Site Characterization

This section provides a brief overview of the Hanford Site, including historical operations of the Site, environmental information, historical waste management practices, and environmental monitoring of the Site.

Overview of Historical Operations

Many reports, documents, and books have been written about the Hanford Site and its history. The following is excerpted from a summary of the 1994 Hanford Site environmental report (Dirkes and Hanf 1995). An anthology of early Hanford history provides additional information that may be of interest (Gerber 1993).

The Hanford Site lies within the semiarid Pasco Basin of the Columbia Plateau in southeastern Washington State (Figure 1). The Hanford Site occupies an area of about 1450 km^2 (approximately 560 mi^2) located north of the City of Richland and the confluence of the Yakima River with the Columbia River. This large area has restricted public access and provides a buffer for the smaller areas onsite that historically were used for producing nuclear materials, waste storage, and waste disposal. Only about 6 percent of the land area has been disturbed and is actively used. The Columbia River flows eastward through the northern part of the Hanford Site and then turns south, forming part of the eastern boundary. The Yakima River flows along part of the southern boundary and joins the Columbia River downstream from the City of Richland. Land in the surrounding environs is used for urban and industrial development, irrigated and dry-land farming, and grazing.

The Hanford Site was established in 1943 to produce raw materials (plutonium) for nuclear weapons and was the first nuclear production facility in the world. The Hanford Site was selected by the U.S. Army Corps of Engineers because it was remote from major populated areas and had ample electrical power from Grand Coulee Dam, a functional railroad, clean water available from the Columbia River, and plenty of sand and gravel available onsite for construction. The Hanford Site was divided into a number of operational areas. Figure 1 shows the various reactor areas. For example, 100-D is the location for the D and DR reactors.

Operations at the Hanford Site resulted in the production of liquid, solid, and gaseous wastes. Most wastes resulting from Hanford Site operations have had at least the potential to contain radioactive materials. From an operational standpoint, radioactive liquid wastes were originally categorized as “high-level,” “intermediate-level,” or “low-level” depending on the level of radioactivity present. High-level liquid wastes were first stored in large underground single-shell tanks. The contents of some of these tanks have since leaked into the soil. In later years, high-level liquid wastes were stored in double-shell tanks, which have not leaked waste into the soil. Intermediate-level liquid waste streams were usually routed to various types of underground structures called “cribs.” Occasionally, trenches were filled with the liquid waste and then covered with soil after the waste had soaked into the ground. Low-level liquid waste

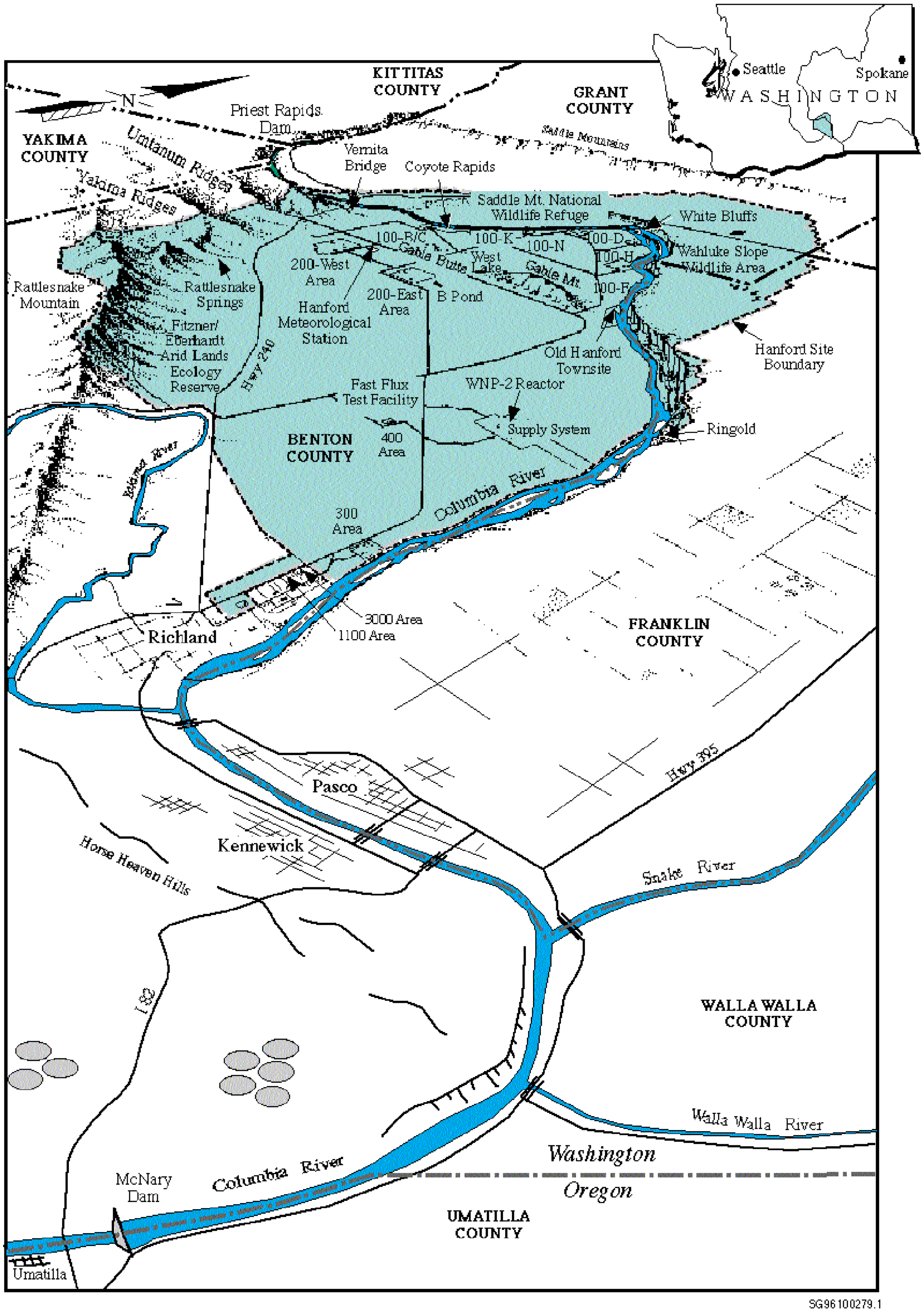

Figure 1. The Hanford Site and Surrounding Area

streams were usually routed to surface impoundments (ditches and ponds). In most cases, intermediate- and low-level liquid wastes were allowed to penetrate the soil to the groundwater. Some of the contaminants that reached the groundwater have subsequently flowed with the groundwater into the Columbia River.

300 Area

From the early 1940s to the present, most research and development activities were carried out in the 300 Area located just north of Richland. The 300 Area was also the location of nuclear fuel fabrication. Nuclear fuel in the form of pipe-like cylinders (fuel slugs) was fabricated from purified uranium shipped in from offsite production facilities. Metallic uranium was extruded into the proper shape and encapsulated. Copper metal was an important material used in the extrusion process; and substantial amounts of copper, uranium, and other heavy metals ended up in 300 Area liquid wastes. Such low-level liquid wastes were routed to ponds located along the shoreline of the Columbia River. In more recent times, the low-level liquid wastes were shipped to a solar evaporation facility in the 100-H Area (100-H Storage Basins).

100 Areas

The fabricated fuel slugs were shipped by rail from the 300 Area to the 100 Areas. The 100 Areas are located on the shore of the Columbia River, where up to nine nuclear reactors were in operation. The main part of the nuclear reactors consisted of a large stack (pile) of graphite blocks that had tubes and pipes running through it. The tubes housed the fuel slugs while the pipes carried cooling water that was eventually returned to the Columbia River. The large collection of slightly radioactive uranium in the reactor piles resulted in an extensive radiation field and a radioactive chain reaction that caused some uranium atoms to be converted into plutonium atoms.

The first eight reactors, constructed between 1944 and 1955, used water from the Columbia River for direct cooling. Large quantities of water were pumped through the piles and discharged back into the river. The discharged cooling water contained radioactive materials that escaped from the fuel slugs, tube walls, etc., during the irradiation process. The radiation field in the pile also caused some of the impurities in the river water to become radioactive from neutron activation. The ninth reactor, N Reactor, was completed in 1963 and was of a slightly different design. Purified water was recirculated through the reactor pile in a closed-loop cooling system. Beginning in 1966, heat from the closed-loop system was used to produce steam, which was sold to the Washington Public Power Supply System to generate electricity at the adjacent Hanford Generating Plant. Although N Reactor did not produce heated cooling water that was returned directly to the Columbia River, the reactor did use a large crib near the shoreline for disposing of radioactive water. Drainage from the crib interfaced with the groundwater, and along the shoreline the drainage created artificial springs containing radioactive materials.

When fresh fuel was pushed into the front of the reactor’s graphite pile, irradiated fuel slugs were forced out the rear into a deep pool of water called a fuel storage basin. After brief storage in the basin and further storage in special freight cars on a railroad siding, the irradiated fuel was transported by rail to the 200 Areas, where the plutonium was recovered. Most of the irradiated fuel produced at N Reactor from the mid-1970s to late 1983 was transported by railcar to the 100-K East and 100-K West fuel storage basins for temporary storage, where some of it remains today.

200 Areas

The 200 East and 200 West Areas are located on a plateau about 11 and 8 kilometers (7 and 5 miles), respectively, south of the Columbia River. These areas housed facilities called separations plants that received and dissolved irradiated fuel and then separated out the valuable plutonium. The REDOX (reduction oxidation) Plant and the PUREX (plutonium-uranium extraction) Plant were the two main separations plants. These plants produced large quantities of waste nitric acid solutions that contained radioactive materials. High-level wastes were neutralized and stored in large underground tanks. Intermediate-level wastes containing fission products, activation products, and nitrate ion were discharged to cribs. Low-level wastes and cooling water from the plants were distributed by open ditch to surface ponds for evaporation and percolation into the ground.

Because the high-level waste stored in tanks was not acidic, various chemicals and radioactive materials precipitated and settled to the bottom of the tanks. This phenomenon was later used to advantage—the liquid waste was heated in special facilities (evaporators) to remove excess water and concentrate the waste into salt cake and sludge, which remained in the tanks. The condensed water contained radioactive tritium (hydrogen-3) and was discharged to cribs.

The REDOX and PUREX separations plants produced uranium nitrate for recycle and plutonium nitrate for weapon component production. Uranium oxide was prepared for reuse and packaged for offsite shipment at the Uranium-Trioxide (UO-3) Plant. The UO-3 Plant discharged wastes containing nitrate ion and uranium to cribs and discharged cooling water to a pond. Plutonium nitrate was received for further processing at one of several buildings collectively known as Z Plant. Processes at Z Plant used nitric acid, hydrofluoric acid, carbon tetrachloride, and various oils and degreasers. Varying amounts of all these materials ended up in intermediate-level waste streams that were discharged to cribs. Cooling water was sent to a pond by an open ditch.

400 Area

In addition to research and development activities in the 300 Area, the Hanford Site has supported several test facilities. The largest of these was the Fast Flux Test Facility, a special nuclear reactor designed to test various types of nuclear fuel. The facility operated for about 13 years and has been shut down since 1993. The reactor was of a unique design that used liquid metal sodium as the primary coolant. The heated liquid sodium was cooled with atmospheric air in heat exchangers. Generated wastes were transported to the 200 Areas.

Richland Areas

Areas near north Richland provide Hanford Site support services. The 1100 Area, about 1.8 kilometers (1.1 miles) west of the Columbia River, is the location of general stores and the transportation maintenance facility for the Hanford Site. Operations at the transportation maintenance facility resulted in ground contamination from several chemicals, oils, and greases. No radioactive waste was discharged to the ground in the 1100 Area. The U.S. Army Corps of Engineers completed remedial actions to remove hazardous waste from the 1100 Area in September 1995.

Other Areas

At the Hanford Site several areas, totaling 665 km^2 (257 mi^2), have been set aside for special uses. The Fitzner/Eberhardt Arid Lands Ecology Reserve, used for ecological research, was established in 1967 on land between the southern boundary of the Hanford Site and Highway 240. In 1975, that portion of the Hanford Site located north of the Columbia River was permitted for use by two government agencies. The U.S. Fish and Wildlife Service manages the Saddle Mountain National Wildlife Refuge, and the Washington State Department of Fish and Wildlife manages a game reserve known as the Wahluke Slope Wildlife Recreation Area. Public access to the wildlife refuge is controlled, whereas the recreation area is open to the public during daylight hours for hunting, fishing, and recreation.

Nuclear operations and activities not under the auspices of the U.S. Department of Energy (DOE) include commercial power production by the Washington Public Power Supply System's WNP-2 Reactor (near the 400 Area) and commercial low-level radioactive waste burial at a site leased and licensed by the State of Washington and operated by U.S. Ecology (near the 200 Areas). Near the southern boundary of the Hanford Site, north of Richland, Siemens Power Corporation operates a commercial nuclear fuel fabrication facility; and Allied Technology Group Corporation operates a low-level radioactive waste decontamination, super-compaction, and packaging disposal facility.

Environmental Setting

Information on the environment at the Hanford Site was summarized from National Environmental Policy Act documentation related to the Hanford Site (Cushing 1995) and other references as noted.

Climate and Meteorology

General climatic conditions for the Hanford Site are recorded at the Hanford Meteorological Station located on the 200 Areas Plateau between the 200 East Area and 200 West Area (Figure 1). Data have been collected at this location since 1945, and historical data summaries have been published by Stone et al. (1972) and Hoitink and Burk (1995). The general climate of the region is influenced by the mountains and hills located west of the Hanford Site. Because of a rain shadow effect caused by the Cascade Mountains, rainfall in the region is limited. The average annual rainfall is 16 centimeters (6.3 inches), and more than half of that occurs from November through February. The hills west of the Hanford Site are a source of cold air drainage, which has a considerable effect on the wind regime on the Hanford Site. Winds along the Columbia River are influenced by the river's topography and are frequently from the west and northwest. Westerly winds occur frequently in the southern part of the Hanford Site. Occasional strong winds out of the southwest at any time of the year can be hazardous to boats on the Columbia River. Fog is common along the Columbia River in the fall when the water is warm and the air is cool.

Geology, Topography, and Soils

The Hanford Site lies within the Pasco Basin of the Columbia River Plateau. The Basin is a structural and topographic low into which the Columbia, Snake, and Yakima rivers drain. Outflow from the basin to the Pacific Ocean is provided by the Columbia River. Through geologic time, a relatively thick sequence of fluvial, lacustrine, and glaciofluvial sediment has accumulated in the Basin. The Hanford formation is the uppermost sedimentary unit covering much of the Hanford Site. Hanford formation sediment consists primarily of sand and gravel deposited by cataclysmic floods during the last ice age. Below these deposits lies the Columbia River Basalt Group, a sequence of continental flood basalts covering more than 160,000 km^2 (about 62,000 m^2) of Washington, Oregon, and Idaho. The Basin boundaries include the Saddle Mountains to the north, the Umtanum and Yakima ridges to the west, and Rattlesnake Mountain and Horse Heaven Hills to the south and southwest. A variety of topography is found on the Hanford Site, including ridges, lower slopes, valleys, ephemeral and discontinuous creeks, and a river.

Fifteen soil types have been identified on the Hanford Site, varying from sand to silty and sandy loam (Hajek 1966). The most important soils associated with the Columbia River include the following:

- Rupert Sand—primarily coarse, sandy, alluvial deposits overlain by windblown sand, located along extensive areas on the west shoreline of the river from near the 100-F Area to the southern boundary of the Hanford Site

- Burbank Loamy Sand—a mantle of loamy sand over gravel, located primarily in the vicinity of the 100-D Area to the 100-H Area

- Ephrata Stony Loam—a medium-textured soil over gravel characterized by topographic hummocks containing many boulders, located near the 100-N Area and 100-K Area

- Ephrata Sandy Loam—a medium-textured soil over deep gravel deposits, occurring from the western boundary of the Hanford Site to the vicinity of the 100-B/C Area

- Riverwash Soil—small areas consisting of sand, gravel, and boulder deposits in wet, periodically flooded areas that make up overflowed islands and shoreland

- Dune Sand—hills and ridges of sand-sized particles that drift into the river upstream of the Washington Public Power Supply System facilities during periods of strong, southwesterly winds

Surface Water

The Columbia and Yakima rivers are the principal surface-water features associated with the Hanford Site. Other onsite surface water bodies include springs, streams, West Lake, and a number of artificial ponds and ditches. Onsite sources of recharge to these surface water bodies include precipitation, overland flow, groundwater, and direct discharge of water from Hanford facilities (Dirkes and Hanf 1996; Cushing 1995; Becker 1990; DOE 1988).

Columbia River

The Columbia River is the second largest river (measuring total flow) in the continental United States and is the dominant surface water body on the Hanford Site. Originating in the mountains of eastern British Columbia, Canada, the river flows south through a gap in the Saddle Mountains, then turns east near Priest Rapids Dam and flows into the northern portion of the Hanford Site. The Hanford Reach of the Columbia River extends from Priest Rapids Dam to the head of Lake Wallula (created by McNary Dam), near the City of Richland, and is currently under consideration for designation as a National Wild and Scenic River. No tributaries enter the Columbia in the Hanford Reach. The bank along the eastern shore of the Hanford Reach in places rises over 150 meters (500 feet) above the surface of the Columbia River, forming the White Bluffs. In total, the water level of the Columbia River drops about 20 meters (70 feet) along its path through the Hanford Site.

The Yakima River runs along part of the southern boundary of the Hanford Site and joins the Columbia River downstream from the City of Richland. Local watershed boundaries reveal that approximately two-thirds of the Hanford Site drains into the Columbia River; the remaining one-third, in the western and southern portions of the Hanford Site, drains into the Yakima River. However, because of the region's small amount of annual precipitation, the Hanford Site does not likely contribute appreciable overland flow into the rivers under normal conditions.

The flow of water in the Columbia River is regulated by 11 dams within the United States, 7 upstream and 4 downstream of the Hanford Site. Priest Rapids Dam is the nearest dam upstream of the Hanford Site, and McNary Dam is the nearest downstream. Flows through the Hanford Reach fluctuate significantly and are controlled primarily by operations at Priest Rapids Dam. Annual flows below Priest Rapids Dam over the last 77 years have averaged nearly 3360 m^3/second (120,000 ft^3/second) (Wiggins et al. 1995). Daily average flows ranged from 1152 to 7787 m^3/second (40,700 to 275,000 ft^3/second). Monthly mean flows typically peak from April through June during spring runoff from melting snow in the upriver watershed. River flow is lowest from September through October and accentuated by extensive river-water removal for agricultural irrigation in the Mid-Columbia Basin.

As a result of fluctuations in discharges, the depth of the Columbia River varies significantly over time. River stage may change along the Hanford Reach by up to 3 meters (10 feet) within a few hours (Dresel et al. 1995). Seasonal changes of about the same magnitude are also observed. River-stage fluctuations measured at the 300 Area are only about half the magnitude of those measured near the 100 Areas because of the effect of the pool behind McNary Dam (Campbell et al. 1993). The width of the Columbia River varies from approximately 300 meters (984 feet) to 1000 meters (3281 feet) within the Hanford Site. Major floods on the Columbia River are typically the result of rapid melting of the winter snowpack over a wide area augmented by above-normal precipitation. Large Columbia River floods have occurred in the past (DOE 1987), but the likelihood of large-scale flooding recurring in the Hanford Reach has been reduced by the presence of dams upstream of the Hanford Site.

Three tributaries join the Columbia River between the Hanford Site and McNary Dam: the Yakima River at river mile 335, the Snake River at river mile 324, and the Walla Walla River at river mile 315. The mean annual discharge of the Yakima River a few miles upstream of the confluence with the

Columbia River at Kiona, Washington, was approximately 70 m^3/second (2500 ft^3/second) for the years 1990-1994 (Wiggins et al. 1995). The Snake River mean annual discharge as measured at Ice Harbor Dam, just upstream of the confluence with the Columbia River, is approximately 1600 m^3/second (54,000 ft^3/second). The mean annual discharge of the Walla Walla River measured prior to entry into the Columbia River is approximately 15 m^3/second (600 ft^3/second). All three contribute a significant volume of sediment to the Columbia River, most notably the Snake River.

Since construction of McNary Dam (completed in 1953), a significant amount of the sediment has been trapped behind the dam (Robertson et al. 1973). However, as is true of the other Columbia River dams, some of the trapped sediment is resuspended and transported downstream by seasonal high discharges. The primary contributor of suspended sediment to the Columbia River is the Snake River (Whetten et al. 1969), but the Yakima and Walla Walla rivers are also significant sources. Sediment contributions from these sources are highly seasonal and related to water-discharge patterns. Sedimentation rates at certain sites behind McNary Dam have been assumed to be as high as 30 centimeters (11.7 inches)/year (Robertson et al. 1973). Subsequent studies by Beasley et al. (1986) reported sedimentation rates to average 7 (±3) centimeters/year along the Oregon shore, 4 (±2) centimeters/year at midchannel, and 2 (±1) centimeters/year near the Washington shore.

Sediment accumulates faster on the Oregon shore than the Washington shore because sediment input from the Snake and Walla Walla rivers is constrained to the near shore (Oregon side). Based on visual observations from past sediment-monitoring samples taken for the Pacific Northwest National Laboratory's (PNNL's) Surface Environmental Surveillance Project characteristics of the top 1-5 centimeter portion of the bed, sediment at Priest Rapids Dam appeared to be dominated by coarse-to-fine sands and silts. By contrast, cobble, coarse, and fine-sand bed sediment was found at sampling locations along the Hanford Site; and silt and clay sediment was observed at the McNary Dam sampling site (Blanton et al. 1995).

Water from the Columbia River, both upstream and downstream from the Hanford Site, is used extensively for crop irrigation. River water is a source of onsite drinking water and industrial cooling water for facilities and is also used by communities downstream from the Hanford Site. In addition, the Hanford Reach is used for a variety of recreational activities including hunting, fishing, boating, water-skiing, and swimming.

Columbia River Springs

Seepage of groundwater into the Columbia River has been known to occur for many years. Riverbank springs, defined as groundwater discharge zones located above the water level of the Columbia River, were documented along the Hanford Reach long before Hanford Site operations began (Jenkins 1922). McCormack and Carlisle (1984) walked the 66-kilometer (41-mile) stretch of the Hanford Reach shoreline of the Columbia River in 1983 and identified 115 springs. They reported that the predominant areas of groundwater discharge at that time were in the vicinity of the 100-N Area, the old Hanford townsite, and the 300 Area. The predominance of springs in the 100-N Area is no longer valid because of declining water-table elevations in response to a decrease in liquid-waste discharges to the ground. Select springs in the 100-B, 100-D, 100-H, 100-K, and 100-N Areas, the old Hanford townsite, and the 300 Area have been sampled routinely by PNNL's Surface Environmental Surveillance Project since 1988 (Figure 2).

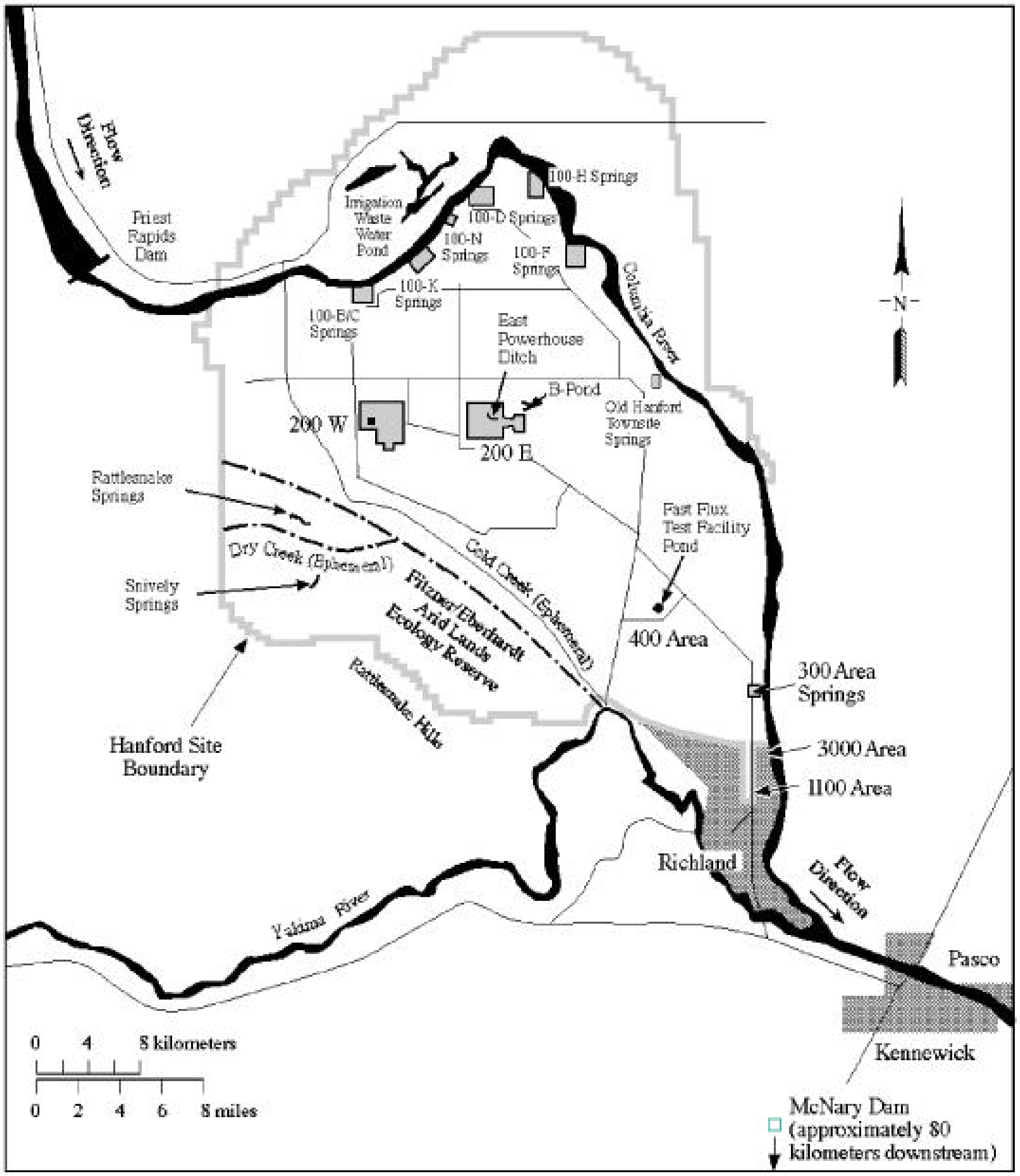

Figure 2. Springs, Ephemeral Streams, Temporary Ponds, and a Ditch on the Hanford Site

However, locating springs in the 100-N Area has become increasingly difficult because of the reduction in volume of liquid-waste discharges there (Dirkes and Hanf 1996).

The presence of springs along the shoreline depends on the height of the water level of the Columbia River. Dresel et al. (1994) reported that groundwater levels in the 100 and 300 Areas were heavily influenced by fluctuations in river stage from operations at Priest Rapids Dam. Water flows into the aquifer (that is, bank storage) as river stage rises, and water flows from the aquifer as river stage falls. Following an extended period of low river discharge, groundwater discharge zones located above the water level of the Columbia River may cease to exist once the level of the groundwater comes into equilibrium with the level of the river. Thus, springs are most readily identified immediately following a decline in river stage.

Bank storage of river water also affects the concentration of contaminants in the spring water. When river stage is high, river water flows into the aquifer and overlays or mixes with groundwater. Typically, this inland flow of river water is restricted to within several hundred feet of the shoreline (McMahon and Peterson 1992). Spring discharge that immediately follows a river stage decline generally consists of river water or a river water and groundwater mix. The percent contribution of groundwater to spring discharge increases over time. Because of the effect of bank storage on groundwater discharge and contaminant concentration, it is difficult to estimate the volume of contaminated groundwater that is discharged to the Columbia River within the Hanford Reach.

Onsite Springs and Streams

Few naturally occurring springs and streams exist on the Hanford Site (Figure 2). All are located in the vicinity of the basalt ridges in the western and southwestern portions of the Hanford Site (Dresel et al. 1995). Rattlesnake Springs and Snively Springs on the Fitzner/Eberhardt Arid Lands Ecology Reserve form small surface streams. Rattlesnake Springs is the largest and flows for approximately 3 kilometers (1.6 miles) before disappearing into the ground.

Onsite Ponds and Ditches

Several ponds and ditches have been created on the Hanford Site for disposing of process and plant cooling waters (Meinhardt and Frostenson 1979; Gephart et al. 1976; ERDA 1975; Summers 1975). The number of ponds and ditches has declined steadily since the shutdown of Hanford Site production facilities. Only two onsite ponds and one ditch remain active in support of current Hanford Site operations. The East Powerhouse Ditch and the 216-B-3C Pond are both located in the 200 East Area, and the Fast Flux Test Facility Pond is located near the 400 Area. The 216-B-3C Pond is one of four ponds (216-B-3, -3A, -3B, and -3C) that are collectively referred to as B Pond. B Pond (Figure 2) was originally excavated in the mid-1950s for disposal of cooling water from B Plant and was expanded in the 1980s. The 216-B-3 and -3A Ponds were decommissioned in 1994, and the 216-B-3B Pond was never activated. The Fast Flux Test Facility Pond was excavated in 1978 for the disposal of cooling water and sanitary water in the 400 Area (Dirkes and Hanf 1995). The 216-B-3C Pond is the only surface disposal facility currently receiving radioactive liquid effluents (Gleckler 1996).

West Lake, the only naturally occurring pond on the Hanford Site, is located north of the 200 East Area (Gephart et al. 1976). West Lake has not received direct effluent discharges from Hanford Site facilities. Its existence is a result of the intersection of the elevated water table with the land surface in a topographically low area south of Gable Mountain and north of the 200 East Area. An artificially elevated water table occurs under much of the Hanford Site and reflects the artificial recharge from Hanford Site operations. The elevation of the water table beneath the 200 Areas has declined since the decommissioning of U Pond in 1984 (200 West Area) and Gable Mountain Pond in 1987 (200 East Area), and the shutdown of other production facilities (Dresel et al. 1994). As a result, the water level in West Lake has dropped such that the pond is often dry during summer and fall.

Yakima River

The Yakima River, which borders a small length of the southern portion of the Hanford Site, has a low annual flow compared with that of the Columbia River. The average annual flow of the Yakima River at Kiona, Washington, for water years 1990 through 1994 was approximately 70 m^3/second (2500 ft^3/second). Daily average flows ranged from 15 to 614 m^3/second (523 to 21,700 ft^3/second) (Wiggins et al. 1995). The Yakima River is generally regarded as a source of recharge to groundwater of the unconfined aquifer in the southern part of the Hanford Site and in the Richland area.

Other Surface Water

The Columbia and Yakima rivers and riverbank springs are the only naturally occurring surface water bodies on or adjacent to the Hanford Site. However, artificial canals, ponds, and wetlands associated with irrigation are also present onsite north of the Columbia River. Offsite, excess irrigation water and drainage water are returned to the Columbia and Yakima rivers at various locations, mostly through canal wasteways. The Ringold Springs Fish Hatchery is a state-owned fish hatchery located on the east shore of the Columbia River upstream from the 300 Area east of the 400 Area. The hatchery uses groundwater from springs created by irrigation.

Groundwater

Both confined and unconfined aquifers are present beneath the Hanford Site. The unconfined aquifer forms the uppermost groundwater zone and has been directly impacted by waste-water disposal at Hanford. The Columbia River is the primary discharge area for the unconfined aquifer. Thus, groundwater beneath the Hanford Site provides a pathway to the Columbia River for contaminants derived from the Hanford Site. The following information on Hanford Site hydrology was summarized from Dirkes and Hanf (1996), Dresel et al. (1996), Cushing (1995), DOE (1988), and other references as noted.

Hydrology

An unconfined aquifer and a sequence of confined aquifers underlie most of the Hanford Site. Perched water-table conditions have been encountered in sediment above the unconfined aquifer in the 200 West Area (Last and Rohay 1993; Airhart 1990) and in irrigated offsite areas east of the Columbia River (Brown 1979). The unconfined aquifer is generally located in unconsolidated to semiconsolidated sediment that overlies the basalt bedrock and is commonly referred to as the Hanford unconfined aquifer. The confined aquifers are located on the tops of basalt flows and sedimentary interbeds located between basalt flows of the Columbia River Basalt Group (Spane and Raymond 1993).

In general, the unconfined aquifer is located in the upper parts of the Ringold Formation. Because the sand and gravel of the Ringold Formation are generally more consolidated, contain more silt, and are less well-sorted, they are about 10 to 100 times less permeable than the sediment of the overlying Hanford formation. Before waste-water disposal operations began at the Hanford Site in 1944, the uppermost aquifer was almost entirely within the Ringold Formation, and the water table extended into the Hanford formation at only a few locations near the Columbia River (Newcomb et al. 1972). However, waste-water discharges caused the water table elevation to rise into the Hanford formation in the vicinity of the 200 Areas and in a wider area near the Columbia River. This rise in the elevation of the water table resulted in an increase in the rate of groundwater flow because of the greater thickness and high permeability of Hanford formation sediments. Depth to the water table ranges from 0 meters (water level of the Columbia River) to more than 106 meters (348 feet) near the 200 Areas. The Columbia River is the primary discharge zone for the unconfined aquifer beneath the Hanford Site (Luttrell et al. 1992).

Recharge to the unconfined aquifer originates from several sources, both natural and artificial (Graham et al. 1981). Natural recharge occurs from the infiltration of precipitation and irrigation in areas west of the Hanford Site and from the Yakima River along the southern boundary of the site. Most onsite artificial recharge of groundwater is from current Hanford Site operations in both the 200 Areas and the 300 Area. Since 1944, the artificial recharge from Hanford Site waste-water disposal operations in the 200 Areas has been significantly greater than natural recharge. However, the groundwater in the southeastern portion of the Hanford Site is impacted more by offsite activities than by Hanford Site operations. Artificial recharge occurs at the City of Richland recharge basins (used to store Columbia River water for later use) and from crop irrigation west of the 1100 Area. Recharge rates at the Hanford Site have been estimated by Fayer and Walters (1995).

Recharge to groundwater across the Columbia River from the Hanford Site is primarily from irrigation and irrigation canal leakage. The water-table elevation to the east of the Columbia River is from 100 to 150 meters (328 to 492 feet) higher than the water-table elevation on the Hanford Site.

Water-Table Levels

Figure 3 is a map of June 1995 water-table elevation contours for the unconfined aquifer underlying the Hanford Site. The locations of measurement points used in preparing the map are also shown. The contour interval is 2 meters (6 feet) in the Hanford Site area west and south of the Columbia River and 50 meters (164 feet) in the area north and east of the Columbia River where the variation in water-table elevations is much greater. The lowest water-table elevations are found near the Columbia River, which indicate that the river is the major discharge area for the unconfined aquifer. Water-table elevations decrease approaching the Columbia River from either side, showing that groundwater flow converges at the river. Water-table changes for the years 1950 through 1980 were documented by Zimmerman et al. (1986).

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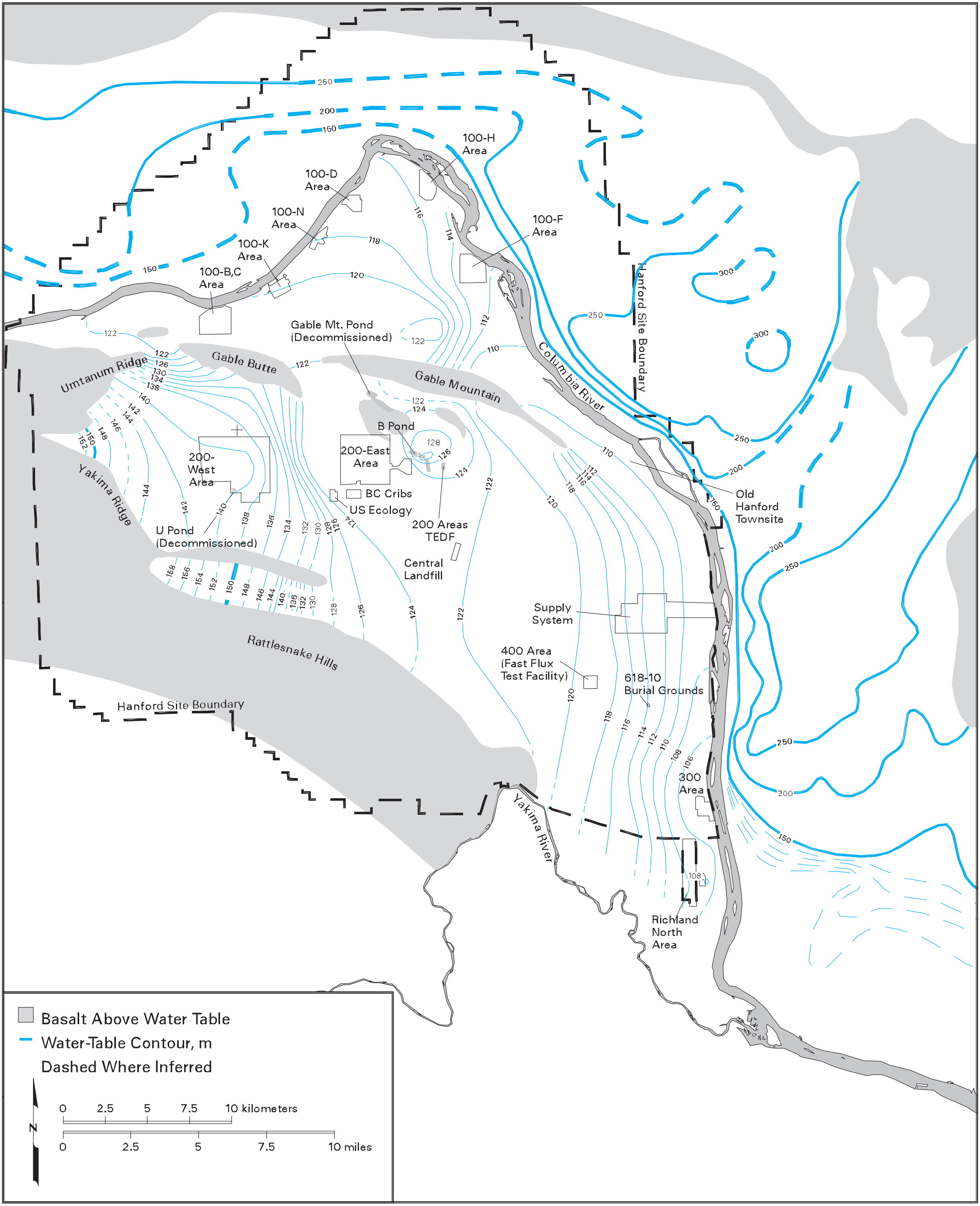
Figure 3. Water-Table Elevations for the Unconfined Aquifer at the Hanford Site and in Adjacent Areas East and North of the Columbia River, June 1995



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Future Water-Table Levels

The volume of water discharged to the ground has been greatly reduced since 1987. As a result, the water table throughout the Hanford Site has begun to decline. The greatest declines of up to 9 meters (30 feet) have been measured in and around the 200 Areas (Kasza et al. 1994). Water levels are expected to continue to decline as the unconfined groundwater system reaches equilibrium with the new level of artificial recharge (Wurstner and Freshley 1994). The largest water level declines are expected to occur around the 200 Areas, but the overall direction of flow should remain the same. Assuming no significant changes in land use, the flow system in the unconfined aquifer will approach pre-Hanford Site conditions as waste-water discharges decrease.

Ecology

The Hanford Site encompasses 1450 km^2 (560 mi^2) of shrub-steppe habitat that is adapted to the region's mid-latitude semiarid climate. Shrub-steppe vegetation in this area typically consists of a shrub overstory with a grass understory. The Columbia River is the dominant aquatic habitat in the area and supports a large and diverse community of plants and animals. Although agriculture and livestock grazing were prevalent at the turn of the century on what would become the Hanford Site, these activities ended when the Hanford Site was established in 1943. Public access to the Hanford Site has been limited since 1943, and most (more than 90 percent) of the land has been idle, allowing vegetation and wildlife to exist relatively undisturbed. For many years, access to the Columbia River was restricted from the Vernita Bridge to the powerline crossing near the point where the Hanford Site boundary crossed the Columbia River upstream of the 300 Area. The following discussion on the Hanford Site's ecology was summarized from Cushing (1995), with additional sources as noted.

Terrestrial Ecology

In the early 1800s, native vegetation of the shrub-steppe was dominated by big sagebrush and underlain by perennial Sandberg's bluegrass and bluebunch wheatgrass. With the arrival of settlers and agriculture, species of non-native vegetation became established and soon dominated the landscape. Approximately 20 percent of all plant species on the Hanford Site are considered non-native. Perennial grasses were mostly replaced with introduced species of annuals such as cheatgrass and Russian thistle (tumbleweed). Annual species remain dominant today in areas that were severely disturbed either by wildfire or human activities, such as historical agricultural practices and current and past construction. A broad definition of vegetation types that occur on the Hanford Site includes shrublands, grasslands, tree zones, riparian areas, and unique habitats.

Shrublands occupy the largest area in terms of acreage and comprise seven of the nine major plant communities on the Hanford Site (Sackschewsky et al. 1992). Of the shrubland types, sagebrush-dominated communities predominate, with other shrub communities varying in composition with changes in soil and elevation. In addition to sagebrush, the Hanford Site has five predominant species of shrubs: green rabbitbrush, gray rabbitbrush, antelope bitterbrush, spiny hopsage, and snow buckwheat.

True grasslands are not present on the Hanford Site, although grasses do occur as an understory in shrub-dominated plant communities. Cheatgrass has replaced many native perennial grass species and is well-established in many low-elevation (less than 244 meters/800 feet) or disturbed areas (Rickard and Rogers 1983). Grass species that prefer moist locations and are associated with the Columbia River include bentgrass, meadow foxtail, lovegrasses, and reed canary grass (DOE 1996).

Trees are unique on the Hanford Site. The landscape lacked trees until homesteaders planted trees near agricultural areas. Currently, approximately 23 species of trees occur on the Hanford Site. Surviving species (for example, cottonwood, poplar, Russian olive, willow, mulberry, and Siberian elm) are aggressive colonizers and have become common and well-established along the Columbia River (DOE 1996).

Riparian areas include sloughs, backwaters, shorelines, islands, and palustrine areas associated with the Columbia River flood plain. Vegetation that occurs along the river shoreline includes emergent water milfoil, water smartweed, pondweed, sedge, reed canary grass, and bulbous bluegrass. Other riparian vegetation occurs in association with perennial springs, seeps, and artificial ponds and ditches on the Hanford Site. The artificial habitats are ephemeral but have contributed to the establishment of cattail, reed canary grass, willow, cottonwood, and Russian olive in areas otherwise devoid of riparian species. Wetland habitat that occurs in association with the Columbia River includes riffles, gravel bars, oxbow ponds, backwater sloughs, and cobble shorelines. These habitats occur infrequently along the Hanford Reach and have acquired ecological significance because of the net loss of wetland habitat elsewhere within the region. Emergent species include reed canary grass, common witchgrass, and large barnyard grass. Rushes and sedges occur along the shorelines of several sloughs along the Hanford Reach at White Bluffs, below the 100-H Area, downstream of the 100-F Area, and at the Hanford Slough.

Unique habitats on the Hanford Site include rock outcrops, bluffs, dunes, and islands. Island habitats account for approximately 474 hectares (1170 acres) and approximately 64 kilometers (40 miles) of river shoreline within the main channel of the Hanford Reach (Hanson and Browning 1959). Islands vary in types of soil and vegetation and range from narrow cobble benches to extensive dune habitats. The islands accommodate many of the same species that occur in mainland habitats. Operation of Priest Rapids Dam upstream of the Hanford Reach creates daily and seasonal fluctuations in river water levels, which may limit the development of plant communities and continued use by terrestrial animals and birds. Shoreline riparian vegetation that characterizes the islands includes willow, poplar, Russian olive, and mulberry. Species occurring on the island interior include sagebrush, buckwheat, lupine, mugwort, thickspike wheatgrass, giant wildrye, yarrow, and cheatgrass (Warren 1980). Management of these islands is a shared responsibility of DOE, the U.S. Fish and Wildlife Service, and the U.S. Bureau of Land Management. Parts of some islands are under private ownership.

To clean up the Hanford Site's approximately 1100 individual inactive waste sites under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC 9601 et seq.), waste sites were grouped into 62 operable units (that is, the specific areas designated for cleanup). Several operable units are located near the Columbia River in the 100 Areas and the 300 Area. The 100 Area operable units, with the exception of 100-HR-3, are characterized by a narrow band of riparian vegetation along the shoreline of the Columbia River with much of the area inland consisting of old agricultural fields dominated by cheatgrass and tumble mustard. The 100-HR-3 operable unit includes a wide riparian band along the northernmost tip of the Hanford Site between 100-D and 100-H Areas. Scattered big sagebrush and gray rabbitbrush also occur throughout the 100 Areas. Washington State threatened, endangered, or sensitive species of vegetation that have been reported for the 100 Area operable units include Columbia yellowcress, southern mudwort, false pimpernel, shining flatsedge, gray cryptantha, and possibly dense sedge (Landeen et al. 1993). Most of these species are located near the 100-B/C Area wetland. The results of a vegetation survey conducted at an operable unit in the 300 Area showed that the shrub-steppe vegetation consisted of an overstory of antelope bitterbrush and big sagebrush with an understory of cheatgrass and Sandberg's bluegrass (Brandt et al. 1993). Dominant riparian vegetation included white mulberry, shrub willow, reed canary grass, bulbous bluegrass, sedges, and horsetail. Columbia yellowcress, a Washington State species of concern, was identified at 18 locations near the 300 Area operable unit (Brandt et al. 1993).

Wildlife

All terrestrial habitats, including riparian areas along the Columbia River, are important to terrestrial species of wildlife. Insects are abundant in emergent grasses and provide forage for fish, waterfowl, and shorebirds. Riparian areas provide nesting and foraging habitat and escape cover for many species of birds and mammals. These areas also are seasonally important to a variety of migratory species. For example, willow plants trap food for waterfowl (such as Canada geese) and other birds (such as Forster's tern) and provide nesting habitat for passerine birds (such as mourning doves). Western toads and frogs are the most common amphibian species occurring near artificial bodies of water and along the Hanford Reach.

Mammals that occur primarily in riparian areas include rodents, bats, furbearers (for example, beaver and mink), porcupine, raccoon, skunk, and mule deer. During the summer months, mule deer rely on riparian vegetation for foraging and periodically cross the Columbia River to access islands or the eastern shorelines. The Columbia River also provides foraging habitat for most species of insectivorous bats (Becker 1993).

Common bird species that occur in riparian habitats include American robin, black-billed magpie, song sparrow, and dark-eyed junco (Cadwell 1994). Predatory birds include common barn owl and great horned owl. Species known or expected to nest in riparian habitat include Brewer's blackbird, mourning dove, black-billed magpie, and the northern oriole. Bald eagles, which have wintered on the Hanford Site since 1960, use trees along the Hanford Reach for daytime perching and communal night roosts. Great blue herons and black crowned night herons are also associated with trees along the Columbia River and use groves or individual trees for perching, nesting, or rookeries.

The Hanford Site is located in the Pacific Flyway, and the Hanford Reach serves as a resting area for migrating waterfowl, shorebirds, and other birds. During the fall and winter months, when ducks and geese are resting along shorelines and on islands, the area between the old Hanford townsite and the Vernita Bridge is closed to recreational hunting.

The White Bluffs, across from 100-F Area and along the eastern side of the Columbia River, provides perching, nesting, and escape habitat for several species on the Hanford Site. The bluffs provide nesting habitat for prairie falcons, red-tailed hawks, and several species of swallows. Bluff areas provide habitat for sensitive wildlife and vegetation species (such as Hoover's desert parsley and the peregrine falcon) that otherwise may be impacted from frequent disturbance.

Columbia River islands afford a unique arrangement of upland and shoreline habitat and provide resting, nesting, and escape habitat for waterfowl and shorebirds. Nesting by Canada geese has been monitored on the islands since 1950. The islands provide suitable habitat for nesting Canada geese because humans are restricted from using the islands during the nesting season and there is suitable substrate, adequate forage, and cover for broods (Eberhardt et al. 1989). The nesting population fluctuates yearly, and in recent years coyote predation has decreased the population (Cadwell 1994). The islands also accommodate large nesting colonies of California gulls and ring-billed gulls. Island areas ranging from 12-20 hectares (30-50 acres) may accommodate colonies of nesting gulls numbering more than 2000.

Insects, reptiles, amphibians, birds, and mammals that occur in CERCLA operable units in general are typical of species that occur across the Hanford Site. During 1991-1993, surveys for birds, mammals, insects, and vegetation were conducted at several of the 100 and 300 Area operable units (Brandt et al. 1993; Landeen et al. 1993). Surveys conducted in 1991 and 1992 at the 100 Area operable units noted the presence of 107 species of birds and 11 of the 29 species of mammals known to occur in the area (Landeen et al. 1993). Species of concern that use the operable units include the American white pelican, bald eagle, and peregrine falcon (Landeen et al. 1993).

Brandt et al. (1993) recorded the results of surveys conducted in 1992 to determine the presence of reptile, bird, and mammal species in the 300 Area operable unit. Reptiles and amphibians present included the western yellow-bellied racer, gopher snake, side-blotched lizard, sagebrush lizard, and several toads and frogs. Fifty-three species of birds, including fourteen riverain and nineteen riparian species were also recorded. Seven species listed as candidates for protection under state or federal regulations included the burrowing owl, common loon, Forster's tern, great blue heron, loggerhead shrike, osprey, and sage sparrow. Fifteen species of mammals were also observed. The most frequently encountered small mammals were the house mouse and Great Basin pocket mouse. Although not observed during the 1992 surveys, Townsend's ground squirrel, black-tailed jackrabbit, Nuttall's cottontail, beaver, mule deer, badger, and coyote are known to use the 300 Area operable unit.

Aquatic Ecology

Two types of natural aquatic habitats can be found on the Hanford Site: the Columbia River and small spring-streams and seeps located mainly in the Rattlesnake Hills. The following discussion was summarized from Cushing (1995) with additional references as noted.

The Columbia River and its Hanford Reach are the dominant aquatic ecosystem on the Hanford Site. The river is a very important resource to the local region. Public Law 100-65, passed by Congress in 1988, authorized the study of the Hanford Reach for possible designation as a wild and scenic river. In 1994, based on the results of this study, the National Park Service (NPS 1994) recommended creation of a 41,310-hectare (102,000-acre) national wildlife refuge. Lands on the Hanford Site currently designated as a wildlife refuge and a game reserve are only administered by the National Fish and Wildlife Service and

Washington State Department of Fish and Wildlife, respectively. The National Park Service further recommended that the Hanford Reach and its corridor be designated as a recreational river in the national wild and scenic rivers system. The refuge and river would be administered by the U.S. Fish and Wildlife Service. Before such a plan can become law, it must be endorsed by the Secretary of the Interior and enacted by Congress. If enacted, the designation would not preclude existing land use and recreational use of the river for boating, hunting, and fishing, but it would preclude expansion of agriculture and other noncompatible development within the refuge and river corridor. Establishing the lands adjacent to the river as a national wildlife refuge would increase protection to all habitat types within and along the reach, protect both terrestrial and aquatic resources, and benefit the entire Hanford Reach ecosystem.

The Columbia River is a complex ecosystem because of its size, number of alterations (for example, dams), biotic diversity, and size and diversity of its drainage basin. With its series of large reservoirs, the Columbia River contains significant populations of primary energy producers (algae and plants) that provide for the basic energy requirements of insects, fish, birds, and mammals. Phytoplankton (free-floating algae) and periphyton (attached algae) are abundant in the Columbia River and provide food for herbivores such as immature insects, which in turn are consumed by carnivorous species. Plankton populations in the Hanford Reach are influenced by communities that develop in the reservoirs of upstream dams, particularly Priest Rapids Reservoir, and by manipulation of water levels in downstream reservoirs. Phytoplankton and zooplankton populations at the Hanford Site are largely transient, flowing downstream from one reservoir to another.

Phytoplankton species identified from the Hanford Reach include diatoms, golden or yellow-brown algae, green algae, blue-green algae, red algae, and dinoflagellates. Diatoms are the dominant algae in Columbia River phytoplankton, usually representing more than 90 percent of the populations (Neitzel et al. 1982a). The peak concentration of phytoplankton is observed in April and May, with a secondary peak in late summer and early autumn. Minimum numbers are present in December and January (Cushing 1967a). Periphyton consists of small plants (benthic microflora) attached mostly to river rocks. However, communities of periphyton will develop on any suitable solid substrate wherever sufficient light exists for photosynthesis. Peaks of production occur in spring and late summer (Cushing 1967b). The dominant genera of periphyton communities are diatoms.

Macrophytes are large plants rooted in areas where the ground is consistently wet or areas are covered with shallow water. Macrophytes are sparse in the Hanford Reach because of strong currents, a rocky bottom, and frequently fluctuating water levels. Macrophytes are more common downstream in the reservoir behind McNary Dam and where rushes and sedges occur along shorelines of slack-water areas such as White Bluffs Slough below the 100-H Area, the slough area downstream of the 100-F Area, and Hanford Slough. Macrophytes are also present along gently sloping shorelines that are subject to flooding during the spring freshet and daily fluctuating river levels (below Coyote Rapids and the 100-D Area). Large areas of macrophytes occur at the confluence of the Yakima and Columbia rivers. Macrophytes have considerable ecological value because they provide food and shelter for juvenile fish and spawning areas for some species of warm-water game fish. However, they encourage increased sedimentation of fine particulate matter, which can have a significant impact on the ecology of the Columbia River.

Populations of zooplankton, which consist of minute animals, are generally sparse in the Hanford Reach. In areas of open water, crustacean zooplankters are dominant. Population densities are lowest in winter and highest in the summer, with summer peak densities ranging up to 4500 organisms/m^3 (130 organisms/ft^3). Winter densities are generally fewer than 50 organisms/m^3 (fewer than 2 organisms/ft^3) (Neitzel et al. 1982b).

Benthic organisms (as opposed to benthic microflora) are small animals found either attached to or closely associated with river rocks or other substrata. All major fresh water benthic taxonomic groups are represented in the Columbia River. Insect larvae such as caddisflies, midge flies, and black flies are dominant. Other benthic organisms include limpets, snails, sponges, and crayfish. Peak larval insect densities are found in late fall and winter, and the major emergence is in spring and summer (Wolf 1976). The stomach contents of fish collected in the Hanford Reach from June through March revealed that benthic invertebrates are important food items for nearly all juvenile and adult fish.

At least 43 species of fish were recorded in the Hanford Reach of the Columbia River by Gray and Dauble (1977). The brown bullhead has been collected since that study, bringing the current total to at least 44. Of these species, chinook salmon, sockeye salmon, coho salmon, and steelhead trout use the Columbia River as a migration route to and from spawning areas and have the greatest economic importance. Both fall chinook salmon and steelhead trout spawn in the Hanford Reach. The relative contribution of upper-river bright stocks to fall chinook salmon runs in the Columbia River increased from about 24 percent of the total in the early 1980s to 50-60 percent of the total by 1988 (Dauble and Watson 1990). The destruction of other Columbia River spawning grounds by dams has increased the relative importance of the Hanford Reach as a spawning area (Watson 1970, 1973). Other fish of importance to sport anglers are mountain whitefish, white sturgeon, smallmouth bass, crappie, catfish, walleye, and yellow perch. Large populations of rough fish are also present, including carp, redside shiner, suckers, and northern squawfish.

Shad, another anadromous species, may also spawn in the Hanford Reach. The upstream range of the shad has been increasing since 1956, when fewer than 10 adult shad ascended McNary Dam. Since then, the number ascending Priest Rapids Dam, immediately upstream of the Hanford Site, has risen to many thousands each year; and current year juveniles have been collected in the Hanford Reach. The shad does not depend on the specific current and bottom conditions that the salmonids require for spawning and has apparently found favorable conditions for reproduction throughout much of the Columbia and Snake rivers.

Studies were initiated in the spring of 1993 to evaluate the potential for using retired 100-K Area water basins for fish production (Dauble et al. 1994). Pilot studies indicated that juvenile fall chinook salmon could be transported to the facility and successfully held before being released in the Columbia River. Other studies were conducted by the Yakama Indian Nation as part of their expansion of fall chinook salmon rearing. In 1994, approximately 500,000 young salmon were successfully reared in 14 net pens and released directly to the Columbia River via a pipeline. Another study involved rearing about 75,000 larval walleye and 27,000 juvenile channel catfish in other basins. In the spring of 1995, the Yakama Indian Nation reared up to 1 million fall chinook salmon at the 100-K facility using two of the basins and up to 28 net pens. The Nez Perce Tribe transferred some young sturgeon from the 100-K facility to a hatchery upstream of Lower Granite Reservoir on the Snake River to be used as brood stock for future supplementation of depleted Snake River stocks.

Wetlands

Several habitats on the Hanford Site could be considered wetlands, but the largest and most important is the riparian zone bordering the Columbia River. The extent of this zone in the Hanford Reach varies but includes extensive stands of willows, grasses, various aquatic macrophytes, and other plants. The riparian zone is extensively impacted by both seasonal water-level fluctuations and daily variations related to power generation at Priest Rapids Dam immediately upstream of the Hanford Site. Other extensive areas of wetlands occur at the confluence of the Yakima and Columbia rivers and in slack-water areas farther downstream in the reservoir behind McNary Dam.

Threatened and Endangered Species

No plants or mammals on the federal list of threatened and endangered wildlife and plant species are known to occur on the Hanford Site. However, three bird species on the federal list have been recorded on the Hanford Site. Table 1 shows threatened and endangered species on federal and state lists that have been recorded on the Hanford Site and, thereby, occur within that portion of the study area.

The bald eagle is the only threatened or endangered animal that uses the Columbia River. It is a regular winter resident and forages on dead salmon and waterfowl but has not yet been observed to nest successfully on the Hanford Reach. Access controls are in place along the river at certain times of the year

Table 1. Threatened (T) and Endangered (E) Species Occurring or Possibly Occurring within the Hanford Site

Common Name	Federal	State
Plants		
Columbia milkvetch		T
Columbia yellowcress		E
Dwarf evening primrose		T
Hoover's desert parsley		T
Birds		
Aleutian Canada goose[a]	T	E
American white pelican		E
Bald eagle	T	T
Ferruginous hawk		T
Peregrine falcon[a]	E	E
Sandhill crane[a]		E
(a) Incidental occurrence.		

to prevent the disturbance of eagles. The Washington State Bald Eagle Protection Rules were issued in 1986, and DOE prepared a site management plan to mitigate eagle disturbance (Fitzner and Weiss 1994).

Four species of plants listed as threatened or endangered by the State of Washington are found on the Hanford Site. Only Columbia milkvetch and Columbia yellowcress are associated with the Columbia River. Milkvetch occurs on dry-land benches along the Columbia River near Priest Rapids Dam, Midway, and Vernita. Yellowcress occurs in the wetted zone of the water's edge along the Hanford Reach. Northern wormwood is another plant listed by the state as an endangered species and is known to occur near the town of Beverly, upstream of Priest Rapids Dam. The shoreline of the Columbia River across from the 100 Areas could provide a suitable habitat for northern wormwood, but it has not been observed there.

Hazardous Waste Materials

Historical operations at the Hanford Site produced considerable quantities of hazardous waste that contained radioactive as well as chemical contaminants. These wastes continue to impact the Columbia River, mainly from contaminated groundwater entering the river. Current operations continue to produce hazardous wastes but in much smaller quantities. Below is a brief summary of historical waste management practices that continue to impact the Columbia River and where current wastes are generated. Additional detail can by found in Dirkes and Hanf (1996), Schmidt et al. (1996), Cushing (1995), ERDA (1975), and other references as noted.

100 Areas

The 100 Areas collectively housed eight plutonium production reactors that operated from 1944 through 1971 and used the Columbia River as a direct source of cooling water. The cooling water became contaminated with radioactive materials that leaked from the nuclear fuel as well as from neutron activation of elements in reactor construction materials and natural elements (mostly uranium) present in Columbia River water. The water was also treated with chemicals (frequently solutions containing chromium) to inhibit fouling and corrosion. After passing through the reactors, the heated and contaminated water was returned to the Columbia River. The composition of the radionuclides and activity level in the discharged cooling water varied considerably (Walters et al. 1992). Important factors were as follows:

- number of reactors operating and their power levels
- seasonal changes in the natural elements found in raw river water
- chemicals used in water treatment
- corrosion rates of piping and fuel-element cladding
- occasional purging of radioactive film from reactor components
- length of time effluent was retained in basins before discharge
- episodic fuel-element failures

The ninth operating reactor, N Reactor, began operations in 1963 and was shut down in January 1987. N Reactor used a closed-loop cooling system, and heated cooling water was not returned directly to the

Columbia River. However, various waste materials were discharged into cribs and ditches at each of the six reactor areas, and groundwater in the unconfined aquifer was subsequently contaminated. Full-scale remediation at 37 former liquid disposal sites in the 100 Areas began in 1996.

As a result of historical water disposal practices, groundwater mounds were created, and water soluble contaminants gradually flowed into the Columbia River at springs and seeps. At the 100-N Area, contaminated water that was discharged into two large cribs located near the shoreline soon created artificial springs along a short stretch of riverbank, which are collectively referred to as N Springs. The 1301-N crib was permanently retired from service in September 1985 and currently does not receive liquid wastes. The 1325-N crib continues to receive small amounts of cooling water, steam condensate, and low-level radioactive liquid wastes from N Reactor facilities. Continued ground disposal and the groundwater mound created during historical operations are responsible for continued water flow at N Springs. Historical operations at the 100-D and 100-H Areas contaminated the groundwater with non-radioactive chromium. In 1994, a groundwater pump-and-treatment system began operation to remove chromium from the contaminated groundwater. The prototype system was shut down in the fall of 1996, and a new, expanded system began operations during the summer of 1997.

Current operations at the 100-K and 100-N Areas continue to dispose of small quantities of liquid wastes to the ground and the Columbia River. Sanitary sewage is currently discharged to the ground at the 100-B, 100-D, 100-H, and 100-K Areas where the disposal systems consist of septic tanks and drainfields. Sanitary sewer waste at the 100-N Area is discharged to a sewage lagoon and five septic tanks. National Pollution Discharge Elimination System (NPDES) permits have been granted for seven discharge points. However, only three discharges (one at 100-K, one at 100-N, and one at 100-N springs) are currently active. The discharge at 100-K Area is associated with the operation of the two fuel storage basins currently storing irradiated fuel relocated from N Reactor in December 1989. The Tri-Party Agreement stipulates that the fuel and sludge in the 100-K basins be removed by December 2002 (Ecology et al. 1994). Discharges at the 100-N Area consist of the return of raw cooling water and condensates through a 2.6-meter (102-inch) diameter pipe and the N Springs. Water samples collected from monitoring wells adjacent to N Springs in 1995 occasionally showed traces of oil, grease, iron, and ammonia, but all within the limits of the NPDES permit. A pump-and-treatment system to remove strontium-90 from the groundwater adjacent to N Springs was installed in 1995 and continues to operate.

200 Areas

Many facilities have operated in the 200 Areas since the startup of operations in 1944. The final shutdown of nuclear production reactors occurred in 1987, and the Hanford Site mission shifted from nuclear materials production to waste management, environmental cleanup and restoration, and technology development. As a result, production and support facilities in the 200 Areas were shut down (for example, the Plutonium Finishing Plant in 1989, PUREX Plant in 1990, and Uranium-Oxide Plant in 1993) or converted to support the current Hanford Site mission (such as T Plant and B Plant). New facilities were constructed to provide waste storage, treatment, and disposal. Wastes produced currently are products of waste management, cleanup, and Hanford Site restoration activities. Nearly all liquid wastes generated in the past, both radioactive and chemical, were either sent to large underground storage tanks or released to the environment through various drains, cribs, trenches, ditches, or artificial ponds. Many of the underground storage tanks are known to have leaked significant quantities of wastes into the soil column beneath the tanks.

In recent years, liquid waste discharges to the ground have been curtailed, and by the end of 1995 only B Pond (Figure 2) in the 200 East Area received effluents containing small amounts of radioactive materials. Current discharges are subject to compliance with a Liquid Effluent Consent Order from the Washington State Department of Ecology. DOE has agreed to use the best available technology/all known and reasonable treatment methods to eliminate or clean up liquid discharges and to obtain operating permits. A plan and schedule for compliance of lower priority miscellaneous liquid waste streams throughout the Hanford Site were approved by the Washington State Department of Ecology in 1995. In partial fulfillment of the compliance plan, the annual volume of water discharged to the ground in the 200 Areas was reduced to 4.9 billion liters (1.3 billion gallons) in 1995 from 11 billion liters (3 billion gallons) in 1993. Furthermore, the flow rate at the end of 1995 was equivalent to an annual volume of 790 million liters (210 million gallons). Other wastes discharged to ground include various sanitary sewage systems and powerhouse waste water. Sanitary sewer wastes in the 200 Areas are discharged to septic tanks and drainfields. Sludge pumped from the septic tanks is taken to the 100-N Sewage Lagoon for disposal. Waste water from the 200 East Area powerhouse, which contains no radioactive or hazardous materials, is discharged to an open ditch (Figure 2).

The following briefly describes 200 Area facilities that treat liquid waste streams to avoid ground and groundwater contamination (Dirkes and Hanf 1996):

- *Liquid Effluent Retention Facility*. The Liquid Effluent Retention Facility was constructed to provide interim storage of 242-A Evaporator process condensate suspected of containing waste listed by the Resource Conservation and Recovery Act (RCRA). The 242-A Evaporator is used to reduce the volume of low-level mixed waste contained in tanks. Construction of the Liquid Effluent Retention Facility was completed in 1993, and the facility became operational in 1994. A total of 33 million liters (8.7 million gallons) of process condensate was stored in the facility at the end of 1995.

- *200 Area Effluent Treatment Facility*. The 242-A Evaporator/ PUREX Plant Process Condensate Treatment Facility (200 Area Effluent Treatment Facility) was constructed to provide effluent treatment and disposal capability required for continued operation of the 242-A Evaporator. The facility provides for effluent collection, treatment, and temporary storage to allow treated effluent characteristics to be verified before discharge. It also provides a state-approved land disposal structure for the effluent. The 200 Area Effluent Treatment Facility became operational in 1995 and operated at a treatment rate of 570 liters/minute (150 gallons/minute). Secondary waste generated by the facility is concentrated and packaged to meet state requirements for storing and/or disposing of solid waste.

- *200 Area Treated Effluent Disposal Facility*. The 200 Area Treated Effluent Disposal Facility began operations in 1995. The facility is a collection and disposal system for 13 non-RCRA-permitted effluent streams from the 200 West and 200 East Areas that already meet discharge requirements. The state operating permit limits the average monthly flow to 2400 liters/minute (640 gallons/minute). The effluent is discharged to B Pond, located east of 200 East Area.

Groundwater transport is the only meaningful pathway for historical waste materials released into the environment in the 200 Areas to reach the Columbia River. Radioactive and chemical constituents of liquid wastes released to the environment during historical operations were either retained in the soil column or washed into the groundwater along with excess water. Studies on the retention properties of Hanford Site soils defined the constituents of radioactive and chemical waste that would be retained within the soil column beneath waste disposal structures. The quantity of waste that could be discharged to a crib or trench without the waste constituents reaching the groundwater, except those soluble in water, was also defined and established the predicted useful life of each waste disposal structure. Monitoring the groundwater for the presence of waste constituents also provided information used to control the disposal of liquid wastes. Under proper waste management practices, materials retained in the soil column tend to remain there for an extended period of time. However, waste constituents are subject to downward transport through the soil column if a source of water, acting as a driving force, becomes available.

The historical inventory of waste materials in the groundwater beneath the 200 Areas is gradually being transported to the Columbia River even though groundwater mounds built up under the 200 Areas have been dissipating since nuclear production operations ceased. Radionuclides detected in the groundwater beneath the 200 Areas in 1995 included tritium (hydrogen-3), cobalt-60, strontium-90, technetium-99, iodine-129, plutonium, uranium, and americium-241. Current discharges do not add significant amounts of waste materials to the existing inventory: in 1995, less than 0.02 curie of tritium (hydrogen-3) and less than 0.5 curie for all other radionuclides (Gleckler 1996). Non-radioactive materials detected in the groundwater included carbon tetrachloride, chloroform, chromium, cyanide, fluoride, and nitrate. Groundwater in the 200 West Area has been pumped and treated for the removal of technetium-99, uranium, carbon tetrachloride, and chloroform. Groundwater in the 200 East Area has been pumped and treated for the removal of cobalt-60, technetium-99, cesium-137, and plutonium.

300 Area

Historical nuclear fuel fabrication and research laboratory operations in the 300 Area resulted in the disposal of contaminated process waste waters to two ponds, a sanitary sewer leaching trench, and various cribs. Beginning in the early 1980s, process liquid wastes containing uranium, copper, and other heavy metal contaminants were transported to the 183-H Solar Evaporation Basins (100-H Area) for solidification. Other process wastes were sent to the 300 Area Process Trenches and were allowed to leach into the soil. The 183-H Basins were subsequently decommissioned when fuel manufacturing operations in the 300 Area were curtailed. Waste sludges were removed from the basins in 1990, and demolition began in 1995. Contaminated sediment was removed from the 300 Area Process Trenches in 1991, and the trenches were retired in 1994. Construction of a new 300 Area Treated Effluent Disposal Facility to receive process wastes was also completed in 1994. An NPDES permit was issued to allow the facility to discharge treated effluents to the Columbia River via a subsurface river diffuser near Johnson Island. Sludge generated from operating the facility is packaged in drums and disposed of in an onsite landfill. Current sanitary sewer wastes are discharged to a septic tank and trench system. In 1994, two new NPDES permit applications were prepared for the discharge of 300 Area powerhouse ash waste water and water intake filter backwash to the Columbia River.

400 Area

No radioactive or hazardous liquid wastes are discharged to the ground in the 400 Area. Process sewer wastes are drained to a process pond for disposal (Figure 2), and sanitary sewer wastes are discharged to a septic system and pond.

Environmental Monitoring

Environmental monitoring of the Hanford Site consists of effluent monitoring and environmental surveillance. Effluent monitoring is performed at the facility or at the point of release into the environment. It includes near facility environmental monitoring conducted in the environment near facilities that currently discharge effluents or have discharged them in the past. Environmental surveillance, including groundwater monitoring, consists of sampling and analyzing environmental media on and off the Hanford Site to detect and quantify potential contaminants and to assess their significance to the environment and human health. Details are provided in an environmental monitoring plan for the Hanford Site (DOE 1994).

Effluent Monitoring

Effluent monitoring includes facility effluent monitoring (monitoring effluent at the point of release to the environment) and near-facility environmental monitoring (monitoring the environment near operating facilities).

Liquid effluent that may contain radioactive or hazardous constituents is monitored at facilities before its release to the Hanford Site environment. Effluent monitoring data are evaluated to determine the degree of regulatory compliance for each facility or the entire Hanford Site as appropriate. The evaluations are also useful in assessing the effectiveness of effluent treatment and control systems and management practices. Radioactive, non-radioactive, and chemical liquid effluents released to the Hanford Site environment are documented and reported each year (Gleckler 1996). In addition, monitoring results for liquid discharges to the Columbia River that are regulated by an NPDES permit are reported monthly to the U.S. Environmental Protection Agency. The following discussion is limited to liquid effluent discharges and is derived from Gleckler (1996) and Dirkes and Hanf (1996), where more detailed information may be found. Additional references are noted below.

Liquid effluents have been discharged from facilities in all areas of the Hanford Site. However, because of the changing Hanford Site mission and facility upgrades, the quantity of liquid waste generated has been greatly reduced, and the number of discharge points continues to decrease. The amounts of radioactive materials in liquid effluents discharged at the Hanford Site are approaching levels indistinguishable from background concentrations. Currently, radioactive liquid effluents are discharged only to B Pond in the 200 East Area and to the Columbia River. The waste-water streams feeding these discharges are sampled and analyzed for total alpha activity, total beta activity, and selected radionuclides. The total amount of all radionuclides discharged to the ground in the 200 Areas during 1995 was about 0.41 curies and consisted mostly of strontium-90, ruthenium-106, and tin-113 with lesser amounts of tritium (hydrogen-3), cesium-137, and isotopes of europium. The total amount of radioactive releases to the Columbia River in 1995 from operations at the 100-K and 100-N facilities was about 0.36 curies, consisting mostly of tritium (hydrogen-3) and strontium-90 (Gleckler 1996). Discharges to the Columbia River from 100-N facilities include a 2.6-meter (102-inch) diameter discharge pipe and N Springs. Releases from N Springs are calculated from results for samples collected from an adjacent groundwater monitoring well and from groundwater flow as predicted by a computer model (Gilmore et al. 1992). The amount of strontium-90 entering the Columbia River from N Springs has fallen dramatically, from approximately 2 curies/year in 1991 to about 0.2 curies/year in 1995 (Gleckler 1996).

Non-radioactive hazardous materials are also monitored in liquid effluent streams. Discharges to B Pond or N Springs did not contain reportable quantities of nonradioactive hazardous materials in 1995 (Gleckler 1996). Discharges to the Columbia River from the 300 Area Treated Effluent Disposal Facility exceeded the NPDES allowable concentrations for total suspended solids, copper, or bis(2-ethylhexyl) phthalate on five occasions in 1995 (Dirkes and Hanf 1996). No other NPDES violations were recorded in 1995.

Chemical releases to the environment consist of hazardous chemicals that are discharged directly rather than through a liquid effluent stream. These releases consist almost entirely of accidental spills. Releases of hazardous substances that exceed specified quantities and are continuous and stable in quantity and rate must be reported as required by CERCLA. A synopsis of CERCLA reportable spills is published each year (Dirkes and Hanf 1996).

The Near Facility Environmental Monitoring Program monitors the release of radioactive materials into the environment from new and existing facilities, from surplus facilities awaiting decontamination and decommissioning, and fugitive emissions from uncontained contaminated areas. Environmental samples are collected from near release points and analyzed for radiological and hazardous chemical contaminants. Near facility monitoring results are published each year. Additional current information can be found in Schmidt et al. (1996).

Although B Pond is currently the only surface water disposal facility operating, all surface water disposal sites are monitored regularly. Radiological analyses of liquid samples from these sites include total alpha, total beta, tritium (hydrogen-3), gamma-emitting radionuclides, and plutonium-239, 240. Radiological analyses of sediment and aquatic vegetation include strontium-90, gamma-emitting radionuclides, plutonium-239 and -240, and uranium. Non-radiological analyses and measurements include nitrate, pH (acidity/alkalinity), and temperature. Thirteen groundwater springs and seeps along the 100-N Area shoreline, sampled in 1995, verified that the reported amount of radionuclides released to the Columbia River, as calculated from groundwater data and computer model predictions, were not underestimated. All results were published in Schmidt et al. (1996).

Environmental Surveillance

Environmental surveillance activities, including groundwater monitoring, are conducted routinely both on and off the Hanford Site and consist of detecting and quantifying radiological and non-radiological contaminants in air, soil, vegetation, food, Columbia River water, groundwater, drinking water, sediment, fish, and other freshwater and marine aquatic life. Two projects, Surface Environmental Surveillance and

Groundwater Monitoring, conduct the majority of environmental surveillance activities at the Hanford Site. Activities are also conducted to demonstrate compliance with environmental regulations, confirm adherence to DOE environmental protection policies, support DOE environmental management decisions, and provide information to the public. Emphasis is placed on surveillance of exposure pathways and chemical constituents that present the greatest potential risk to humans and the environment. Samples to be collected, sampling frequency, and the analyses required are identified each year in a master sampling schedule (Bisping 1996a).

Environmental surveillance is conducted as an independent program under DOE Order 5400.1, "General Environmental Protection Program"; DOE Order 5400.5, "Radiation Protection of the Public and Environment"; and the guidance in *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991).

Environmental surveillance results were recorded in quarterly reports from 1946 to 1958. Since 1958, results have been available as annual reports. Current surveillance results for the offsite and onsite environs and a summary of groundwater monitoring results are given in the annual *Hanford Site 1995 Environmental Report* (Dirkes and Hanf 1996). Full details and results for the groundwater monitoring program are given in annual groundwater monitoring reports (for example, Dresel et al. 1996). Additional reports are published when special studies are completed.

Surface Environmental Surveillance

The following discussion is limited to environmental surveillance activities associated with the Columbia River and groundwater flowing into the Columbia River from springs and seeps. The surveillance of springs and seeps is in addition to effluent monitoring at N Springs. River water quality monitoring is currently conducted by PNNL and by the U.S. Geological Survey. More detailed information can be found in Dirkes and Hanf (1995) and Dirkes (1993).

Columbia River Surface Water. The Columbia River has been monitored at the Hanford Site since 1945, shortly after the startup of the original plutonium production reactors. Historically, radiological analyses were the primary focus of river-monitoring activities, with non-radiological analyses gaining importance in recent years. Samples have been collected routinely from several locations including stations upstream of the Hanford Site, along the Hanford Reach, downstream of the Hanford Site, and along the coast of the Pacific Ocean at Willapa Bay, Washington. Following the shutdown of the last single-pass cooling reactor in 1971, the quantity of radionuclides released to the Columbia River decreased significantly. As expected, the amounts of radioactive materials detected in Columbia River water, sediment, and biota decreased accordingly (Cushing et al. 1981; Robertson and Fix 1977; Robertson et al. 1973). Surveillance activities at the Hanford Site were greatly streamlined following the dramatic change in operations in 1971. Emphasis was placed on evaluating the contribution of Hanford Site effluents to radiation doses received by persons living in the vicinity of the Hanford Site and using the Columbia River and its water. The development of computerized databases and computer models to predict environmental concentrations and calculate estimated radiation doses have greatly enhanced the surveillance program.

The main focus on surveillance of the Columbia River is to detect environmental impacts and establish compliance with public health standards, and environmental standards or protection guides, rather than to detail a radiological and chemical characterization. Media from the Columbia River that are collected and analyzed for radionuclides include river water, sediment, vegetation, fish, and other freshwater and marine aquatic life. Current radionuclide analyses include gross alpha, gross beta, gamma scan, tritium (hydrogen-3), strontium-90, technetium-99, iodine-129, plutonium, and uranium. Non-radioactive analyses include metals, anions, and volatile organic compounds.

Currently, only a few fixed sample locations of the Columbia River monitoring network remain. Columbia River sampling locations for 1995 are shown in Figure 4. These locations were chosen to represent background conditions upstream of the Hanford Site (Priest Rapids Dam) and to estimate the amount of radionuclides in Columbia River water at the first downstream point of withdrawal (Richland Pumphouse). In addition, the 300 Area monitoring station is routinely sampled as part of an onsite drinking water surveillance program. Water monitoring results for the years 1980-1989 along the Hanford Reach were summarized by Dirkes (1994). River monitoring results for 1995 are summarized in Dirkes and Hanf (1996), and all results from the surveillance program for 1995 are available in Bisping (1996b). The radionuclides currently measured in Columbia River water, sediment, and biota are from worldwide fallout and the remnants of historical activities at the Hanford Site (Dirkes 1994). Very early in the monitoring program, questions were addressed on how representative shoreline river sampling locations were, with respect to the overall Columbia River. In addition to the routine sample locations, cross-river sampling at numerous transect locations was conducted during the years of peak liquid effluent discharges to observe the channeling of reactor effluent within the river, to better understand the dispersion characteristics of the river, and to accurately interpret single-point monitoring stations located on the river (Sonnichsen et al. 1970; Soldat 1962; Backman 1962; Haney 1957; Honstead 1957; Norton 1957; Honstead 1954; Honstead et al. 1951). Soldat (1962) published data relating to dispersion studies and measurements of radioactivity made on the Columbia River in the vicinity of the Hanford Site from 1946 through early 1961. Results of these studies indicated that contaminant plumes entering the river along the shoreline tended to remain near the shore for several miles downstream of the discharge point. Backman (1962) concluded that effluents discharged from the 300 Area were nearly completely mixed by the time they reached the Pasco water treatment pumping station, approximately 26 kilometers (16 miles) downstream.

Cross-sectional surveys, which were all but eliminated following the shutdown of the single-pass cooling reactors, were reinstated in 1991 as a result of findings of a special study conducted during 1987 and 1988 (Dirkes 1993). The study concluded that under certain flow conditions, tritium (hydrogen-3) entering the river near the old Hanford townsite from the 200 Area groundwater plume was not completely mixed by the time it reached the Richland Pumphouse, located approximately 10 kilometers (6 miles) downstream of the most southerly discharge point of the plume. Interest in cross-sectional sampling was renewed in response to the change in how the primary source of radioactive materials entered the river—from direct effluent discharges to the seepage of contaminated groundwater resulting from past discharges to the ground.

Separately since 1986, under the National Stream Quality Accounting Network program, the U.S. Geological Survey has collected water samples along transects of the Columbia River at Vernita

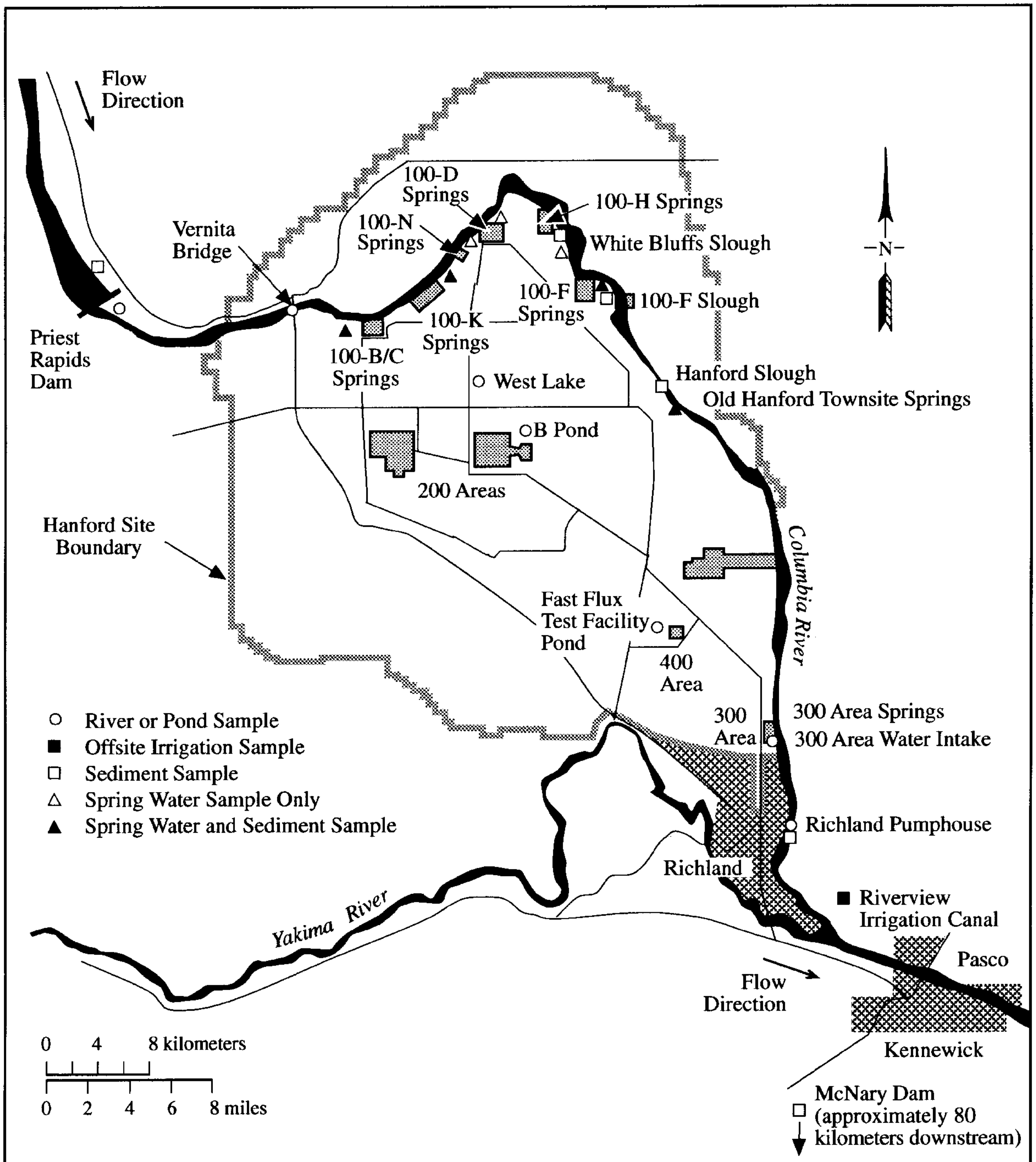

Figure 4. Water and Sediment Sampling Locations, 1995

Bridge and the Richland Pumphouse. Physical measurements and chemical analyses are performed on the samples. Results are reported annually by the U.S. Geological Survey (for example, Wiggins et al. 1996).

Columbia River Sediment. Sediment in the Columbia River contains low levels of radionuclides and non-radioactive metals of Hanford Site origin as well as radionuclides from worldwide fallout (Woodruff et al. 1992; Beasley et al. 1981; Robertson and Fix 1977). Shoreline surveys conducted in 1979 indicated that measurable radioactive contamination resulting from past Hanford generations was present along the shoreline of the Columbia river (Sula 1980). In 1994 the Washington Department of Health conducted a study of the health effects of artificial radioactivity in Columbia River sediment (WA 1994). This study, which did not address "sky shine" from facilities near the river, shoreline "seeps," or effluent pipes, concluded that the doses resulting from artificial radioactivity in Columbia River sediment were very low, less than 1 percent of natural background.

Public exposure to these contaminants is well below the level at which routine surveillance is required. However, periodic sampling is conducted to confirm the low levels and to ensure that no significant changes have occurred. The locations where sediment samples were collected in 1995 are shown in Figure 4. Results for sediment samples collected in 1995 are summarized in Dirkes and Hanf (1996). To understand the distribution of radioactive materials in Columbia River sediments, a special study was conducted in 1995 on the difference in grain-size composition and the total organic carbon content of sediment samples (Blanton et al. 1995).

Columbia River Seeps and Springs. As noted previously, the Columbia River is the primary discharge area for the unconfined aquifer underlying the Hanford Site. Contaminated groundwater enters the river through surface and subsurface discharges. Discharge zones located above river water level are usually called springs. When the flow rate is very low, the discharge is called a seep. Usually, only springs are sampled because of their readily available water. Because of the influence of river water level on spring and seep flow rate, the amount of water discharged to the Columbia River is unknown but believed to be about 0.02 percent of the total flow of the river. The locations of spring sampling for 1995 are noted in Figure 4. Routine monitoring of select riverbank springs was initiated in 1988 at the 100-N Area, the old Hanford townsite, and the 300 Area (Dirkes 1990). Monitoring was expanded in 1993 to include the 100-B, 100-K, 100-D, and 100-H Areas. A spring at 100-F Area was added in 1994. Results for radiological and non-radiological analyses on spring and seep samples collected in 1995 are summarized in Dirkes and Hanf (1996).

Groundwater Monitoring

Groundwater monitoring (surveillance) is an integral part of the groundwater protection plan for the Hanford Site (DOE 1995). The plan integrates monitoring at active waste disposal facilities to comply with RCRA, operational monitoring in and adjacent to reactor and chemical processing facilities, and sitewide groundwater monitoring. Monitoring is also carried out during cleanup investigations under CERCLA programs (DOE 1992). The RCRA and operational monitoring programs are managed by the Hanford Site operating contractor. The CERCLA program is managed by the environmental restoration contractor. The sitewide monitoring program is conducted by PNNL as part of the Hanford Groundwater Surveillance Project. This project uses data from all groundwater monitoring programs to provide as complete an interpretation of present conditions as possible. More detailed information on sitewide monitoring can be found in Dresel et al. (1996) and Dirkes and Hanf (1995). Results for operational monitoring are summarized by Johnson (1993).

Figure 5 shows the locations of unconfined groundwater wells monitored by the various programs in 1995. Groundwater samples are collected from wells completed in the unconfined and upper-confined aquifers. The unconfined aquifer is monitored because it provides a pathway for contaminants to reach onsite water supply wells and the Columbia River. The upper-confined aquifer is monitored less extensively because it provides only a potential pathway for contaminants to migrate off the Hanford Site.

Wells located within known contaminant plumes are monitored to characterize and define trends in the concentrations of the associated radiological or chemical constituents. Wells located along the Hanford Site perimeter are monitored to assess the potential for contaminants to migrate offsite through the groundwater pathway. Background concentrations of naturally occurring chemical and radiological constituents in groundwater are measured in samples from wells located in areas unaffected by Hanford Site operations, including upgradient locations, and provide the best estimate of pre-Hanford Site groundwater quality.

Samples at a particular well were selected for analysis based on the waste materials previously disposed of to the ground in the area, ongoing waste disposal activities, and chemical contaminants observed in the past at that location. Samples were collected at various frequencies depending on the historical trends of constituent data, regulatory or compliance requirements, and characterization requirements. Sampling frequencies range from monthly to annually, with some constituents monitored less frequently than annually in some wells. The annual sampling schedule for 1996 lists the wells to be sampled, analyses to be performed, and frequency of sample collection (Bisping 1996a). Current radionuclide analyses include gross alpha, gross beta, gamma scan, tritium (hydrogen-3), carbon-14, strontium-90, technetium-99, iodine-129, americium-241, plutonium, and uranium. Analyses for chemical constituents include total carbon, total organic carbon, total organic halogens, metals, anions (nitrate), cyanide, ammonium ion, volatile organic compounds, semi-volatile organic compounds, polychlorinated biphenyls (PCBs), dioxins/furans, and pesticides/herbicides. Various physical and chemical properties are also measured.

Certain soluble contaminants, especially tritium (hydrogen-3) and nitrate, move freely with the flow of groundwater. Tritium (hydrogen-3) has been a component of many waste streams discharged to the ground from Hanford Site operations. As a result, the extent of contamination in the groundwater from historical operations, and to some degree current operations, is generally reflected by the distribution of tritium (hydrogen-3) plumes. Figure 6 shows the current distributions of several tritium (hydrogen-3) plumes in the groundwater beneath the Hanford Site. The half-life of tritium (hydrogen-3) is about 12 years, so the plumes gradually change shape as radioactive decay, addition, transport, and dilution take place. Because the amounts of contaminants and volume of process water discharged to the ground have been sharply reduced, radioactive decay becomes the most important factor influencing reduced concentrations of tritium (hydrogen-3) in groundwater.

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Figure 5. Hanford Site Monitoring Well Locations, 1995

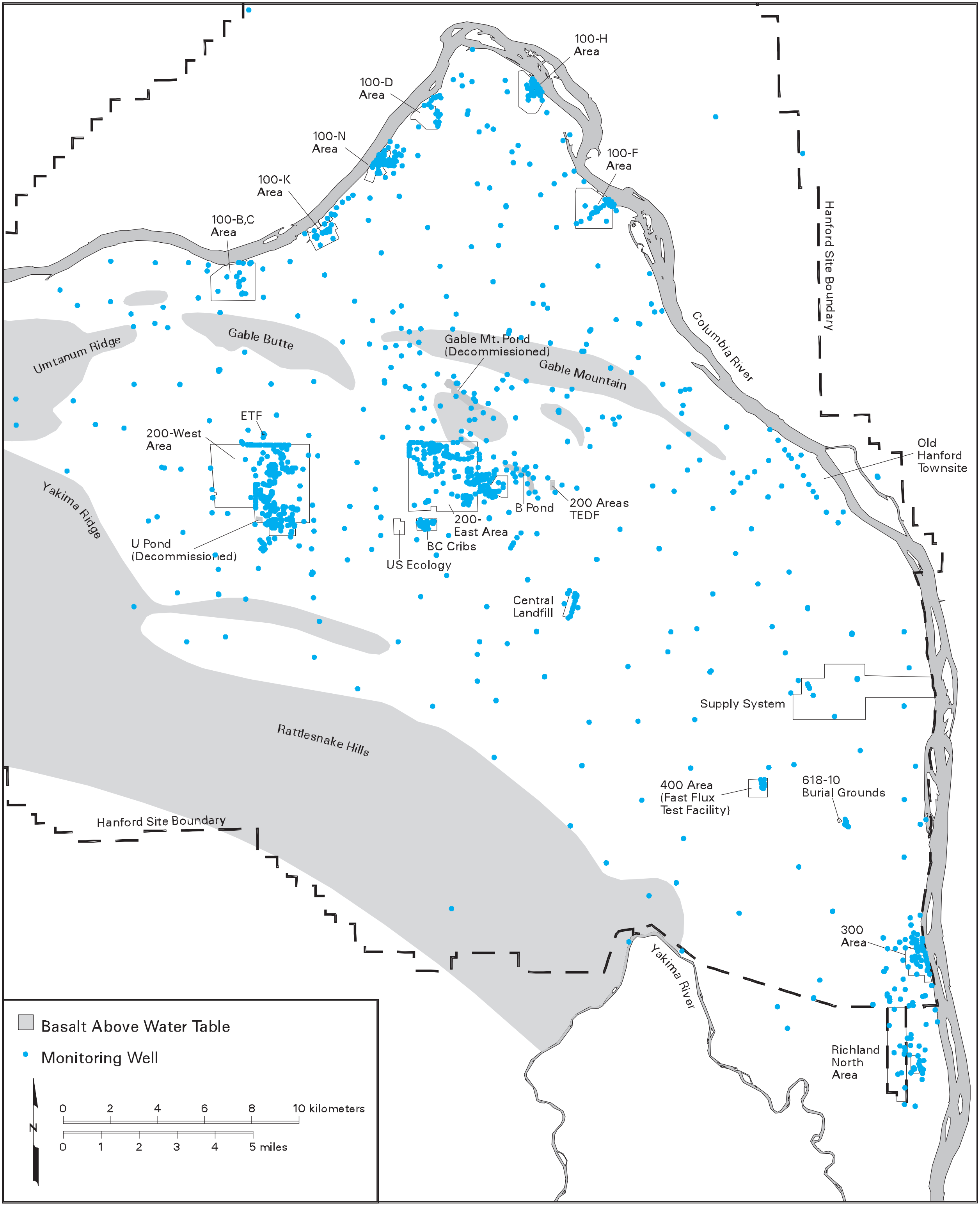

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Figure 6. Distribution of Tritium (Hydrogen-3) in the Unconfined Aquifer, 1995

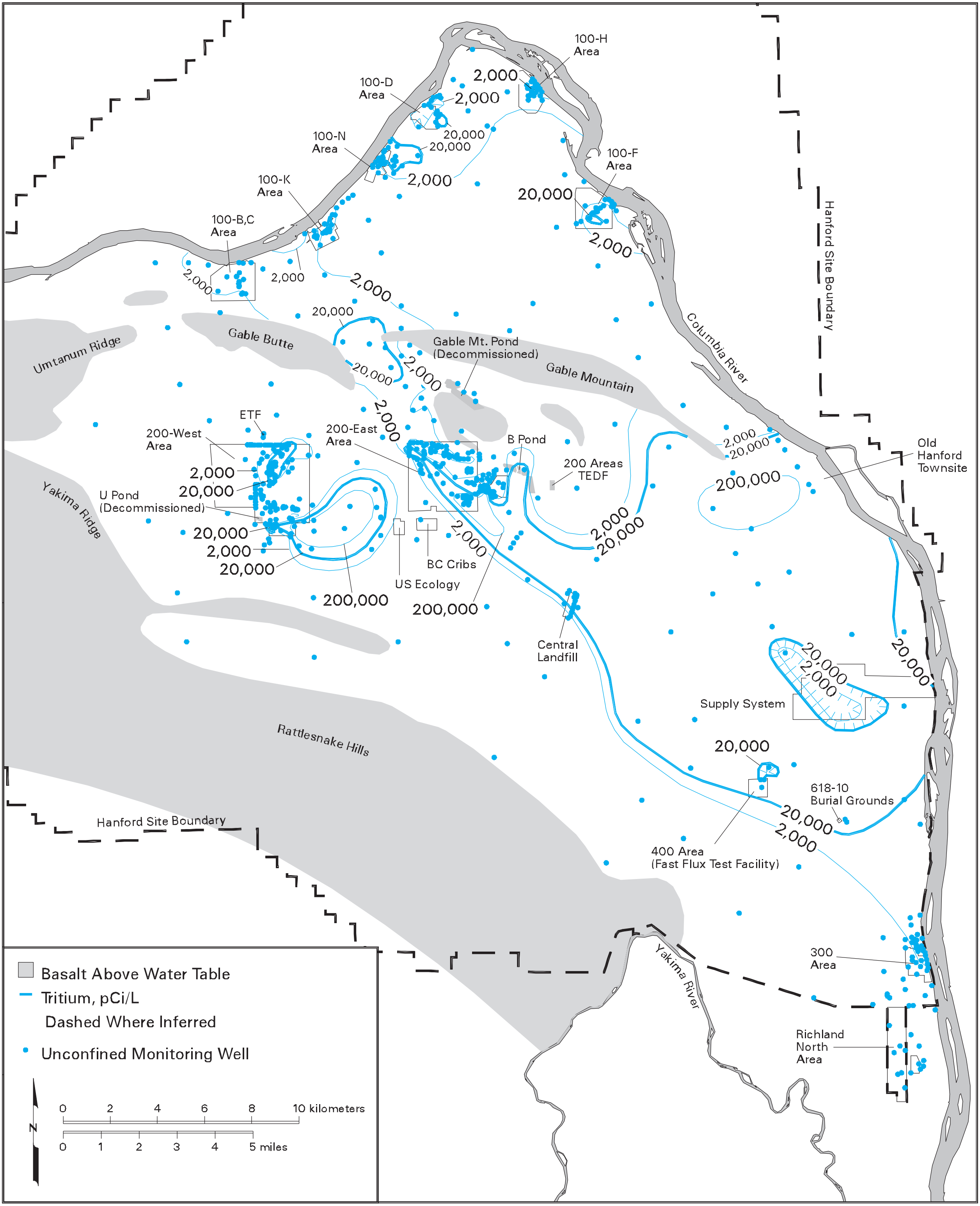

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Figure 7 shows the current plume distribution of nitrate, another soluble groundwater contaminant. Nitrate differs from tritium (hydrogen-3) in that it is a chemical contaminant and does not decay. The shapes of nitrate plumes change primarily in response to addition, transport, and dilution. Contaminants originating from the 200 Areas eventually enter the Columbia River from the vicinity of the old Hanford townsite to the 300 Area. Table 2 lists the groundwater contaminants entering the Columbia River from historical Hanford Site operations. The concentrations detected were greater than the radionuclides in Columbia River water at the first downstream point of withdrawal (Richland Pumphouse) and the respective Drinking Water Standard.

Table 2. Groundwater Contaminants Entering the Columbia River from Historical Hanford Site Operations[(a)]

Location	Contaminant
Near the old Hanford townsite to north of the 300 Area	Tritium (Hydrogen-3), Iodine-129
100-B Area	Strontium-90
100-D Area	Tritium (Hydrogen-3), Chromium
100-F Area	Tritium (Hydrogen-3), Strontium-90, Nitrate
100-H Area	Strontium-90, Chromium
100-K Area	Tritium (Hydrogen-3), Strontium-90, Chromium
100-N Area	Tritium (Hydrogen-3), Strontium-90
300 Area	Uranium

(a) At concentrations greater than the respective Drinking Water Standard as reported in Dirkes and Hanf (1996) and Dresel et al. (1996).

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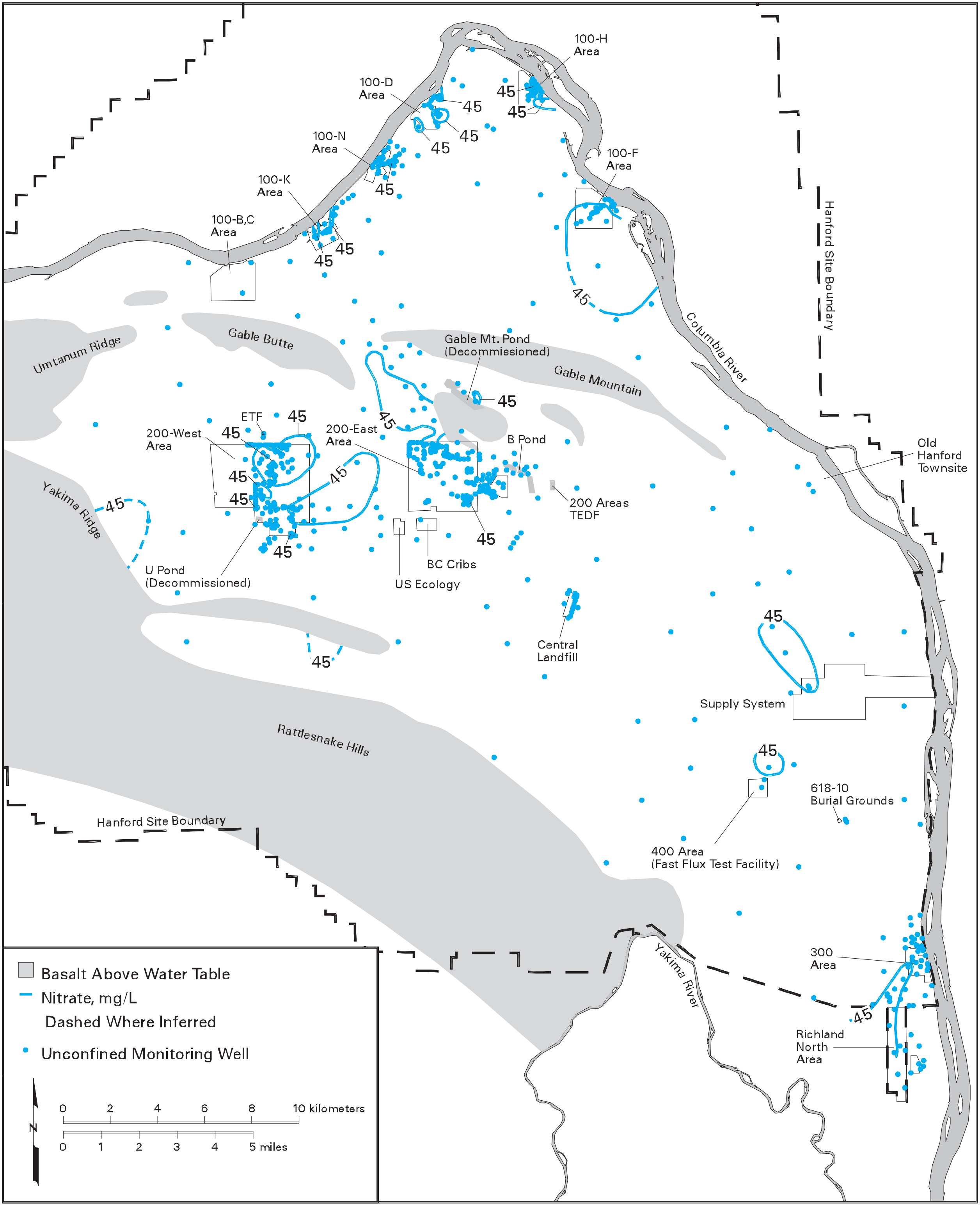
Figure 7. Distribution of Nitrate in the Unconfined Aquifer, 1995



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