MONITORING THE HANFORD SITE AND SURROUNDING ENVIRONMENT: LONG-TERM TRENDS

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ABSTRACT

Environmental monitoring has been conducted on the U.S. Department of Energy's (DOE) Hanford Site for 45 years. Current monitoring objectives are to detect and assess potential impacts of facility operations on air, surface and ground water, soil, vegetation, foodstuffs, fish and wildlife. Data from monitoring efforts are used to calculate the overall radiological dose to humans working onsite or residing in nearby communities.

In 1988, measured Hanford Site perimeter concentrations of airborne radionuclides were below applicable DOE and Environmental Protection Agency guidelines. Tritium and nitrate continued to be the most widespread constituents in onsite ground water. Chromium, cyanide, fluoride and carbon tetrachloride were found in ground water near operating wells. Concentrations of radionuclides and nonradiological water quality in the Columbia River were in compliance with applicable standards. Foodstuffs irrigated with river water taken downstream of the Site showed low levels of radionuclides that were similar to concentrations in foodstuffs from control areas (i.e., foodstuffs not irrigated with Columbia River water). Low levels of ^{90}Sr and ^{137}Cs in some onsite wildlife samples were typical of those attributable to worldwide fallout, as were concentrations of radionuclides in soils and vegetation from onsite and offsite locations. The calculated effective dose potentially received by a maximally exposed individual (i.e., a hypothetical individual using worst-case assumptions for all routes of exposure) in 1988 (0.08 mrem/yr) was similar to doses calculated for 1985 through 1987.

In addition to monitoring radioactivity in fish and wildlife, population numbers of key species are determined. Chinook salmon (Oncorhynchus tshawytscha) spawning in the Columbia River at Hanford has increased in recent years with a concomitant increase in the number of bald eagles (Haliaeetus leucocephalus) that overwinter onsite. The Site also serves as a nesting area and refuge for great basin Canada goose (Branta canadensis moffitti) and great blue heron (Ardea herodias), and supports stable or growing populations of elk (Cervus elaphus), mule deer (Odocoileus hemionus), coyote (Canis latrans), and a variety of plants and other animals.

KEY WORDS: Environmental Monitoring, Radionuclides, Chemicals, Fish, Wildlife

INTRODUCTION

The U.S. Department of Energy's (DOE) Hanford Site occupies a land area of about 1,450 km^2 (560 mi^2) in semi-arid southeastern Washington, U.S.A. (Figure 1). The Columbia River flows through the Site and forms part of its eastern boundary. Flow of the Columbia River is regulated daily according to electric power demands. Although the river was once closed to public access, public use for recreational and barge traffic is again practical. The southwestern portion of the Site includes the southern terminus of the Rattlesnake Hills with elevations exceeding 1,000 m. Both unconfined and confined aquifers lie beneath the Site.

Nuclear and non-nuclear industrial and research activities have been conducted at Hanford since 1943. The most environmentally significant activities have involved the production of nuclear materials and the chemical processing and waste management associated with the major product, plutonium. Byproduct wastes have included gamma, beta, and alpha-emitting radionuclides and various nonradioactive chemicals in gaseous, liquid and solid forms.

There are currently four major DOE operations areas on the Hanford Site (Figure 1). The 100 Areas located along the Columbia River include the dual-purpose N Reactor that produced plutonium for national defense and steam for the Hanford Generating Project (HGP), operated by the Washington Public Power Supply System (WPPSS), and eight, now deactivated single-purpose, plutonium production reactors. The plutonium uranium extraction (PUREX) plant (reactor fuel reprocessing), plutonium finishing plant (Z Plant), and waste-disposal facilities are located in the 200 Areas on a plateau (elevation 229 m) about 11.3 km west of the Columbia River. The 300 Area, located just north of Richland, Washington contains the uranium fuel manufacturing facilities in support of N Reactor, and research and development laboratories. The Fast Flux Test Facility which has operated intermittently since 1981 to test new fuels and materials for future breeder reactor technology is located in the 400 Area. Nongovernment facilities within Hanford Site boundaries include HGP, the WPPSS nuclear plant (WNP) sites, WNP-1, WNP-2 and WNP-4, including one commercial reactor (WNP-2) that achieved full operational status in the fall of 1984, and a commercial low-level radioactive-waste burial site near the 200 Areas, operated by U.S. Ecology. The Advanced Nuclear Fuels Corp. (formerly Exxon) fuel fabrication facility is immediately adjacent to, but not located on, Hanford Site property.

Environmental monitoring has been conducted at Hanford for over 45 years. The monitoring program is designed to assess potential impacts to individuals and populations that may be exposed to radionuclides, ionizing radiation and hazardous chemicals. Environmental monitoring currently includes air, surface and ground water, soil, vegetation, foodstuffs (fruits, vegetables, milk), fish and wildlife. Fish and wildlife are monitored for radioactivity and to determine the population status of key species.

RADIOLOGICAL MONITORING

Air

Potential airborne transport of stack releases containing radionuclides from Hanford facilities offers a direct pathway for human exposure.

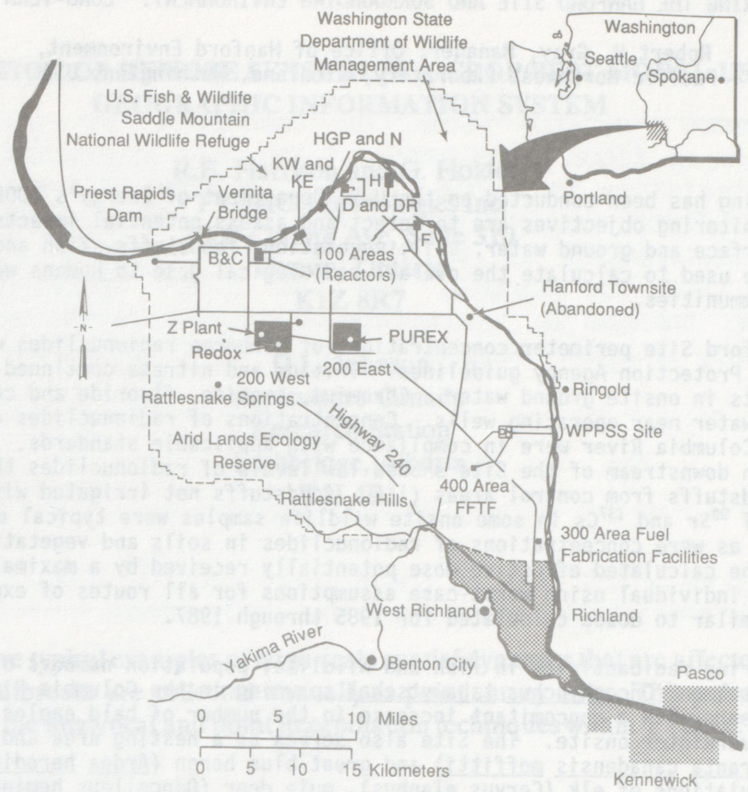

FIGURE 1. The Hanford Site. HGP = Hanford Generating Project; Redox = reduction-oxidation; PUREX = plutonium uranium extraction; WPPSS = Washington Public Power Supply System; FFTF = Fast Flux Test Facility.

Thus, air is sampled continuously for airborne particulates and analyzed for radionuclides at 50 locations onsite, at the Site perimeter, and in nearby and distant communities (Jaquish and Bryce, 1989). At selected locations, gases and vapors are also collected and analyzed. Many of the longer-lived radionuclides released at Hanford are also present in atmospheric fallout that resulted from nuclear weapons testing in the 1950s and 1960s or from nuclear accidents that occurred elsewhere.

In May and June, 1986, air samples collected onsite as well as those from distant locations showed increases in several long- and short-lived radionuclides (e.g., ^{137}Cs, ^{131}I ^{103}Ru) that resulted from the reactor accident at Chernobyl, April 1986, in western Russia. However, even then, no sample exceeded 0.17% of the applicable DOE derived concentration guide (DCG) for areas permanently occupied by the public (PNL, 1987).

Ground Water

The shallow unconfined (water-table) aquifer has been affected by waste-water disposal practices at Hanford more than the deeper, confined aquifers. Discharge of water from various industrial processes has created ground-water mounds near each of the major waste-water disposal facilities in the 200 Areas, and in the 100 and 300 Areas (Figure 1). Discharge to ground water in the 200 Areas may contribute ten times more water annually to the unconfined aquifer than natural input from precipitation and irrigation (Graham et al., 1981). These ground-water mounds have altered local flow patterns in the unconfined aquifer, which are generally from west to east.

Ground water, primarily from the unconfined aquifer, is currently sampled from over 550 wells and analyzed for radionuclides (Jaquish and Bryce, 1989). Tritium (^{3}H) occurs at relatively high levels in the unconfined aquifer, is one of the most mobile radionuclides, and thus, reflects the extent of ground-water contamination from onsite operations. Many liquid wastes discharged to the ground at Hanford have contained ^{3}H. The PUREX facility is currently the main source for ^{3}H-containing wastes (DOE, 1983). Tritium from releases prior to 1983 that passed downward through the vadose (unsaturated) zone to the unconfined aquifer continues to move with ground-water flow toward the Columbia River. Tritium concentrations in Hanford ground water range from less than 300 pCi/L to over 2,000,000 pCi/L near or within the 200 Areas (PNL, 1987; Jaquish and Mitchell, 1988; Jaquish and Bryce, 1989).

Ground water from the unconfined aquifer enters the river through subsurface flow and springs that emanate from the riverbank. McCormack and Carlile (1984) identified 115 springs along a 41-mile stretch of river. Tritium concentrations in wells near the springs ranged from 19,000 to 250,000 pCi/L and averaged 176,000 pCi/L in 1985 (Price, 1986). Although the distribution of ^{3}H and other radionuclide concentrations in springs generally reflected those in nearby ground-water wells, the magnitude was generally less in springs due to mixing of ground and surface water. Tritium concentrations in the river were generally less than those in springs. Tritium concentrations in springs were less than 4% of the DOE DCG (2,000,000 pCi/L). Tritium concentrations in the river near the springs were less than 0.5% of the DCG and less than half the regulatory limit for drinking water (20,000 pCi/L) (EPA, 1976). From

1983-1988, annual average ^{3}H concentrations in the river (<200 pCi/L) were at least a factor of 100 below the drinking water limit (Jaquish and Bryce, 1989). It is noteworthy that ^{3}H also occurs in the Columbia River upstream of Hanford. From 1983-1988, annual average ^{3}H concentrations in the river, upstream at Priest Rapids Dam, ranged from 70-100 pCi/L.

Surface Water

Columbia River water is used for drinking at downstream cities, for crop irrigation and for recreational activities (fishing, hunting, boating, waterskiing, swimming). Thus, it constitutes a primary environmental pathway to people for radioactivity in liquid effluents. Radionuclides can enter human foodstuffs through crops irrigated with river water and cow's milk through irrigated alfalfa and other cattle forage. Although radionuclides associated with Hanford operations, worldwide fallout and natural phenomena continue to be found in small but measurable quantities in the Columbia River, concentrations are below Washington State and Environmental Protection Agency (EPA) drinking water standards.

Deep sediments in downstream reservoirs still contain low concentrations of some long-lived radionuclides (Nelson and Haushild, 1970; Haushild et al., 1975; Robertson and Fix, 1977; Sula, 1980; Beasley et al., 1981). Trace amounts of ^{239}Pu ^{60}Co, ^{137}Cs, and ^{152}Eu persist in sediments accumulated above the first downstream dam (McNary). In 1977, about 20 to 25% of the total plutonium inventory (^{239,240,241}Pu) in Lake Wallula sediments, 100 km downstream, was believed to originate from the 1944 through 1971 releases at Hanford (Beasley et al., 1981). However, only ^{239}Pu was believed to actually reflect earlier reactor operations. Furthermore, this ^{239}Pu was derived from ^{239}Np (produced by neutron capture in natural uranium followed by decay to ^{239}Np), an abundant isotope in Columbia River water. Thus, plutonium may not have been released to the river from reactor operations.

Fish and Wildlife

Fish are collected at various locations along the Columbia River and boneless fillets are analyzed for ^{60}Co, ^{90}Sr, and ^{137}Cs. Carcasses are analyzed to estimate ^{90}Sr in bone. Following shutdown of the last single-purpose, once-through cooling reactor and installation of improved liquid effluent control systems at N Reactor, short-lived radionuclides, including the biologically important ^{32}P and ^{65}Zn, essentially disappeared from the river (Cushing et al., 1981) through radioactive decay. Radionuclide concentrations in fish collected from the Hanford Reach of the Columbia River are similar to those in fish from upstream locations.

Deer (Odocoileus sp.), ring-necked pheasants (Phasianus colchicus), mallard ducks (Anas platyrhynchus), Nuttall cottontail rabbits (Sylvilagus nuttallii) and black-tailed jack rabbits (Lepus californicus) are collected and tissues are analyzed for ^{60}Co and ^{137}Cs (muscle), ^{239,240}Pu (liver) and ^{90}Sr (bone). The doses that could be received by consuming wildlife at the maximum radionuclide concentrations measured in 1985-1988 were below applicable DOE standards (Price, 1986; PNL, 1987; Jaquish and Mitchell, 1988; Jaquish and Bryce, 1989).

Soil and Vegetation

Airborne radionuclides are eventually deposited on vegetation or soil. Samples of surface soil and rangeland vegetation (sagebrush) are currently collected at 15 onsite and 23 site perimeter and offsite locations (Jaquish and Bryce, 1989). Samples are collected from nonagricultural, undisturbed sites so that natural deposition and buildup processes are represented. Sampling and analyses in 1985 through 1988 showed no radionuclide buildup offsite that could be attributed to Hanford operations (Price, 1986; PNL, 1987; Jaquish and Mitchell, 1988; Jaquish and Bryce, 1989).

Foodstuffs

The most direct way for deposited radionuclides to enter the foodchain is through consumption of leafy vegetables. Samples of alfalfa and several foodstuffs, including milk, vegetables, fruits, wine, beef, chickens, eggs and wheat, are collected from several locations, primarily downwind (i.e., south and east) of the Site (Jaquish and Bryce, 1989). Samples are also collected from upwind and somewhat distant locations to provide information on radiation levels attributable to worldwide fallout. Foodstuffs from the Riverview Area (across the river and southeast) are irrigated with Columbia River water withdrawn downstream of the Site. Although low levels of ^{3}H, ^{90}Sr, ^{129}I, and ^{137}Cs have been found in some foodstuffs, concentrations in samples collected near Hanford are similar to those in samples collected away from the Site.

Penetrating Radiation

Penetrating radiation (primarily gamma-rays) is measured in the Hanford environs with thermoluminescent dosimeters to estimate dose rates from external radiation sources. Radiation surveys are routinely conducted at numerous onsite locations including roads, railroads and retired waste-disposal sites located outside of operating areas. Onsite and offsite measurements and survey results for 1985-1988 were similar to past years. Dose rates near some operating facilities were only slightly higher than natural background rates.

Overall Impact from Hanford Operations

Beginning in 1974, evaluation of radiation doses has included assessment of the maximum external dose rate at a location accessible to the general public, doses to a hypothetical maximally exposed individual, and doses to the population within 80 km (50 mi) of the Site. The calculated 50-year whole-body cumulative dose received by the maximally exposed individual ranged from 0.5 to 3 mrem during the years 1981 through 1986 (PNL, 1987). This hypothetical person receives the maximum calculated radiation dose using worst-case assumptions for location, inhalation of radioactive emissions, consumption of contaminated food and water, and direct exposure to contaminants. Expressed as effective dose equivalents, the calculated dose received by a hypothetical maximally exposed individual was 0.05 to 0.1 mrem annually from 1985 through 1988. The average per capita effective dose from 1985 through 1988, based on the human population of 340,000 within 80 km of the Site, was 0.01 to 0.03 mrem annually (Price, 1986; PNL, 1987; Jaquish and Mitchell, 1988; Jaquish and Bryce, 1989). Based on these assessments, potential radiation doses to the public from Hanford operations have been consistently below applicable standards, and substantially less than doses from other routinely encountered sources of radiation, such as natural terrestrial and cosmic background radiation, medical treatment and x-rays, natural internal body radioactivity, worldwide fallout and consumer products (Figure 2).

CHEMICAL MONITORING

Air Quality

Nitrogen oxides are routinely released onsite from fossil-fueled steam and chemical processing facilities, most notably the PUREX plant. Nitrogen dioxide is currently sampled at seven onsite locations by the Hanford Environmental Health Foundation (HEHF). Nitrogen dioxide concentrations measured in 1984-1988 were well below federal (EPA) and local (Washington State) ambient air quality standards (Price, 1986; PNL, 1987; Jaquish and Mitchell, 1988; Jaquish and Bryce, 1989;).

Ground Water

In 1988, samples from 328 ground-water wells were collected and analyzed for chemical constituents. In addition, onsite drinking water sources (not public) were sampled and analyzed by HEHF for water quality. Detected constituents included several metals, anions, coliform bacteria, and total organic carbon. Many of these constituents are expected in natural ground water. Chromium, cyanide, fluoride, carbon tetrachloride, and trichloroethylene were found in wells not used for drinking water near operating areas.

Columbia River

Nonradioactive waste water is discharged at seven locations along the Hanford Reach of the Columbia River. Discharges consist of backwash from water intake screens, cooling water, water storage tank overflow, a building drain, and fish laboratory waste water. Effluents from each outfall are monitored by the operating contractors. The Columbia River is also monitored by the United States Geological Survey, upstream and downstream of the Site, to verify compliance with Washington State, Class A (WSDOE, 1977) water-quality requirements.

Numerous studies have evaluated and resolved the potential environmental issues associated with water intake and thermal discharge structures on the Columbia River at Hanford. For example, retrofitting of the HGP water intake and a newer design for the intake used at WNP-2 have ensured safe downstream migration of juvenile chinook salmon (Page et al., 1977; WPPSS, 1978; Gray et al., 1979, 1986). Other studies have concluded that thermal discharges from N Reactor and HGP to the Columbia River were biologically insignificant (DOE, 1982; Neitzel et al., 1982).

HANFORD FLORA AND FAUNA

Most of the Hanford Site consists of undeveloped land that supports stands of native vegetation and a few exotic species (e.g., cheatgrass, Bromus tectorum; Russian thistle, Salsola kali; and tumble mustard, Sisymbrium altissimum), is free from agricultural practices, and has been essentially free from livestock grazing and hunting for 45 years. Thus, the Site serves as a refuge for migratory waterfowl, elk (Cervus elaphus), mule deer (Odocoileus hemionus), coyote (Canis latrans) and other plants and animals (Gray and Rickard, 1989). Restricted land use has favored native wildlife that frequent riverine habitats, for example, mule deer, great basin Canada goose (Branta canadensis moffitti), and great blue heron (Ardea herodias).

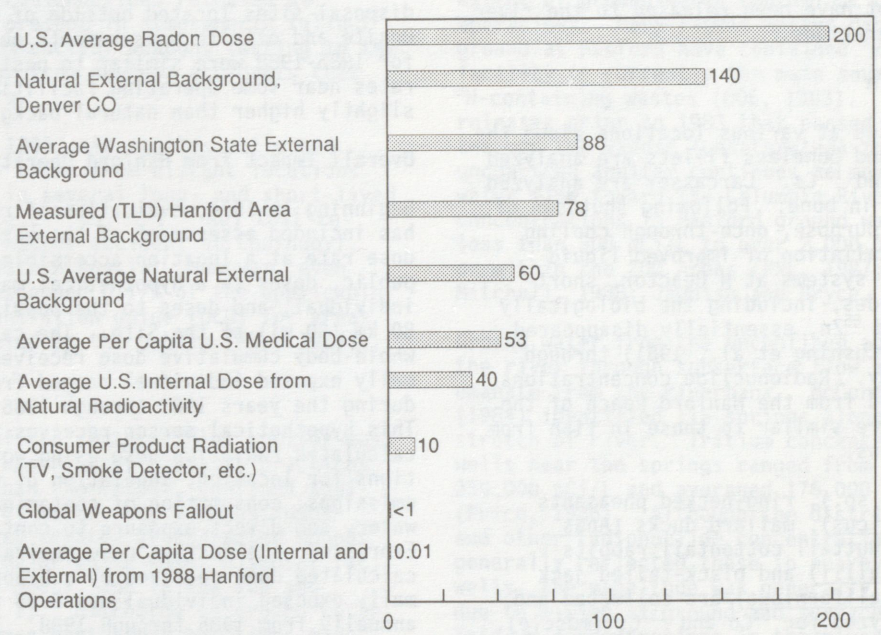

FIGURE 2. Annual radiation doses from various sources: U.S. average radon, external background, medical and internal doses, consumer product radiation and weapons fallout from NCRP (1987b); external background, Denver, Colorado from NCRP (1987a), Washington State from Oakley (1972); Hanford external background and average per capita dose from Jaquish and Bryce (1989); TLD = thermoluminescent dosimeter, does not include neutron component; mrem/yr = millirem per year.

The Columbia River at Hanford supports up to 48 species of fish (Gray and Dauble, 1977) and serves as a migration route for upriver runs of Chinook (Oncorhynchus tshawytscha), coho (O. kisutch) and sockeye (O. nerka) salmon, and steelhead trout (O. mykiss, formerly Salmo gairdneri). The Hanford Reach supports the last remaining mainstem spawning habitat for fall chinook salmon. Steelhead trout also spawn in the Hanford Reach. The salmon population is maintained by a combination of natural spawning, artificial propagation and regulated commercial and sport harvest of returning adults.

Based on redd (nest) counts from the air, fall chinook salmon spawning in the Hanford Reach of the mainstem Columbia River has increased dramatically since 1980 (Figure 3). Recent observations by divers (Swan et al., 1988) showed salmon redds at depths below those visible by boat or aircraft and suggests that salmon spawning in the Hanford Reach may be even greater than previously estimated. The increase in salmon spawning has attracted increasing numbers of wintering bald eagles (Haliaeetus leucocephalus).

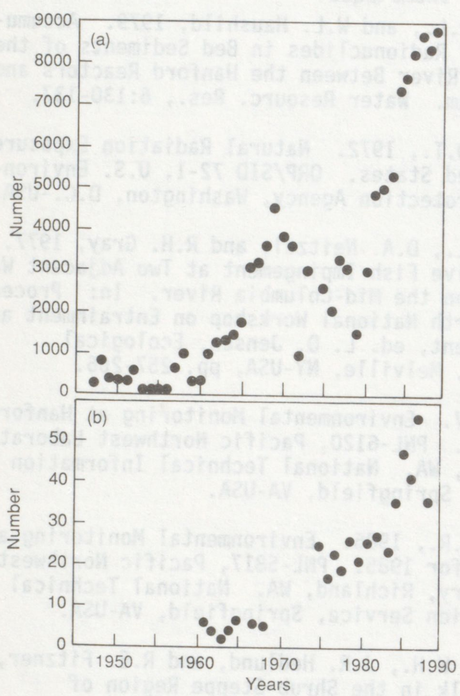

FIGURE 3. Numbers of (a) salmon redds (nests) and (b) wintering bald eagles (there were no counts from 1969-1974) at Hanford (adapted and updated from Rickard and Watson, 1985; Gray and Rickard, 1989).

The sparsely vegetated islands in the Columbia River have historically been used as nesting habitat for great basin Canada goose (Hanson and Eberhardt, 1971; Fitzner and Rickard, 1982). From the mid-1950s to the mid-1970s the number of goose nests declined from a high of 250-300 to about 100 annually. From the late 1970s to the present, the number of nests has increased and appears to have stabilized at about 150-200. Initially, closure of the Hanford Reach was beneficial to the geese by providing freedom from human intrusion. However, the coyote, a natural goose predator, also benefitted, and is believed to be the major cause of the decline in numbers of goose nests into the mid-1970s.

Initially there were no nesting great blue heron on the Hanford Site. However, there are now four active colonies (Gray and Rickard, 1989) consisting of about 35-40 birds each and herons are present year round.

Elk first arrived on the Hanford Site in 1972 (Rickard et al., 1977). From a small founding population, the herd size grew to about 80 animals in 1987 (Figure 4). The rapid increase in elk is attributed to the lack of predation or human disturbance during calving, absence of onsite hunting, and the lack of competition from sheep and cattle for available forage. For the last three years, offsite hunting has limited further population increases by removing about 15 to 20 animals annually from the herd.

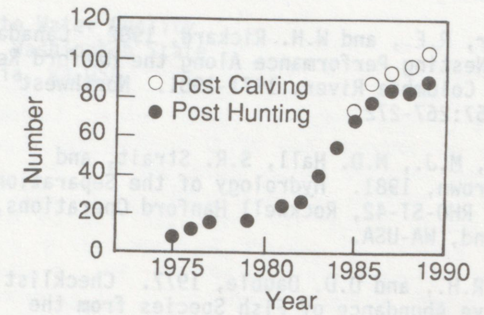

FIGURE 4. Numbers of elk at Hanford after calving in spring and offsite hunting in fall (updated from Gray and Rickard, 1989).

The mule deer population at Hanford is estimated at several hundred animals and appears stable even in the absence of onsite hunting. Coyote predation on fawns is believed to be an important factor that maintains the stable deer population (Steigers and Flinders, 1980).

SUMMARY

The Pacific Northwest Laboratory (PNL) conducts an environmental monitoring program to assess potential effects of Hanford Operations on the local environs, onsite workers, and the offsite public. Monitoring for radiological emissions at Hanford has been ongoing for 45 years and includes air, surface and ground water, soil, vegetation, foodstuffs, fish and wildlife. Measured and calculated radiation doses to the public have been consistently below applicable regulatory limits. The Hanford Site now serves as a refuge for key fish and wildlife species.

ACKNOWLEDGMENTS

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