contamination. For most persons living in the area, future exposure will be limited—most Hanford areas will be used for industrial purposes. Persons could, however, be exposed to contaminants at levels of health concern. For example, certain traditional Native American tribal practices, if resumed in the future at the Hanford Site, could expose persons to radionuclides and chemicals present in the area, as described below.

Native American Activities

Soil

The tribal practice of wrapping food in soil before cooking could expose persons to soil contaminants. The exposure could cause adverse health effects if persons use traditional tribal food preparation methods exclusively, use soil from the most contaminated Hanford lands, and if some of the soil adheres to the food that is consumed. Persons could also be exposed to contaminants in game if these foods are cooked prior to deboning them, or if bones or antlers are added to soups or stews for thickening. Using these deboning or thickening food preparation practices could result in an increase of the amounts of Hanford contaminants such as strontium, uranium, and lead to which persons could be exposed.

Plants and Animals

Persons who in the future rely on the most contaminated parts of the Hanford Site for their food or water—through activities such as hunting, food or medicine gathering—could be exposed to contaminants at levels that could result in harmful health effects. Examples include exposure to cadmium in wild plants (e.g., berries) and lead in wild game and plants.

Land and Buildings, New Activities, and Catastrophic Events

Other possible pathways through which persons could potentially be exposed to contaminants originating from the Hanford Site include 1) the use of Hanford lands and buildings, if residual contaminants are present at levels that could be health hazards; for example, children could be exposed to lead in soil if the land is used for non-industrial use; 2) potential releases of wastes from new activities

Future Pathways

health detriment, as described below.

While the Hanford Site is under federal ownership—as it is currently— public access is not permitted to many areas of the site, including all contaminated areas, without escort. Additionally, the land cannot be used for private residential or agricultural purposes. This situation is unlikely to change substantially before the year 2020. Nevertheless, in anticipation of expected changes in land ownership from federal to private after that time, this chapter explores the potential for persons to be exposed in the future to residual contaminants on lands formerly part of the Hanford Site.

Parts of the 300-Area have been decontaminated for eventual release and future public industrial use. The Department of Energy (DOE) plans to remediate the 300-FF-1 area soil and all 300-Area groundwater to levels suitable for industrial use (DOE 1995e). Other areas of the Hanford Site will also likely be decontaminated for scientific, agricultural, or industrial uses, rather than residential use. Some more heavily contaminated areas, such as waste disposal sites in the 200 Area, will not be remediated to levels that allow public use in the future. Also, because groundwater moving under the 100-Area toward the Columbia River is contaminated by 200-Area tank farm leaks, much of the Hanford Site to the north and east of the 200 Area may not be suitable for future agricultural development.

6.2 Native American Activities

Once Native American tribes reclaim access to parts of the Hanford Site—as they are planning to do—tribal people could be exposed to Hanford contaminants from hunting, cooking, gathering foods and medicines, and pasturing livestock on former Hanford lands. One way that persons could be exposed is through the use of food-wrapping, a traditional tribal cooking method that involves encasing food, such as fish or game, in soil before cooking it in a fire. Any contaminants in the soil, such as cadmium or copper, being used to wrap the food could be ingested by persons who consume some of the soil remaining on the food. Another exposure pathway could be through consuming contaminants, such as strontium, uranium, lead, or cadmium, in local game and in wild plants used as food or medicine.

Table 6-1 summarizes the future exposure pathways that could introduce contaminants into the diets of persons who consume food from the Hanford Site. Persons could be exposed to contaminants through more than one of the pathways listed in Table 6-1. The contaminants of possible concern are discussed further in Chapter 7, and the potential health effects associated with these contaminants are discussed in Chapter 8.

Future Pathways

Kalispel Tribe, Kootenai Tribe of Idaho, Nez Perce Tribe, Spokane Tribe, and Yakima Indian Nation.

Federal law requires DOE to restrict public access to areas that could pose hazards to human health (McLeod 1995; DOE 1995e). Although DOE is committed to maintaining controls that will limit future use of the Hanford Site to industrial users, the Agency for Toxic Substances and Disease Registry (ATSDR) considered the possibility that the land along the Columbia River currently being held in trust for one or more of the tribes could one day revert to traditional tribal use. The following paragraphs address tribal activities and potential for exposure if Hanford lands are eventually released for tribal use.

6.2.2 Soil Pathway

When tribes reoccupy Hanford Site lands in the future, exposures to radiation and chemical contaminants at concentrations of possible health concern could occur for persons who adhere exclusively to traditional food preparation. For example, food-wrapping (i.e., encasing food in soil), as discussed below, could increase the amount of contaminated soil ingested inadvertently (CTUIR 1995). Also, fish and game might be cooked before being deboned, or soups and stews could have bones or antlers added for thickening, which could increase the amounts of certain radionuclides such as strontium and uranium, and nonradionuclides such as lead that may be ingested with the fish and game.

In some traditional tribal food preparation practices, food items may be encased in soil prior to cooking to control the heat from the cooking fire (CTUIR 1995). The rate of soil consumption by a 154-pound adult from eating soil-encased food could amount to 5 grams (one teaspoonful) of soil daily over a lifetime. If the soil came from the most contaminated areas of Hanford, possible health effects from eating food encased in soil could occur from consuming cadmium or copper if these substances are present at high enough levels in the food-encased soil. Possible health effects for sensitive individuals from eating food encased in soil prior to cooking from the most contaminated areas of Hanford include kidney damage from eating cadmium in the soil. Consuming copper present in the food-encased soil could lead to stomach and intestinal irritation, especially for persons who already have liver damage or certain metabolic problems. In addition, some persons could develop skin spots from ingesting silver in soil-encased food; these

When food is wrapped in soil, as is done in some traditional tribal food preparation practices, some of the soil may adhere to the food and may be ingested, along with any contaminants present in the soil.

Future Pathways

Accountability Project (GAP). GAP expressed concern that workers and others were exposed to elevated levels of radiation at the Richland Specialty Extrusions factory which, at that time, leased part of the Hanford 313-building to produce aluminum objects. These concerns were based on testing done by GAP. The WDOH found that the site had unrestricted access despite signs, chain-link fences, and shield blocks identifying radiological areas and attempting to prevent unintentional entry. One “hot spot” was identified by the WDOH in an inaccessible area; the WDOH stated that this area did not expose anyone to doses above 100 mrem, which is the annual DOE dose limit to members of the public. The DOE and ATSDR concluded that no public health risk existed from external exposure to radiation at the site. See Appendix K for a more detailed discussion of the aluminum factory and Building 313 radiation testing results.

6.3.2 Clean-up Standards based on Industrial Use

There is public concern that clean-up standards based on industrial use are not adequate because limiting land use to industrial activities cannot be ensured. For example, if future users create a day-care center for workers in the area, the persons operating and using the day-care center would not necessarily be aware that they could be exposing children to lead in soil. This potential exists because the area was remediated to industrial, not residential, standards; some parts of this area were not remediated and still contain lead in the soil.

ATSDR advised the Port of Benton that properties formerly part of the 1100-Area of Hanford should be limited to industrial or commercial use, rather than residential use.

Also, barriers to contamination that do exist (e.g., caps) could be breached. The health effects of children exposed to lead in soil include reduced growth and IQ; the health effects associated with children ingesting lead in soil are discussed in more detail in Chapter 8.

In 1998 a portion of the 1100-Area was acquired by the Port of Benton, with the intention that it would become part of the Horn Rapids Industrial Park. ATSDR notified the Port of Benton that this transfer should include sufficient safeguards to protect public health from exposure to unremediated areas and to guard against the breaching of barriers created in the course of remediation (e.g., caps). Because DOE’s remediation was to industrial standards, less restricted use such as residential or agricultural use may not be protective of public health. If the Fast Flux Test Facility (FFTF) is restarted a major community concern is the potential for the release of tritium. On December 19, 2001, DOE announced that the FFTE would not be restarted and that its deactivation would proceed.

6.4.2 Earthquakes, Floods, and Terrorist Acts

In addition to fires, there is the potential for earthquakes, floods, and terrorist acts. The potential for adverse health effects depends on the intensity of the event. Review of contingency plans is the responsibility of the Federal Emergency Management Agency (FEMA).

6.5 Drinking Water

Several contaminants, such as radioactive tritium in on-site groundwater, are above drinking water standards. ATSDR does not expect to drill new wells in the contaminated groundwater. Still, as groundwater flows toward the Columbia River, higher levels of contamination could reach seeps and springs, the North Richland well field, and the river.

Radioactive tritium in Hanford groundwater could reach the Columbia River in the future. Concentrations are currently being reduced by one-half every 12 years due to natural decay. Persons would not be expected to be exposed to harmful levels of other contaminants in the River because detected levels of groundwater contaminants are low, in part due to dilution with clean river water, and because most levels of contaminants are expected to decay naturally to less than the levels of concern before they reach municipal water supplies.

Other sources of possible future contamination of groundwater or Columbia River water include offshore river sediments—if stirred or dredged—currently immobile contaminants that might be released in the future from sources such as single-shell tanks, K basins or disposal facilities, and radiological particles along the shoreline of the Columbia River.

6.5.1 Increased Water Usage

The return of Hanford lands to unrestricted public use could increase the possibility that some residents would use local river water or groundwater (e.g., private wells, springs, seeps) as a source of drinking water. A number of contaminants have been found in on-site groundwater at levels that are above drinking water standards. Also, some groundwater-related exposure pathways could transport contaminants to persons who drink water from these sources. All wells in Benton County require permits, and it is unlikely that permits would be granted for wells on lands with contaminated groundwaters.

Most persons will continue to drink water from uncontaminated municipal water supplies (e.g., the City of Richland) and these water supplies could be extended in

6.5.3 Trichloroethylene and Nitrate

If trichloroethylene (TCE) and nitrate currently in the groundwater plume near the 1100-Area from the Siemens Power Corporation were to reach the Columbia River, persons might be exposed to these chemicals. Levels of these contaminants would most likely be below levels of health concern before reaching Richland City water intakes.

6.5.4 Potential new sources of contamination

It is possible that some previously immobile contaminants may begin to move in the future and that new contamination may be released to soil and water from sources such as additional single-shell tanks, K basins, and disposal facilities. Also, if offshore river sediments are stirred (e.g., by boating) or dredged in the future, exposure could occur through skin contact with or ingestion of contaminants in the sediments. Another source of potential future exposure might be contact with radiological particles along the Columbia River shoreline.

6.6 Air

Contaminants in air releases from the Hanford Site in the future are not expected to pose a health concern to persons. Current levels are consistently below regulatory health limits, and no new releases of airborne contaminants above these limits are anticipated to be released in the future.

6.7 Health Effects from Past Exposures

Certain health effects associated with particular radionuclides or chemicals might not appear until quite some time after a person was exposed to the substance. This time lag between exposure to a substance and the onset of disease related to that exposure is known as a “latency period”. For example, persons who were exposed to I-131 as children may not see a health effect until they are adults.

Some persons may have been exposed in the past to radiation and chemicals from Hanford, but health effects from that exposure may not appear until sometime in the future.

The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages. Children are more vulnerable to the effects of iodine in milk for several reasons

7

Contaminant Screening

7.0 Chapter Summary

Exposure Evaluation Process

For environmental contamination to pose a health concern, three conditions must be met 1) the contaminants must be present in the environmental media (e.g., air, water, soil, etc.), 2) persons must come in contact with the environmental media containing the contamination, and 3) the level of contamination must be high enough to affect human health.

Each environmental medium was evaluated to determine whether persons would come into contact with the contaminants through ingestion, dermal (skin) absorption, inhalation or whole body exposure. Target populations, which have factors that could influence their extent or duration of exposure, were also identified (e.g., children and tribal members).

Once a potential for exposure was identified, the ATSDR determined whether the levels of contamination were high enough to produce adverse health effects. This was done by first comparing the contaminant concentration against a *screening value*. The screening values are media-specific concentrations of a substance that are not expected to cause adverse health effects.

The ATSDR uses two sets of screening values, one set for carcinogens and one for non-carcinogens. Provisional consumption rates are generated to help determine if people's ingestion of contaminated foods exceed the screening values for those contaminants.

Contaminants Eliminated

Some contaminants were eliminated because ATSDR determined that the contamination was not a human health concern. The list of contaminants eliminated can be found in tables at the end of this chapter. Table 7-1 lists contaminants not in an exposure pathway. Table 7-2 lists chemicals below ATSDR's screening values. The tables list the contaminant, the maximum concentration found, where the contaminant was on the Hanford Site, and the screening value used by ATSDR.

Contaminants Selected for Further Evaluation

For each medium, contaminants for further evaluation were identified. The substances were selected because they were above our screening value or there was a community concern.

Contaminant Screening

remediated to below their screening values. Cesium-137, cobalt-60, neptunium-237, strontium-90, and plutonium-239/240 were found in soil or sediment in completed soil exposure pathways, but not above their screening values. Because of the communities' concerns these radioisotopes are discussed in Chapter 8.

Substance	Air	Columbia River	Plants and Animals	Soil and Sediment
Antimony			√	○
Arsenic		√		○
Barium			√	○
Cesium-137*		○	○	np
Cobalt-60		○	np	np
Iodine-131	√			
Ionizing Radiation*		○		
Lead		√	○	√
Manganese			√	○
Plutonium*	○		np	np
Silver				√
Strontium-90		√	√	np
Tritium		√		
Uranium		√	√	○

√ = above screening value in an exposure pathway
 ○ = below screening value in an exposure pathway
 np = not found in an exposure pathway (i.e., no pathway)
 * Cesium-137, ionizing radiation (As-76, P-32, Np-239, Na-24, Zn-65), and plutonium were selected for further evaluation even though they did not exceed screening values.

Contaminant Screening

Much of the data reviewed by ATSDR was provided by the U.S. Department of Energy (DOE), the City of Richland, and the Washington State Department of Health (WADOH). The DOE data were obtained from documents that were previously reviewed by the U.S. Environmental Protection Agency (EPA), the Washington State Department of Ecology (WADOE), and (in some cases), by the WADOH to ensure reliability of the information sources. Another major source of information, estimated source terms and doses, was the Hanford Environmental Dose Reconstruction (HEDR) Project.

The Agency requested data from each of these sources. All requested data were provided, and no data or document requests were refused by DOE, by the City of Richland, or by the State of Washington. The availability of DOE data was greatly facilitated by the HEDR project and by the public's Freedom of Information Act requests that resulted in the declassification of thousands of documents.

Data from private organizations, such as the Hanford Education Action League, was also considered whenever such organizations felt individual privacy would not be violated.

7.1.2 Exposure Pathways

ATSDR considered the potential for past, current, and future exposures to the environmental contamination. Chapters 4, 5, and 6 discuss the pathways and the target exposure populations for each time period.

Each environmental medium (e.g., air, surface water, groundwater, etc.) was evaluated to determine if people would come in contact with the contaminants through ingestion, dermal absorption, inhalation, or whole body exposure. Table 7-1 lists the contaminants in the environment, but that ATSDR believes will not result in human exposure.

Target populations for each exposure were then identified. Unique factors that would influence extent or duration of exposure were also identified. For example, Native American Indians would have more exposure to contaminants associated with the Columbia River. Another example is children who drank goat's milk during 1945–1952, when the most of air releases occurred which contained higher doses of iodine-131.

7.1.3 Potential for Health Effects

Contaminant Screening

and limiting doses used for radioactive substances in this public health assessment, see Section 7.1.6.

RMEG	reference dose (or concentration) media evaluation guide
UTL	upper tolerable limit (for an essential nutrient)
UTL-MEG	upper tolerable limit media evaluation guide

Table 7-1. Contaminants Eliminated — May be above screening values, but not in exposure pathway

Contaminant	Maximum Concentration	Units	Screening Value	Screening Value Source	Location	Description
Air — All contaminants considered in a potential exposure pathway.						
Surface water — All contaminants considered in a potential exposure pathway.						
Groundwater* All groundwater contaminants considered in an incomplete exposure pathway						
Carbon-14	23,000,000	pCi/L	2,550	MCL (4 mrem/year)	100K-Area	monitoring well
Cesium-137	10,500	pCi/L	109	MCL (4 mrem/year)	100N-Area	monitoring well
Cesium-137	18	pCi/L	109	MCL (4 mrem/year)	200-Area upper aquifer	monitoring well
Cobalt-60	34,600	pCi/L	435	MCL (4 mrem/year)	Hanford town site	monitoring well
Europium-154	12,000	pCi/L	720	MCL (4 mrem/year)	Hanford town site	monitoring well
Iodine-129	50	pCi/L	14	MCL (4 mrem/year)	200-Area, upper aquifer	monitoring well
Iodine-129	911	pCi/L	14	MCL (4 mrem/year)	300-Area	monitoring well
Strontium-90	83,500,000	pCi/L	53.7	MCL (4 mrem/year)	100N-Area	monitoring well
Technetium-99	2,750,000	pCi/L	2,310	MCL (4 mrem/year)	100H-Area	monitoring well
Tritium	3,324,000,000	pCi/L	77,200	MCL (4 mrem/year)	100K-Area	monitoring well
Tritium	378,000	pCi/L	77,200	MCL (4 mrem/year)	200-Area upper aquifer	monitoring well
Uranium-234	90,400	pCi/L	20	MCL (4 mrem/year)	300-Area	monitoring well
Uranium-238	210,000	pCi/L	33	MCL (4 mrem/year)	300-Area	monitoring well
Ammonia	1,520	ppb	3,000	Intermediate Child EMEG	100D-Area	monitoring well
Antimony	47	ppb	4	child RMEG	300-Area	monitoring well
Arsenic	15	ppb	10	MCL	300-Area	monitoring well
Benzene	31	ppb	40	Child RMEG	300-Area	monitoring well
Chromium	2,500	ppb	20,000	Child RMEG, chromium-III	100K- Area	monitoring well

Table 7-2. Contaminants Eliminated — Below Screening Values

Contaminant	Maximum Concentration	Units	Screening Value	Screening Value Source	Location	Description
Air — All contaminants eliminated, other than iodine-131 released between 1945 and 1972.						
Surface Water *						
Technetium-99	330	pCi/L	2,310	MCL (4 mrem/year)	North of 300-Area	
Mercury	0.22	ppb	3	Child RMEG	100H-Area seep	not at Richland intake
Nitrate	5.5	ppb	20,000	Child RMEG	100-H, Seep 110-1	not at Richland intake
Zinc	261	ppb	3,000	EMEG	100H-Area, Seep 149-1	not detected at intakes
Groundwater † All groundwater contaminants are considered to be in an incomplete exposure pathway						
Game, Fish, and Vegetation ‡						
Europium-152	13	pCi/g	2,500	25 mrem/year	Hanford town site	dry algae, 6/24/1992
Cadmium	0.60	ppm	1.76	provisional	300-Area	mulberry leaves & stems
Chromium	15	ppm	176	provisional	300-Area	mulberry, 1992
Zinc	32	ppm	52	provisional	300-Area	mulberry leaves & stems
Soil and Sediment §						
Beryllium	1.9	ppm	100.0	Chronic Child EMEG	300-Area, process trenches	surface soil
Cadmium	23	ppm	50	Oral Child RMEG	300-Area, sanitary trenches	surface soil
Chromium	177	ppm	80,000	Child RMEG chromium-III	300-Area, process trench	surface soil
<i>cis</i> + <i>trans</i> 1,2-Dichloroethene	1	ppm	20,000 (<i>cis</i>) 10,000 (<i>trans</i>)	Intermediate child EMEG	300-Area, process trench	surface soil
Mercury	4.1	ppm	20.0	Oral child RMEG	300-Area, sanitary trenches	surface soil
PCBs	0.323	ppm	0.40	Oral CREG	300-Area, north process pond	surface soil

Table 7-2. Contaminants Eliminated — Below Screening Values (Continued)

Contaminant	Maximum Concentration	Units	Screening Value	Screening Value Source	Location	Description
Trichloroethylene	0.15	ppm	60	Oral CREG	300-Area, process trenches	surface soil
Vanadium	176	ppm	200	Intermediate child EMEG	300-Area, process trenches	surface soil
Vinyl chloride	0.031	ppm	0.50	Oral CREG	300-Area, process trenches	surface soil
Zinc	3,830	ppm	20,000	Chronic oral child EMEG	300-Area, sanitary trenches	surface soil
<p>* Surface water. Volume II: Appendices of DOE (1997a), WADOH (1993), DOE (1993b), and CRITFC (1994). † Groundwater. Volume II: Appendices from DOE (1997a), Westinghouse (1992b, 1995a, 1995c), and DOE (1992a, 1993a, 1995b). ‡ Game, fish, vegetation. Bird nest, mouse, rabbit feces, Westinghouse (1987), tumbleweed, Appendix A, Johnson (1994), mulberry, DOE (1993b), fish, DOE (2002); all others, Volume II, Appendices, DOE (1997a). For intake assumptions, see footnotes c and d of Table 4D. § Soil and sediment. 100-Area from Volume II, Appendices from DOE(1997a), 200-Area data from DOE (1993c), 300-Area data from DOE (1992b).</p>						

Table 7-3 Contaminants Selected for Further Evaluation

Contaminant	Maximum Concentration	Units	Screening Value	Screening Value Source	Location	Description
Air *						
Iodine-131	approximately 740,000 curies (Ci) released 1945–1972; 0.0014 Ci 1990					
Plutonium-239/240	0.0000281	pCi/L	81	EPA FGR13 & EPA EFH	200-East Area, 291 A stack	average concentration 1991
Surface Water (Columbia River) †						
Arsenic-76	736	pCi/L	923	MCL (4 mrem/year)	near Richland	average 1944–1971
Cesium-137	3.2	pCi/L	109	MCL (4 mrem/year)	100-K Spring	found only in springs
Cobalt-60	92	pCi/L	435	MCL (4 mrem/year)	100-N Spring 8-13	found only in springs
Europium-154	13	pCi/L	720	MCL (4 mrem/year)	100-N Spring 8-13	only at springs
Neptunium-239	1,800	pCi/L	1,860	MCL (4 mrem/year)	near Richland	average 1944–1971
Phosphorous-32	130	pCi/L	616	MCL (4 mrem/year)	near Richland	average 1944–1971
Sodium-24	22.2	pCi/L	3,400	MCL (4 mrem/year)	near Richland	average 1944–1971
Strontium-90	10,900	pCi/L	53.7	MCL (4 mrem/year)	Seep 8-13 near 100-N Spring	now found only in seeps, springs
Strontium-90	1.27	pCi/L	53.7	MCL (4 mrem/year)	Richland	average 1944–1971
Tritium	173,000	pCi/L	77,200	MCL (4 mrem/year)	Old Hanford town site, Spring 28-2	above MCL only at springs/seeps
Tritium	< 200	pCi/L	77,200	MCL (4 mrem/year)	Columbia River	split sample with DOE & WADOE
Uranium-234	65	pCi/L	20	MCL (4 mrem/year)	300-Area Spring 42-2	Only detected at springs
Uranium-238	58	pCi/L	33	MCL (4 mrem/year)	300-Area Spring 42-2	Only detected at springs
Gross alpha	<4	pCi/L	20	MCL (4 mrem/year)	Richland Pump-house intake	Surrogate for total uranium
Zinc-65	213	pCi/L	375	MCL (4 mrem/year)	near Richland	average 1944–1971
Arsenic	3	ppb	10	MCL	300-Area spring	only detected in springs

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Public Health Implications

was stored pasturage. Native American workers consumed little milk, and most of it was canned. Drinking water came from wells, city reservoirs, and irrigation ditches. Farm food (asparagus, corn, potatoes, and peas) was purchased at roadside stands or prepared traditionally (e.g., fresh and dried roots and dried corn) by Native American workers. Workers and their families spent much of their time outdoors. Reports concluded that this population was primarily “vulnerable to radiation exposure through the air and water pathway . . . due to the extended . . . time spent out-of-doors, exposure to mud and dust in the fields, and drinking and swimming in local surface waters.”—as well as from the consumption of local vegetables (Duffie and Willard, 1997).

A number of factors may have reduced migrant workers’ radiation exposures. The migrant worker camps were primarily upgradient, upwind, and upstream from Hanford radioiodine sources. The seasonal nature of migrant work also limited exposure time. Because inhaled I-131 was not first bioconcentrated (as it was in milk from backyard cows fed fresh pasturage), direct inhalation of this isotope contributed no more than 10% of the total dose to persons maximally exposed during the peak releases. External exposure (e.g., swimming in surface water) supplied 5% of the dose. Fresh non-leafy vegetables supplied 5% (corn is protected from direct iodine deposition by husks, peas by pods, and potatoes and other roots by soil). Soil ingestion supplied 0.02% of the dose.

ATSDR could find no evidence that the migrant worker group is a high-risk population from radiation exposure. Still, their use of irrigation water for drinking, swimming, and bathing could have exposed them to pesticides.

Some Hanford Downwinders received much higher doses than the farm workers because of their location or the quantity of fresh-pastured backyard cow’s milk they consumed (TSP 1994). A previous study of 35,000 persons given I-131 for medical reasons failed to find any association between dose and thyroid cancer among adults, but did find a statistically non-significant trend among children (this trend was at a much lower than that expected from the same dose from external radiation) (Hall et al. 1996). ATSDR could find no evidence that the migrant worker group is a high risk population because of radiation exposure, but their use of irrigation water for drinking, swimming, and bathing could have exposed them to pesticides. Their hazard from pesticide exposure would depend on the kinds of pesticides in use at the time and on the concentrations of these substances in the irrigation water.

ATSDR responded to HHES advice to research independently the issue of historically special populations. From the Franklin County Historical Society, the ATSDR learned that the greatest immigration of Mexican-Americans into the

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detectable, levels were 6-10 times lower than those assumed for the maximum dose calculations (TSP [p. 44]).

Modeling based on bioconcentration factors was more relevant to fish that spend their entire lifespans feeding in the river, as distinct from the ocean-going species favored by a traditional Japanese diet or the anadromous species favored by the tribes. Using the maximum dose estimates and a three-meal-a-day (440 pounds per year, 6 ounces of fish per meal) rate of local fish consumption, HEDR project results did not indicate that the regulations in effect at the time for public whole-body exposure were exceeded. No 5-consecutive-year period produced a mean annual

HEDR project results indicated that consumption of five or more 6-ounce meals of local fish per week during the 1950s and 1960s could have resulted in radiation doses that might have exceeded the recommended dose limits for members of the general public. This estimate applied only to local fish, not salmon or steelhead, which migrate back and forth from the ocean.

estimated dose exceeding 500 mrem and the lifetime (70 years including the maximum release years) annual mean was not shown to exceed 100 mrem per year (10 CFR 20). Persons eating fifteen 6-ounce servings per day would not have exceed regulations in effect at that time if their dietary fish sources were primarily anadromous species that feed in the ocean more than 80% of their lifespans, or if 80% of the fish and shellfish they consumed were ocean-dwellers (e.g., tuna, octopus, and shrimp).

Current ICRP and NCRP recommendations as adopted in federal regulations (10 CFR 20) limit the public's exposure to less than 500 mrem for any 5-year period and a lifetime average of 100 mrem per year. HEDR project results indicated that consumption of five or more 6-ounce meals of resident fish per week during the 1950s and 1960s could have exceeded the regulations and recommendations in effect in the 1990s. Persons eating three 6-ounce servings per day would not exceed current regulations and recommendations if their dietary fish sources were primarily anadromous species that feed in the ocean more than 80% of their life spans, or if 80% of the fish and shellfish they consumed were ocean-dwellers (e.g., tuna, octopus, and shrimp) (ICRP 1977, 1990b, NCRP 1993, TSP 1994).

Oothers have challenged HEDR dose modeling for the river pathway. Hoffman et al (1997) reported that the bioconcentration factors used by HEDR (which yielded up to 10 times higher radioactivity in the fish meat than was measured in samples) were lower than the highest available published factors, and because HEDR assumed filets, rather than whole fish (including bony parts), would be eaten (Hoffman et al. 1997).

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For example, strontium-90 (Sr-90) is chemically similar to calcium, so the body uses strontium in bones in much the same way it uses calcium. Sr-90 concentrates in the bone, and thus the organ (in this case the bone) receives a larger dose from this radioisotope than do other organs or tissues in the body.

Another example is I-131. The thyroid is thought to concentrate about 30% of the iodine taken into the body, with the remainder distributed throughout the body or excreted; the iodine dose to the thyroid is much more than the dose to the remainder of the body.

Other radioactive substances (e.g., tritium), do not concentrate in one organ, but are distributed uniformly throughout the body. Table 8-1 lists 11 major radioactive materials released from Hanford activities, the most vulnerable organs, and the physical half-lives of the radioactive material.

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The International Commission on Radiological Protection has also recommended 100 parts per billion as a drinking water standard protective against kidney toxicity when limiting the kidney-uranium concentration to 3- μg per gram kidney (Wrenn et al. 1985).

Gastrointestinal absorption of insoluble uranium, which is the form present in past contaminated parts of Hanford because of soil and soil and groundwater pH, has been estimated at 0.2% (Kocher 1989). Higher concentrations of insoluble forms of uranium (compared to soluble forms) may be needed to cause kidney injury (Leggett 1989).

Food Preparation — The amount of insoluble uranium in surface soil that might cling to ingested food prepared by traditional methods would not be likely to cause kidney toxicity in healthy persons who might subsist in the area in future decades.

Vegetation — (Lust 1974) states, however, that if yarrow contaminated with up to 24 μg uranium-238 per gram of plant tissue is used to treat persons for blood in their urine, —a possible indication of kidney injury or disease— a possibility of harm could arise.

The appearance of uranium in the plant tissues may indicate that the uranium has become solubilized. A 10-kilogram child's daily dose of uranium from 15 g yarrow could be as high as 0.36 mg (3.6 mg/kg/day), which is almost twice the dose that caused moderate injury in healthy rabbits (EPA 1998b). A 70-kilogram adult's daily dose of uranium from 60 g yarrow could reach 1.4 μg , or 20 $\mu\text{g}/\text{kg}/\text{day}$ to a 70-kg adult), about 1% of the dose that caused moderate injury in healthy rabbits (EPA 1998b). It is possible, but unlikely that this much soluble uranium would exacerbate a kidney problem being treated with the yarrow (DOE 1992b).

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Contributors

Appendix A

Glossary

[*Note*: Phrases in italics are defined in this glossary.]

Absorption - The process of taking in. Fluids or other substances can be taken up by the skin, mucous surfaces, or vessels.

Absorbed dose - The fundamental quantity in radiation dosimetry; the amount of energy deposited in a material by ionizing radiation per unit mass of the material. The S.I. unit of *absorbed dose*, in gray (Gy), is a measure of energy absorbed (in joules) per kilogram of material. The traditional unit of absorbed dose is rad, where 1 rad equals 0.01 Gy. See also *dose*, *effective dose*, and *equivalent dose*.

Acute exposure - Exposure to radiation or chemicals occurring over a short time, less than or equal to about 14 days, and usually a few minutes or hours. Depending on magnitude, an *acute* exposure can result in short-term or long-term health effects.

Acute effect - An *acute* effect of exposure to radiation or chemicals is one that is manifest a short time (up to 1 year) after exposure.

Additive Effect - The effects of two or more insults are said to be additive when their combined effect is approximately equal to the sum of the individual effects that would be produced by each insult independently of the others.

Adverse Health Effect - A change in body function or in the structures of cells that can lead to disease or health problems. (Also see *Health Effect*.)

Antagonistic Effect - Less response from exposure to a mixture of substances than would be predicted by adding together the effects from exposures, one at a time, to the same amounts of each substance in the mixture.

Agency for Toxic Substances and Disease Registry (ATSDR) - *ATSDR* is a federal health agency in Atlanta, Georgia that addresses issues regarding hazardous substances and waste sites. *ATSDR* provides information about harmful chemicals in the environment. The agency also evaluates whether persons are exposed to hazardous substance, and if so, whether that exposure is harmful and should be stopped or reduced. The agency may also recommend appropriate *public health actions* to address community *concerns* and exposures.

Beta particles - Negatively charged electrons released from atoms during radioactive decay. Electrons may travel up to about six feet in air or half an inch in water or tissue. Examples of beta-emitting radionuclides include iodine-131, phosphorus-32, and strontium-90.

Bioaccumulation - The progressive increase in the amount of a substance in an organism that occurs because the rate of intake exceeds the organism's ability to remove the substance from the body.

Biological clearance half-time - The amount of time it takes for exactly one half of a radioactive substance or non-radioactive material to be removed by an organ or tissue (or from the whole body) due to natural biological processes (metabolism, urination, defecation, exhalation, and perspiration).

Biological uptake - The transfer to and assimilation of radioactive or chemical substances from the environment to plants, animals, and humans.

Body burden - The total amount of a radioactive material or chemical substances in the body as the result of biological uptake.

Cancer - A class of diseases characterized by uncontrolled cell division that occurs when cells in the body become abnormal and grow, or multiply, out of control; a malignant growth capable of invading surrounding tissue or spreading to other parts of the body.

Carcinogen - Any substance that may induce cancer.

Case-control study - A common type of epidemiologic (human) study involving two groups that are compared. Individuals in one group may have been subjected to a treatment or insult, whereas individuals in the control group are not exposed or treated. Information is collected in the same way from individuals in both groups regarding specific exposures or treatments. Characteristics of the individuals that may have increased or decreased susceptibility to the treatment or exposure are also compared. The two groups are compared to determine the degree to which the exposures, characteristics, or other factors may be related to an association between insult, treatment, or exposure, and the prevalence of an observed effect or disease.

Central nervous system - The parts of the nervous system that includes the brain and the spinal cord.

effect so that the relationship of the effect and the exposure is not recognized, or make it appear as though there is a relationship to an effect when, in fact, none exists.

Contaminant - Any substance or material in a system (the environment, human body, food, etc.) in larger amounts than it is normally found, that renders it impure or unsuitable.

Cancer Risk Evaluation Guide (CREG) - The contaminant *concentration* estimated to result in one excess cancer case in a million persons exposed over a 70-year lifetime.

Cumulative effect - Effects that can result from repeated or chronic exposure to a substance. The cumulative effect occurs (or increases) with an increase in the total amount of the substance delivered to a particular tissue.

Curie - A unit used to quantify the amount of *radioactive* material. (It was originally based on the number of atoms that decay each second from one gram of radium). One curie is equal to 37 billion atoms undergoing radioactive decay per second. A "nanocurie" is one billionth of a curie. A "picocurie" is one trillionth of a curie.

Delayed effect - A health effect after exposure to a substance that does not become apparent for days, months, or years after the exposure.

Derived concentration guide (DCG) - An *effective dose equivalent* to members of the general public defined as exactly 1 mSv/year (100 mrem/year) from a specific radionuclide in air or water. *Derived Concentration Guides* serve as reference values for comparisons to environmental levels, and do not represent exposure limits.

Dermal - Referring to the skin (for example, *dermal* absorption means absorption through the skin).

Disease rate - The prevalence or occurrence of a disease in a population during a given year, often expressed as the number of cases per 100,000 persons per year.

Disease registry - A structured record-keeping system for collecting and maintaining information on the occurrence of disease in a population.

quality; it is the sum of equivalent doses to organs and tissues, each multiplied by the appropriate tissue weighting factors.

Effective half-life - The time required to reduce the radioactivity in a tissue or organ by 50 percent, taking both physical and *biological retention half-time* into account.

Environmental media evaluation guide (EMEG) - The *concentration* of a radioactive contaminant calculated from ATSDR's minimum risk level (MRL), which is an estimate of the daily exposure, usually for a lifetime, to a contaminant that is unlikely to cause adverse health effects, given conservative uncertainty factors to allow for differences between laboratory conditions and environmental exposure scenarios. An EMEG value is usually derived for chronic exposure (over two years to a natural lifespan), but EMEGs can also be derived for intermediate periods (six months to two years) and short-term (two weeks or less) exposures.

Environmental contaminant - A substance present in a system (person, animal, or the environment) in amounts higher than that normally found at *background or expected levels as the result of activities of man*.

Environmental contamination - The presence of hazardous substances in the soil, water, or air from the activities of man. From a public health perspective, *environmental contamination* is addressed when it potentially affects the health and quality of life of persons living and working near the contaminated *environmental media*.

Environmental exposure - Exposure to substances through the environment.

Environmental media - Usually refers to the air, water, and soil in which chemicals of interest are found; sometimes refers to the plants and animals that are eaten by humans. (Also see *exposure pathway*.)

Environmental Protection Agency (EPA) - A federal agency that develops regulations and enforces environmental laws to protect the environment and the public's health.

Equivalent Dose - In radiation dosimetry, a measure of radiation risk or detriment to an organ or tissue; the sum of the contributions of dose from different radiation types, each multiplied by its appropriate radiation weighting factor.

Gamma rays - Photons (electromagnetic waves) that are emitted from the atomic nuclei of radioactive materials. *Gamma rays* carry no charge and pass through the human body at the speed of light. As *gamma rays* pass through the body, they impart energy, which may damage cells. Cesium-137 is an example of a radioactive material that emits gamma radiation.

Graves' Disease - A disease characterized by an enlarged thyroid, a rapid pulse, and an increased basal metabolism due to excessive thyroid secretion; a form of hyperthyroidism (over-active thyroid).

Gray - The *SI* unit for *absorbed dose*. One Joule of energy deposited in one kilogram of matter. One gray (1 Gy) is equivalent to 100 rads.

Green Run - An intentional release of iodine-131 into the air from a fuel processing facility at the Hanford Site on December 2–3, 1949, to determine the characteristics of I-131 transport through the atmosphere.

Half-life - The amount of time it takes for any given amount of a radioactive substance to decay to one half of its value. Half-lives for different substances vary from millionths of a second to billions of years. Iodine-131 (I-131) has a half-life of approximately 8 days. At the end of 8 days, half of any given amount of I-131 becomes stable xenon-131. After another eight days, half of the remaining I-131 will decay into stable xenon-131, and so on.

Hashimoto's thyroiditis - An autoimmune disease of the thyroid caused by lymphocytes entering and spreading throughout the thyroid. The disease results in goiter, tissue damage, and *hypothyroidism*.

Hazard - A danger or risk of harm.

Hazardous Waste - Substances that are no longer in use, that may have been released or thrown away into the environment and, under certain conditions, could be harmful to persons who come into contact with them.

Health consultation - A response to a specific question or request for information pertaining to a hazardous substance or facility (which includes waste sites). It often contains a time-critical element that necessitates a rapid response; therefore, it is a more limited response than a public health assessment.

Hormesis - Beneficial health effects from low doses of *ionizing radiation* or hazardous chemicals due to adaptive response or other radiobiological mechanism.

Hot spot - A term used to describe an area where the *concentration* of contaminants is much greater than that in the surrounding area.

Hyperparathyroidism - A condition caused by too much parathyroid hormone in the body, resulting from not being able to properly regulate the levels of calcium and phosphorus.

Hyperthyroidism - A condition caused by enlarged or overactive thyroid and greater-than-normal amounts of *thyroid* hormones produced, causing an elevated basal metabolic rate and symptoms such as nervousness, constant hunger, weight loss and tremors.

Hypothyroidism - A thyroid deficiency of too little hormone production causing symptoms such as fatigue, weight gain, and skin and hair changes.

Immune system disorders - Abnormalities that include *autoimmune diseases* and other disruptions of the immune surveillance system. The primary function of the normal immune system is to detect and eliminate foreign substances, including foreign matter, germs, and proteins.

Ingestion - Swallowing (such as eating or drinking), one *route of exposure* by which substances can enter a person's body. Chemicals can get in or on food, drink, utensils, cigarettes, or hands, where they can be swallowed. After *ingestion*, chemicals may either be eliminated or be absorbed into the blood and distributed throughout the body.

Inhalation - Breathing. A *route of exposure*. Exposure may occur from breathing contaminants in if they can be deposited in the lungs, taken into the blood, or both. Some, but not all, substances that are taken into the lungs can diffuse across the walls of the lung capillaries (tiny blood vessels) into the bloodstream.

Internal radiation - Exposure to a *radioactive* substance that is inside the body after ingestion, inhalation, or absorption.

In utero - In the uterus or womb.

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Lymphocyte - A type of white blood cell primarily formed in lymphoid tissue such as lymph nodes, tonsils, the spleen, and the thymus. Lymphocytes provide protection against some kinds of infections.

Lymphopietic neoplasm - A tumor consisting of *lymphocytes* that can be either benign or *cancerous*.

Malignancy - See *Cancer*.

The Manhattan Project - The name of the U.S. Government scientific/military project, begun in 1939, that developed the world's first uranium reactor and the first atomic bomb. Hanford was part of the Manhattan Project, producing plutonium used in the atomic bomb dropped on Nagasaki, Japan.

Maximum contaminant level (MCL) - A regulatory value for the maximum contaminant *concentration* in public drinking water systems that EPA deems safe to public health over an individual's normal (70-year) lifetime.

Media - Soil, water, air, plants, animals, or other parts of the environment that can contain contaminants.

Medical monitoring - Periodic medical testing to screen persons at significant increased threat of disease.

Metabolism - All the chemical reactions that are caused by living things and that change a substance from its original chemical form. For example, food is *metabolized* (chemically changed) to supply the body with energy. Chemicals can be *metabolized* and made either more or less harmful by the body. Some chemicals can be *metabolized* by organisms in the environment. This is called “environmental *metabolism*”. Persons may then be exposed to the changed chemicals, which may be either more or less harmful to their bodies than the original chemicals.

Metabolite - Any product of *metabolism*.

Metastasis - The spread of *cancer* from the original site of the disease to another part of the body.

Millirem (mrem) - A millirem (mrem) is one-thousandth of a rem.

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near the releases. Populations near the sites may have had prior exposure to radiation or chemicals.

National Toxicology Program (NTP) – The *National Toxicology Program* conducts toxicological testing on substances most often found at sites on the EPA National Priorities List, for which there is the greatest potential for human exposure. NTP also assigns substances to cancer classes such as “Known *Carcinogen*” or “Reasonably Assumed a *Carcinogen*”.

Neoplasm - An abnormal growth of tissue that can be *cancerous* or *non-cancerous*.

Neural tube defects - The neural tube develops into the spinal cord and brain. Defects occur when the neural tube fails to close completely during the early stages of pregnancy.

No Observed Adverse Effect Level (NOAEL) - The highest dose of a chemical or radiation (below the lowest *LOAEL*) in a study, or group of studies, that did not cause harmful health effects in persons or animals.

Non-ionizing radiation - *Radiation* which does not have enough energy to cause atoms to lose electrons and become ions. This includes visible, ultraviolet, and infrared light, as well as radio waves. Also see *ionizing radiation*.

No apparent public health hazard - Category assigned to sites where human exposure to contaminated *media* is occurring or has occurred in the past, but having contaminant levels below those that are expected to cause adverse health effects.

No public health hazard - Category assigned to sites for which data indicate no current or past exposure or no potential for exposure and, therefore, no health *hazard*.

No threshold - The premise that there is no level below which exposure to radiation or chemicals does not increase the risk of disease; for cancer from chemical or radiation exposure, the hypothesis that any dose of ionizing radiation or a specific chemical carcinogen may increase the risk of developing cancer in organs or tissues of the body.

Nuclear fallout - The descent of airborne particles of dust, debris, and radioactive substances. About 200 different radionuclides of many different elements are

the area of a playground that has contaminated dirt; a contaminated spring used for drinking water; fruits or vegetables containing contamination from contaminated soil; or the backyard area where someone might breathe contaminated air.

Potential/indeterminate public health hazard - Category assigned to sites for which no conclusions about public health hazard can be made because data are lacking.

Potentially exposed - Condition in which valid information (usually analytical environmental data) indicate the presence of contaminant(s) of public health concern in one or more environmental media (i.e., air, drinking water, soil, food chain, surface water), with evidence that some of those persons have an identified route(s) of exposure (e.g., drinking contaminated water, breathing contaminated air, having contact with contaminated soil, or eating contaminated food).

Public comment - An opportunity for the general public to comment on agency findings or proposed activities. The public health assessment process, for example, includes the opportunity for public comment.

Public health action - Designed to prevent exposures and mitigate or prevent adverse health effects in populations living near hazardous waste sites or releases. Public health actions are identified from information developed in public health advisories, public health assessments, and health consultations. These actions include recommending dissociation (separation) of individuals from exposures (for example, by providing an alternative water supply), conducting studies on biologic indicators of exposure to assess exposure, and providing health education for health care providers and community members.

Public health hazard - Sites that could put people's health at *risk* as the result of exposures to harmful substances.

Rad - A unit used to express the amount of energy absorbed by matter. Equal to 100 ergs energy deposited per gram of matter.

Radiation - Energy radiated in the form of energetic particles or waves (photons).

Radiation standards - Recommendations for limiting the exposure of persons (workers and members of the general public) to radiation or radionuclides in air and water, to maximum permissible levels established by highly reputable scientific groups such as the National Council on Radiation Protection and

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Rem - A unit of dose equivalent that is used in the regulatory, administrative and engineering design aspects of radiation safety practice. One rem is equal to 0.01 sievert, and a millirem (mrem) is one thousandth of a rem.

Representative dose estimate - An approximation of the amount of substance taken in by a typical individual who represents a larger group of people; often is based on lifestyle factors.

Risk - The estimated probability that a *hazard* (e.g., an environmental contaminant shown to harm animals at higher than environmental doses) will cause harm (e.g., disease, injury, or death to persons) under specific exposure conditions.

Risk Assessment - A process used to estimate the likelihood of *adverse health effects*, or evaluation of levels, exposure or dose, and biological effects; to determine likely risk of such exposure in human populations..

Route of exposure - The way a substance gets on or into the body. Three primary *routes of exposure are: inhalation* (breathing), *ingestion* (eating or drinking), and *dermal* (skin) contact (e.g., through bathing or other skin contact with a substance).

Safety factor - See *uncertainty factors*.

Sievert - The *SI* unit for *dose equivalent*. One sievert equals 100 rem; the abbreviation is Sv.

Significant health risk - Circumstances in which persons are or could be exposed to hazardous substances at levels that pose an *urgent public health hazard* or a *public health hazard*; public health advisories are generally issued when *urgent public health hazards* have been identified.

Somatic effects or injury - The harm from radiation or chemical exposure that results from damage to non-reproductive cells. The harm may become clinically observable if the body does not spontaneously repair the damage. *Somatic effects* are not passed on to succeeding generations.

Source (of contamination) - The place where a substance comes from (such as a landfill, pond, creek, incinerator, tank, or drum). *Contaminant source* is the first part of an *exposure pathway*.

Thyroid function tests - There are two standard blood tests commonly used to evaluate *thyroid* function: 1) the measurement of *thyroid* hormones, referred to as T3 and T4, and 2) the measurement of thyrotrophin or *thyroid-stimulating hormone (TSH)*. The TSH test is usually performed before tests for T3 and T4.

Thyroid nodules - Lumps in the *thyroid* gland which may be benign or cancerous. "Cold *nodules*" are non-functioning lumps in the *thyroid* gland. "Hot *nodules*" refer to overactive *thyroid* lumps.

Thyroid nuclear scan - A test that measures the uptake of radioiodine by the *thyroid* gland. The *thyroid nuclear scan* can help evaluate a *thyroid nodule* and can provide additional information about how the *thyroid* is functioning, whether it is hyperactive or underactive, or whether it is cancerous.

Thyroid palpation - The most common procedure for checking the *thyroid* gland; a simple physical examination which consists of feeling the gland in the neck with the fingers, often as the patient swallows water. Palpation can determine the size and texture of the gland and can also detect larger nodules.

Thyroid stimulating hormone (TSH) - A hormone released by the pituitary gland near the brain that controls *thyroid* hormone production. When the *thyroid* gland is not working properly, the pituitary releases large amounts of *TSH* to try to stimulate the *thyroid* gland into producing *thyroid* hormone. The *TSH* circulating in the blood stream thus indicates *thyroid* failure.

Thyroid ultrasound scan – An image of the *thyroid* gland created by reflected sound waves. The ultrasound scan can detect abnormal small lumps in the gland.

Toxic - Harmful. Almost any substance, even pure water, can be *toxic* at a certain *dose* (amount). The *dose* is what determines the potential harm of a substance and whether it would cause someone to get sick.

Toxicological profile - A document about a specific substance in which *ATSDR* scientists interpret known information on the substance and specify levels below which people are unlikely to be harmed if exposed for various periods of time. A *toxicological profile* also identifies significant knowledge gaps, and serves to initiate further research when needed.

Appendix A – Glossary

atomic nuclei of a dense target anode, rather from the decay of an unstable atomic nucleus.

Appendix B

Hanford Health Studies

Appendix C

200-Area Facilities

Appendix C – 200-Area Facilities

- AW** Six double-shell storage tanks with maximum operating capacities of 1,140,000 gallons. These tanks were constructed between 1978 and 1980.
- AX** Four single-shell storage tanks with maximum operating capacities of 1,000,000 gallons per tank. These tanks were constructed between 1963 and 1964.
- AY** Two double-shell storage tanks with maximum operating capacities of 980,000 gallons each. These tanks were constructed between 1968 and 1970.
- AZ** Two double-shell storage tanks, each with a maximum operating capacity of 980,000 gal. These tanks were constructed between 1971 and 1977.
- B** Twelve single-shell storage tanks with maximum operating capacities of 500,000 gallons per tank, and four tanks with maximum operating capacities of 55,000 gallons per tank. These tanks were constructed between 1943 and 1944.
- BX** Twelve single-shell storage tanks, each with a maximum operating capacity of 500,000 gallons. These tanks were constructed between 1946 and 1947.
- BY** Twelve single-shell storage tanks with maximum operating capacities of 750,000 gallons. These tanks were constructed between 1948 and 1949.
- C** Twelve single-shell storage tanks with maximum operating capacities of 500,000 gallons and four single-shell tanks with maximum operating capacities of 55,000 gallons. These tanks were constructed between 1943 and 1944.
- S** Twelve single-shell storage tanks with maximum operating capacities of 750,000 gallons each. These tanks were constructed between 1950 and 1951.
- SX** Fifteen single-shell storage tanks with maximum operating capacities of 1,000,000 gallons per tank. These tanks were constructed between 1953 and 1954.
- SY** Three double-shell storage tanks with maximum operating capacities of 1,140,000 gallons per tank. These were constructed between 1974 and 1976.

Appendix C – 200-Area Facilities

Table C-1. 200-Area Tank Farms				
Tank Farm	Single (S) or Double (D) Shell	Number of Tanks	Individual Tank Capacity (m³)	Tank Farm Total Volume (gal)
A	S	6	3,800	6,023,304
AN	D	7	4,300	7,951,818
AP	D	8	4,300	9,087,792
AW	D	6	4,300	6,815,844
AX	S	4	3,800	4,015,536
AY	D	2	3,800	2,007,768
AZ	D	2	3,800	2,007,768
B	S	12	2,000	6,340,320
B	S	4	210	221,911
BX	S	12	2,000	6,340,320
BY	S	12	2,800	8,876,448
C	S	12	2,000	6,340,320
C	S	4	210	221,911
S	S	12	2,800	8,876,448
SX	S	15	3,800	15,058,260
SY	D	3	4,300	3,407,922
T	S	12	2,000	6,340,320
T	S	4	210	221,911
TX	S	18	2,800	13,314,672
TY	S	6	2,800	4,438,224
U	S	12	2,000	6,340,320
U	S	4	210	221,911
Totals		177	58,243	124,471,049
Reference: US Department of Energy. 1987. Disposal of Hanford defense high-level, transuranic and tank wastes. Washington, DC: DOE/EIS-0113.				

Appendix D

**Operable Unit 300-FF-2
Burial Grounds**

Appendix D – Operable Unit 300-FF-2 Burial Grounds

Burial Ground	Dates Used	Waste	Description
618-1	1944–1951	Uranium (U), plutonium (Pu), fission products	See Figure 6 . NE corner operable unit (OU) near bldg 333. 2 north-south trenches 200' long, 16' wide, 8' deep. 15' east-west pits 20' deep. 16 tons U, some Pu, fission products, additional laboratory wastes. Now covered with buildings and tank farms. Nitric acid spill from tanks in bldg 334 dissolved much of U and iron, which migrated to groundwater.
618-2	1951–1954	U, fission products, tin, lead, auto batteries	See Figure 6 . NE of bldg 333. 4 east-west trenches 150' X 51' X 15' for disposal of U-contaminated oxides from cuttings for fuel fabrication, Pu, fission products, tin, lead, auto batteries. Fire '54. Surface readings of 35 R/hr '55.
618-3	1954–1955	U	W of 618-2. 1 trench or several pits. U-contaminated building materials from building 313.
618-6	1944–1946	solid U	See Figure 6 . 1944-1946 near bldg 325 (about 700' SW of SW corner South Proc. Pond), exhumed, moved twice and relocated to bldg 324 (about 700 ft east of first site) 1951-1962, then relocated to 618-10, see below).
618-7	1955–1956 or 1960–1973	U-contaminated solvents, beryllium-contaminated zircaloy chips, low-level U- and thorium-contaminated matter	½ mile west of North Process Pond. 2 drive-in E-W trenches 160'X100'X12' and 1 V-shaped pit 140'X20' used for thorium disposal, low-level U- and thorium from fuel fabrication. Drummed U-contam. solvent and hundreds 30 gallon drums with beryllium-contaminated flammable zircaloy chips packed in water. Drums leaked water; chips potential an explosion hazard.
618-8	1943–1944	Solid U wastes from uranium fuel fabrication	Under parking lot about ¼ mile SW of North Process Pond. Several burial trenches. Radiation markers lost when parking lot built. Contamination found outside burial ground borders.

Appendix D – Operable Unit 300-FF-2 Burial Grounds

Burial Ground	Dates Used	Waste	Description
Buried construction waste area #2	1972–1974	Construction waste	Near north-central border of 400-Area (see Figure 4).
Suspected burial ground	Unknown, believed inactive	Unknown	¾ mile NE of 400-Area (see Figure 4). Now covered with soil mounded 15' above ground level.
Undocumented construction waste area #1	1977–1979	Construction waste	Just east of "buried construction waste area #1" (see above).
Undocumented construction waste area #2	1972–1974	Construction waste	Just west of "buried construction waste area #2" (see above).

Appendix E

Building 313

Appendix E – Building 313

Radiation levels were at background levels near the building perimeter. WDOH soil samples near the 313-building found higher levels of uranium-234 and uranium-238 than at off-site locations.

WDOH concluded that the 313 Building location fully complied with applicable DOE and WDOH radiation safety regulations, adding that “there is no public health risk from external exposure or residual radioactive contaminants” at the property leased to Richland Specialty Extrusions in the 313 Building (Danielson 2000).

Appendix F

Figures

Appendix F – Figures

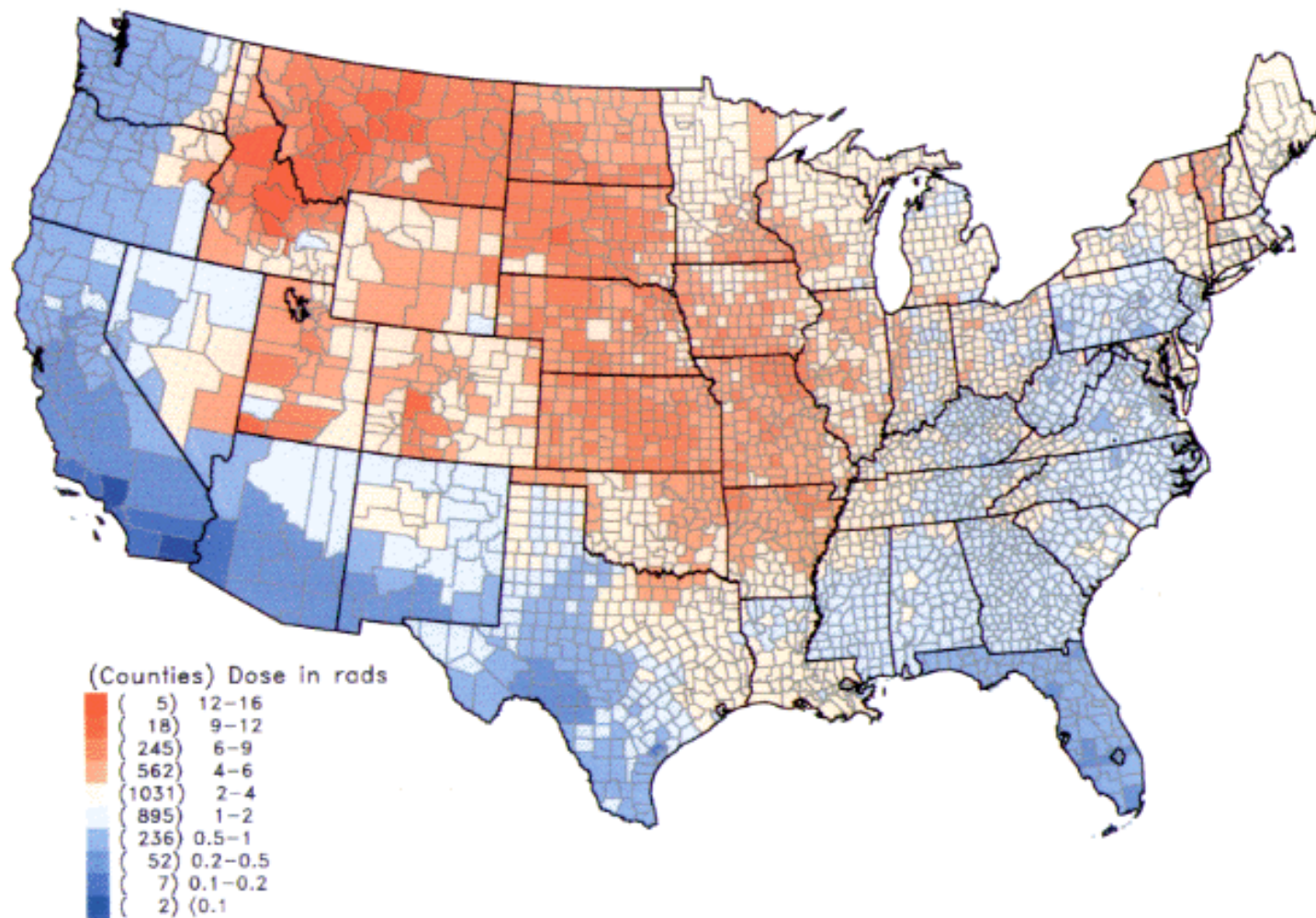


Figure 13. Overall I-131 per Capita Dose from Nevada Test Site Fallout (from reference HHS 1997)