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BIOTRANSPORT OF RADIONUCLIDES IN THE 100 AREAS

Author

E. M. Greager

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BIOTRANSPORT OF RADIONUCLIDES IN THE 100 AREAS

Prepared By: Eric M. Greager Date: 11/23/81
E.M. Greager
Environmental Engineer

Reviewed By: J. J. Dorian Date: 11/23/81
J. J. Dorian, Manager
Environmental Control

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SUMMARY

The potential for biotransport of radionuclides exists in the 100 Areas of the Hanford Site due to past and current operations.

To assess the role an animal may have in the biotransport of radionuclides, the diet preferences of the more abundant and radioecologically important animals that reside in the 100 Areas are examined in this report. The most important herbivores in the 100 Areas are the mule deer, black-tailed hare, cottontail rabbit, Great Basin pocket mouse, and deer mouse while the most important carnivorous animals include coyotes and raptors (hawks, owls, and other birds of prey).

Radioanalysis of animals collected in the 100 Areas has been part of environmental surveillance programs at Hanford for the last several years. Radionuclide concentrations detected in tissue samples from animals collected in the 100 Areas indicate that animals with the highest radionuclide concentrations occur at 100-N Area. Thus, the potential for biotransport of radionuclides is higher at this area than at the retired 100 Areas.

The major source of radionuclides that accumulate in the biota at 100-N Area is the 1301-N Facility. Small mammals and rabbits, mainly deer mice and cottontails, may feed on vegetation growing in the 1301-N trench or drink directly from the trench, resulting in high concentrations of radionuclides in their tissues.

To greatly reduce the potential for the biotransport of radionuclides from the 1301-N Facility, a project to provide a cover for the 1301-N trench is scheduled to be completed in FY 1982. The trench cover is expected to be effective in reducing radionuclide biotransport at 100-N Area.

It appears that biotransport of radionuclides occurs in the 100 Areas, most significantly between small mammals and rabbits to their natural predators, especially raptors. Although biotransport of radionuclides occurs to some extent in the 100 Areas, this biotransport does not result in any significant radioactive dose to the off-site human population.

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1.0 INTRODUCTION

The potential for biotransport of radionuclides exists in the 100 Areas of the Hanford Site due to past and current operations. Although N Reactor is the only operating reactor in the 100 Areas, approximately 50 radioactive liquid waste disposal sites, 23 solid waste burial grounds, 35 contaminated facilities, and 20 liquid waste areas containing past leakage were established in the retired 100 Areas. These radioactively contaminated areas offer the potential for the biotransport of radionuclides.

The purpose of this investigation is to determine the potential for radionuclide biotransport in the 100 Areas and asses its significance. To accomplish this, the food habits of the more important animals residing in the 100 Areas are examined in this report followed by an inspection of radioanalytical data of animal samples collected in the 100 Areas. Bioconcentration factors are discussed to show the potential radionuclide burdens that could be deposited in a carnivorous animal in a top trophic level as radionuclides are concentrated through the food chain to a top carnivore. Mechanisms of the biotransport of radionuclides are discussed followed by an evaluation of radionuclide biotransport in the 100 Areas.

To assess the role an animal may have in radionuclide biotransport, knowledge of its food habits is needed to identify the types of food consumed and determine the relationship of the species to the overall food web in the local area. The diets of the more important animals residing in the 100 Areas is examined in this report. Food habits of the Great Basin pocket mouse, deer mouse, Townsend's ground squirrel, black-tailed hare, mule deer, coyote, and raptors on the Hanford Site is well documented while diet preference information for other species is more general.

The most important herbivores in the 100 Areas are the mule deer, black-tailed hare, cottontail rabbit, Great Basin pocket mouse, and the deer mouse. The grasshopper may also be an important herbivore. The most important carnivorous animals include coyotes and raptors.

Radioanalysis of animals collected in the 100 Areas has been part of environmental surveillance programs at Hanford for the last several years. Radionuclide concentrations detected in tissue samples from animals collected in the 100 Areas indicate that animals with the highest radionuclide concentrations occur at 100-N Area. Thus, the potential for biotransport of radionuclides is higher at this area than at the retired 100 Areas.

The major source of radionuclides that accumulate in the biota at 100-N Area is the 1301-N Facility. Small mammals and rabbits, mainly deer mice and cottontails, may feed on vegetation growing in the

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1301-N trench or drink directly from the trench, resulting in high concentrations of radionuclides in their tissues.

Radionuclides present in the food base of a particular organism may be retained and concentrated in various tissues of that organism. In some instances, the bioconcentration may result in predator species containing significantly higher radionuclide concentrations than their prey.

There are several methods of transporting radionuclides between biotic components. Plants become radioactively contaminated through root uptake of contaminated water or foliar deposition. Animals become radioactively contaminated by ingestion of radioactive materials, inhalation of contaminated particles, or dust bathing in radioactive soils. Once contaminated, animals may transport radionuclides to higher trophic levels through the food chain.

Based on the radioanalytical results of vegetation and wildlife samples collected in the 100 Areas, it appears that a limited amount of radionuclide biotransport is occurring in the 100 Areas. The highest potential for biotransport occurs at the last remaining 100 Area in operation, the 100-N Area. Although occurring to some extent, this radionuclide biotransport does not result in any significant radioactive dose to the off-site human population.

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2.0 DESCRIPTION OF THE 100 AREAS

The 100 Areas border directly on the Columbia River in the northernmost portion of the Hanford Site. Figure 2.1 is a map of the Hanford Site showing the location of the 100 Areas.

The biotic components of the Hanford Site are termed shrub-steppe, named for the characteristic plant species present. The shrub-steppe ecosystem contains several distinct ecological communities, all with the common distinguishing feature that the vegetation is adapted to tolerate semi-arid conditions. The major plant communities in the 100 Areas include the sagebrush cheatgrass community located primarily on abandoned agricultural areas where wildfires have occurred and where construction activities have been present, and the riparian plant community found along the Columbia River. The major plant and animal species found in the 100 Areas will be discussed in the next section.

Initial operation of the original 100 Area facilities at Hanford began in 1944. A total of eight graphite moderated reactors using Columbia River water for once-through cooling, and a dual-purpose reactor (N Reactor) utilizing a recirculating water coolant, were eventually built in the 100 Areas. Currently, N Reactor is the only plutonium production reactor in operation at Hanford. The by-product steam is used for electrical generation at the adjacent Hanford Generating Project, which is owned and operated by the Washington Public Power Supply System. All other plutonium production reactors at Hanford have been retired.

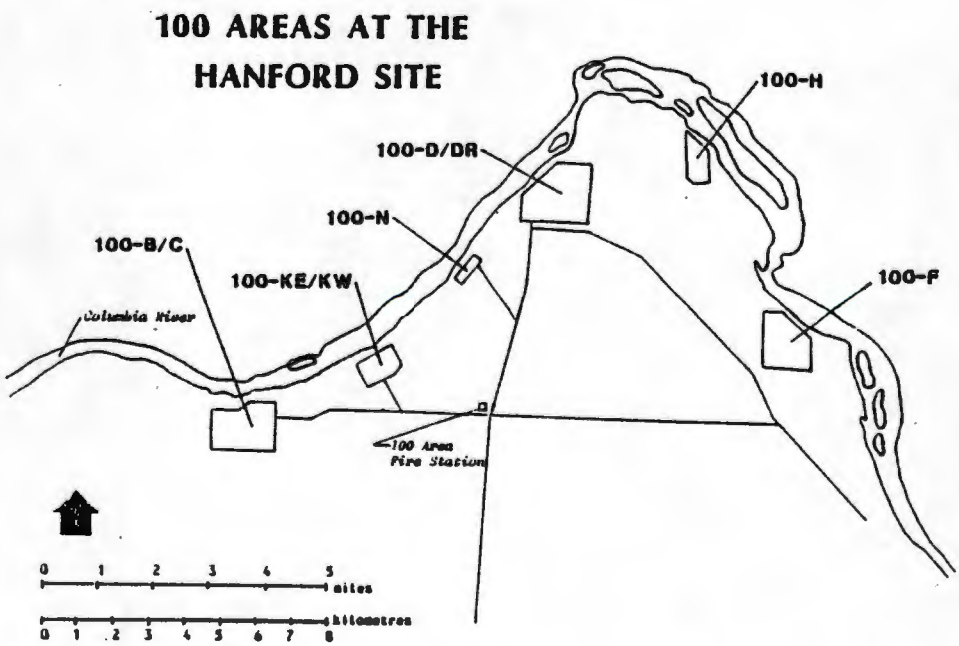

Figure 2.1. The 100 Areas at the Hanford Site.

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2.1 100-N Area

The 100-N Area includes approximately 90 acres of the Hanford Site at Columbia River mile 380. N Reactor is the only Hanford reactor still in operation which was designed for the production of plutonium. A map of 100-N Area is included in Appendix A.

Radionuclides may enter the biosphere from 100-N Area due to emissions of airborne and liquid effluents. There are, however, no radioactive solid waste burial grounds at 100-N Area.

The primary airborne radionuclide release points from 100-N Area include the 116-N stack and the 109-N Zone I roof vents. Emissions from these sources contain significant amounts of short-lived radioactive noble gases (Gr81a), especially Argon-41 ($T_{1/2}$ = 1.8 hours). Measurable quantities of particulate radionuclides are also released from the stack and roof vents, but in quantities which are orders of magnitude less than noble gas releases.

The 1301-N Facility system is the primary liquid radwaste disposal system for N Reactor. Radioactive liquid effluents from the reactor coolant system, spent fuel storage basin, periphery coolant systems, and various radioactive drain systems throughout the reactor facility are discharged to the 1301-N Facility. The 1301-N Facility is a ground disposal facility that makes use of the natural filtration and ion exchange properties of soil to remove radioactive material from effluent water.

The 1301-N Facility is located on a river bank bluff, 60 feet above and 860 feet back from the Columbia River. Liquid streams from reactor systems discharge into a concrete trough then spill into a crib. The crib itself is a rectangular basin (125 by 290 feet) created by excavating the existing soil and then surrounding the excavation with a soil and gravel embankment. The bottom of the crib is filled with a layer of large stones. The water level in the crib is maintained well below the surface of the stones by limiting the flow to the crib and through the use of an extension trench connected to the north side of the crib.

The crib extension trench is an excavated ditch approximately 1600 feet long, 50 feet wide, and 12 feet deep, extending in a zigzag pattern. A wire mesh cover is provided over the entire trench to prevent larger animals and larger birds from obtaining food, water, or shelter within the trench. The water level in the trench is maintained at a nearly constant depth of approximately 3 feet.

Water discharged to the crib percolates over time through the underlying soil to an unconfined aquifer in communication with the Columbia River. During the movement of water in the ground underlying the crib and trench, radioactive materials are retained in the soil through precipitation and ion exchange reactions. Additional loss of radioactive material occurs by decay of the shorter lived

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radionuclides in the discharge water during transit to the river. Hydrological analyses have indicated that flow pathways to the river are a complex system in that the water may enter the river from beneath the river bed or from springs on the river shoreline, and that the pathways may lead directly to the river, or may parallel the river for several miles before entry. Radionuclide sampling studies have shown that the most radioactive spring water enters the river via the shortest crib-to-river pathway.

Since the 1301-N disposal facility utilizes a natural soil column composed of sand (particulate filtration) and clay (cation exchange), the column is noticeably more effective for radionuclides predominantly in the particulate and cationic forms. The predominantly anionic and nonionic species such as iodine, ruthenium, and antimony were removed by the soil column to a lesser extent than the particulate and cationic radionuclides such as iron, cesium, zirconium, and manganese.

Some radionuclides exhibit characteristics indicating a mixture of the various physicochemical forms. Radionuclides of this type emerge at the river springs in essentially anionic and nonionic forms as their particulate and cationic fractions are retained by the soil column. Tritium, which is chemically indistinguishable from water, is not removed during transit to the river.

Detectable amounts of radionuclides are also discharged directly to the Columbia River from 100-N Area via the 102-inch Raw Water Return line. For most nuclides, the quantities of nuclides discharged from the 102-inch line is a few orders of magnitude less than the quantities discharged from the 1301-N Riverbank Springs.

The quantities of gaseous and liquid radionuclides released from 100-N Area each year are compiled and documented in an annual effluent release report. The 1980 report (Gr81a) is listed in the reference section.

2.2 Retired 100 Areas

The first plutonium production reactor at Hanford began operating in September, 1944, and by January, 1971, all eight once-through cooling plutonium production reactors had been shut down. All eight of these reactors have been retired.

During the course of reactor production work, approximately 50 radioactive liquid waste disposal sites, 23 solid waste burial grounds, 35 contaminated facilities, and 20 liquid waste areas containing past leakage, all of which are now deactivated, were established in the 100 Areas (Do78). These deactivated facilities present the greatest potential for biotransport of radionuclides in the retired 100 Areas. Appendix A includes maps of the retired 100 Areas indicating the waste management facilities at each area.

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The 100-B/C Area is approximately 650 acres and is furthest upstream of the six 100 Areas. This area contains two reactors, 105-B and 105-C. Essentially all facilities in the area are retired with the exception of the B/C water system which provides the water supply for the 200 Areas.

The 100-K Area (135 acres) is 2.5 miles downriver from the 100-B/C complex and is 2.3 miles upriver from 100-N Area. 100-K Area contains two reactors, K East and K West. The 105-KE and 105-KW storage basins are used to store spent fuel irradiated in N Reactor. The 1706-KE laboratory is used for research and development. Detectable concentrations of radionuclides are released from both airborne and liquid sources at 100-K Area, however, these concentrations are insignificant and are lower than the releases from 100-N Area.

The 100-D/DR Area (960 acres) is located 1.7 miles downstream of 100-N Area. Even though both 100-D Area reactors are retired, this area is used extensively. Although an engineering laboratory and other facilities are used in the area, there are no detectable levels of radionuclides released from active facilities at 100-D/DR Area.

The 100-H Area (320 acres) is located 3.2 miles downriver of 100-D/DR Area. Very little activity continues in this area. The 183-H basins are used as solar evaporation basins for the storage of liquid wastes from the UNC Fuels Fabrication Facilities. The wastes contain large concentrations of copper and nitrates, and trace quantities of natural uranium.

The 100-F Area (540 acres) is 3.2 miles downstream of 100-H Area and is the reactor area closest to the Tri-Cities. Although the 105-F Reactor was shut down in 1965, biology laboratory facilities were operated until the mid-1970's. Studies were conducted on animals of the effects of inhaled or ingested radioactive and toxic materials.

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3.0 FOOD HABITS OF ANIMALS IN THE 100 AREAS

To assess the role an animal may have in the biotransport of radionuclides, one must first determine the types of food consumed by the animal. If the food items chosen by a particular species contain concentrations of radionuclides, it is likely that radionuclides will be deposited, and possibly concentrated, in certain tissues of the consumer.

After identifying the food habits of the local animal population, sampling and radioanalysis directed towards the food items would be valuable in evaluating the potential for the biotransport of radionuclides.

Ingestion is considered a more important pathway for radionuclide biotransport in the 100 Areas than the pathways of inhalation or surface contamination. Airborne radionuclide concentrations in the 100 Areas compare with offsite concentrations (very low) and, as mentioned previously, the majority of the radioactive airborne effluents consist of the short-lived noble gases. Although surface contamination of plants and animals is more important than inhalation from a biotransport perspective, this pathway is secondary in importance to ingestion due to the possibility of uptake of radionuclides by plants growing over areas with underground contamination. Additionally, small animals may ingest radionuclides directly by drinking from the 1301-N Facility.

In the following subsections, a listing of the more radioecologically important animals likely to be found in the 100 Areas is presented along with their food habits and other characteristics which may contribute to the biotransport of radionuclides.

3.1 Mammals

The mammalian species found in the 100 Areas have broad, geographic distributions that extend throughout the semi-arid regions of the Pacific Northwest. None is indigenous to the state of Washington or regarded as rare or endangered species. For the most part, two broad mammalian habitat categories are present: (1) the shrub-steppe habitat with food base and shelter provided by sagebrush, associated shrubs, herbaceous species, and annual grasses and (2) riparian (streamside) habitats with permanent surface water which provides succulent, green vegetation during the summer months. Riparian vegetation consists of deciduous trees and shrubs, and a rich mixture of perennial grasses and forbs not associated with shrub-steppe vegetation.

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Table 3.1 lists the mammals that are present in the 100 Areas (Ri74).

Table 3.1. Mammals in the 100 Areas.

Common Name	Scientific Name
Mule Deer	Odocoileus hemionus
Coyote	Canis latrans
Bobcat	Lynx rufus
Beaver	Castor canadensis
Porcupine	Erethizon dorsatum
Raccoon	Procyon lotor
Badger	Taxidea taxus
Striped Skunk	Mephitis mephitis
Black-Tailed Hare	Lepus californicus
Cottontail	Sylvilagus nuttallii
Muskrat	Ondatra zibethica
Mink	Mustela vison
Townsend Ground Squirrel	Spermophilus townsendii
Long-Tailed Weasel	Mustela frenata
Northern Pocket Gopher	Thomomys talpoides
Montane Meadow Mouse	Microtus montanus
Grasshopper Mouse	Onychomys leucogaster
House Mouse	Mus musculus
Deer Mouse	Peromyscus maniculatus
Great Basin Pocket Mouse	Perognathus parvus
Vagrant Shrew	Sorex vagrans

3.1.1 Mule Deer

The mule deer is the only big game mammal found on the Hanford Site, with major concentrations occurring along the Columbia River in the vicinity of the 100 Areas. Mule deer are wanderers, which makes them important from a human dose standpoint since the deer may incorporate radionuclides into their soft tissues while onsite and then be collected and consumed by hunters offsite.

Mule deer eat a variety of plants. Important food items include the browse suppied by streamside willows (Salix sp.) in summer and bitterbrush (Purshia tridentata) in winter (Ri74). A study of mule deer diets at Hanford (Ur80) indicated Russian thistle (Salsola kali) and goldenrod (Solidago sp.) were also preferred items. Although abundant in the 100 Areas, gray rabbitbrush (Chrysothamnus nauseosus) and cheatgrass (Bromus tectorum) were not preferred food items. The average deer diet consisted of forbs (52%), shrubs (43%), and grasses (2%).

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3.1.2 Coyote

The coyote is the most abundant, widespread and most important mammalian predator in the 100 Areas. Adult coyotes have the ability to travel far from waste management zones, allowing them to disperse radionuclides through fecal and urinary deposits.

An investigation of coyote food habits (St76) indicated that coyotes eat a variety of animals and plants. Coyotes feed on black-tailed hares and cottontail rabbits throughout the year, supplemented with pocket mice, deer mice, and insects, especially darkling beetles and grasshoppers, when they are locally available. Other small mammals, birds, reptiles, fruit, and grasses are also included in the coyote diet. Coyotes can kill mule deer fawns and occasionally adult deer.

3.1.3 Bobcat

The bobcat is present on the Hanford Site in small numbers. Bobcats are more exclusively carnivorous than coyotes. They feed on birds, small mammals, rabbits, and have been known to kill mule deer fawns. Bobcats are less important as top trophic level consumers than coyotes because of the generally low bobcat population.

3.1.4 Beaver

Beavers are highly aquatic animals, spending most of their lives in or adjacent to permanent ponds or streams. There are active beaver colonies along the Columbia River, especially in areas where quiet backwaters occur. Beaver diets consist primarily of tree twigs, leaves of deciduous trees, bark, and the succulent green plants found in riparian habitat.

3.1.5 Porcupine

Porcupines are found in riparian habitats and abandoned orchards along the Columbia River, especially between the abandoned townsite of Hanford and 100-D/DR Area. Porcupines eat twigs, leaves, buds and bark of deciduous trees and various herbs associated with riparian habitats.

3.1.6 Raccoon

Raccoons are found mostly in the riparian vegetation growing along the Columbia River. They eat a variety of plant and animal foods associated with the riparian habitat, i.e., fish, crayfish, garter snakes, frogs, birds, and small mammals.

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3.1.7 Badger

Badgers can be encountered throughout the shrub-steppe and riparian habitat in the 100 Areas, although they are few in number. Due to their digging abilities, the badger is considered the most important mammal in relation to dry buried waste. Badgers are strongly carnivorous, eating birds and small mammals, chiefly Townsend ground squirrels.

3.1.8 Striped Skunk

Skunks can be expected anywhere in the 100 Areas, but mostly in the riparian habitats. Skunks are omnivorous, eating a variety of plant and animal foods as they become seasonally available.

3.1.9 Black-Tailed Hare

The black-tailed hare is the most abundant species of rabbit in the 100 Areas. A study of hare diets utilizing fecal pellet examination techniques (Ur75) indicated that yarrow (Achillea millifolium), turpentine cymopterus (Cymopterus terebinthinus), Jim Hill mustard (Sisymbrium altissimum), Erigeron sp., and rabbitbrush were the plant species consumed most frequently. For the most part, these plant species were also the most important food items found in radioactive fecal pellets. Besides being a part of the diet, rabbitbrush, and other shrubs, are important to rabbits since they provide protection from predators and shelter from adverse weather. Although cheatgrass and Russian thistle were abundant in the study area, neither plant species was eaten by black-tailed hares. Hares do not require drinking water since, even under drought conditions, water can be extracted from consumed vegetation.

3.1.10 Cottontail Rabbit

Cottontails can be expected to occur anywhere in the shrub-steppe habitat where burrows or protective cover are available. As an example, the cottontail population near 100-N Area has apparently increased since large boulders were piled outside of the 1301-N Facility security fence. This has increased the protective cover in this area. Additionally, the rabbit population has probably increased due to the coyote suppression program at Hanford. Cottontails feed on seasonally available herbs and shrubs.

3.1.11 Muskrat

Muskrats are common along the Columbia River, especially in the quiet backwater areas. Muskrats are not quite as aquatic as beavers and are much smaller than beavers. They eat a variety of succulent plants commonly found in riparian habitats.

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3.1.12 Mink

Mink are present on the Hanford Site in riparian habitats. They eat fish, crayfish, frogs, mice, rabbits, muskrats, and waterfowl.

3.1.13 Townsend Ground Squirrel

Townsend ground squirrels are abundant and occur in loosely organized colonies throughout the steppe habitat. In terms of biomass, ground squirrels are often the most important small mammal. Studies of ground squirrel diets (Ro80, Jo77, Jo75) have indicated that bluegrass (*Poa* sp.), tansy mustard (*Descurainia pinnata*), lupine (*Lupinus laxiflorus*) and phlox (*Phlox longifolia*) are the plant species most frequently eaten. Cheatgrass is not eaten by ground squirrels.

3.1.14 Long Tailed Weasel

Weasels are scarce in the 100 Areas, probably occurring in the riparian habitat along the Columbia River. Food items of weasels consist mainly of small rodents and sometimes rabbits and birds.

3.1.15 Northern Pocket Gopher

Pocket gophers are found throughout the shrub-steppe habitat spending most of their time below ground. They eat a variety of plants - both above and below ground plant parts.

3.1.16 Montane Meadow Mouse

The montane meadow mouse is mainly associated with riparian habitats and feeds mainly on the succulent stems and leaves of forbs found in streamside vegetation. Grasses are usually not eaten.

3.1.17 Grasshopper Mouse

Grasshopper mice occur in small numbers throughout the steppe habitat. Most of their food is of animal origin and consists of arthropods such as grasshoppers and beetles. Grasshopper mice also eat seeds and occasionally lizards.

3.1.18 House Mouse

House mice are found in riparian habitat and frequently the reactor areas. These mice are omnivores, eating seeds, fruits, vegetables, insects, and meat.

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3.1.19 Deer Mouse

Deer mice are found in both the steppe and riparian habitats. Next to the pocket mouse, deer mice are the most abundant mammal on the Hanford Site. Deer mice are omnivorous, eating plant parts and insects.

Studies of the deer mouse diet (Kr74, Wi59, Wh66, Fl73, Jo75) have indicated that the diet preference is controlled by insect abundance. Deer mice rely heavily on arthropods from spring through autumn, when the insects are abundant. During this time, green plant matter is of secondary importance with seeds even less important than plants in the diet. During the winter, plant matter (mainly seeds) was the most important dietary constituent.

3.1.20 Great Basin Pocket Mouse

Pocket mice are the most abundant mammals on the Hanford Site. They prefer open, shrub-dominated vegetation with a sparse herb understory of cheatgrass and sandberg bluegrass.

According to several studies of the pocket mouse diet (Kr74, OF75a, Sc78, Jo75, Ga79), the single most important item consumed by pocket mice at Hanford is cheatgrass seeds. In the spring, prior to seed ripening, the preferred food is arthropods with green plant material of secondary importance.

3.1.21 Vagrant Shrew

Although shrews have been reported from only a few locations on the Hanford Site, they are likely to be more abundant in riparian rather than steppe habitats. Vagrant shrews are known to eat immature and adult insects.

3.2 Birds

Birds are a conspicuous element of shrub-steppe ecosystems in the Pacific Northwest. However, the harsh climate conditions and the simplicity of the vegetation structure limit the number and diversity of bird species in shrub-steppe regions.

Birds generally found in the Pacific Northwest shrub-steppe are listed in Table 3.2.

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Table 3.2. Species List of Birds Associated Either Directly or Peripherally with the Pacific Northwest Steppe (Ro77).

Status	Species	Status	Species
Permanent Residents	Marsh Hawk	Migrants	Ferruginous Hawk
	Red-tailed hawk		Golden Eagle
	Sharp-tailed Grouse		Merlin (Pigeon Hawk)
	Sage Grouse		Sandhill Crane
	Chukar		Common Flicker (Red-shafted)
	Ring-necked Pheasant		Mountain Bluebird
	Gray Partridge		House Finch
	Short-eared Owl		American Goldfinch
	Horned Lark		Savannah Sparrow
	Black-billed Magpie		Dark-eyed Junco (Oregon and slate-colored)
	Common Raven		White-crowed Sparrow
	Common Crow		Song Sparrow
	Western Meadowlark		
	California Quail		
Summer Residents	Prairie Falcon	Peripherals	American Kestrel (Sparrow Hawk)
	Long-billed Curlew		California Quail
	Mourning Dove		Killdeer
	Burrowing Owl		California Gull
	Swainson's Hawk		Ring-billed Gull
	Common Nighthawk		Great Horned Owl
	Barn Swallow		Long-eared Owl
	Sage Thrasher		Eastern Kingbird
	Loggerhead Shrike		Western Kingbird
	Grasshopper Sparrow		Ash-throated Flycatcher
	Vesper Sparrow		Say's Phoebe
	Lark Sparrow		Cliff Swallow
	Black-throated Sparrow		Bank Swallow
	Sage Sparrow		Rough-winged Swallow
	Brewer's Sparrow		Rock Wren
Winter Residents	Rough-legged Hawk		Northern Oriole (Bullock's)
	Northern Shrike		Lazuli Bunting
	Bald Eagle		

3.2.1 Raptors

Although other bird species at the Hanford Site are limited in number, the site harbors a large and diverse population of birds of prey, especially in the 100 Areas. This large raptor population is a result of the seclusion of the Hanford Site since it was closed to unauthorized human trespass and the large number of introduced trees and abandoned orchards in the 100 Areas that provide a favorable habitat for the birds.

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Table 3.3 provides a listing of all the raptors that have been observed on the Hanford Site.

Table 3.3. Taxonomic Listing of the Birds of Prey on the Hanford Site (Fi81).

Common Name	Scientific Name
Turkey vulture	Cathartes aura
Goshawk	Accipiter gentilis
Cooper's Hawk	Accipiter cooperii
Sharp-shinned hawk	Accipiter striatus
Marsh hawk	Circus cyaneus
Rough-legged hawk	Buteo lagopus
Ferruginous hawk	Buteo regalis
Red-tailed hawk	Buteo jamaicensis
Swainson's hawk	Buteo swainsoni
Golden eagle	Aquila chrysaetos
Bald eagle	Haliaeetus leucocephalus
Osprey	Pandion haliaetus
Gyrfalcon	Falco rusticolus
Prairie falcon	Falco mexicanus
Peregrine falcon	Falco peregrinus
Pigeon hawk	Falco columbarius
American kestrel	Falco sparverius
Screech owl	Otus asio
Flammulated owl	Otus flammeolus
Great horned owl	Bubo virginianus
Long-eared owl	Asio otus
Short-eared owl	Asio flammeus
Snowy owl	Nyctea scandiaca
Burrowing owl	Athene cunicularia
Saw-whet owl	Aegolius acadicus
Barn owl	Tyto alba

The diet of raptor species are dictated by several factors. Besides the availability of certain prey species, of major importance are the physical prey catching capabilities of each species. Studies have shown (0173) direct relationships between the size of the raptor and the size of the prey items they feed on. For instance, the small kestrels and burrowing owls are not capable of capturing rabbits while the large hawks and owls are quite capable of catching rabbits and other large prey species.

An analysis of raptor diets (Fi81) revealed that burrowing owls ate the greatest diversity of prey species and was mainly an insectivore. Great horned owls, long-eared owls, and barn owls are primarily small mammal consumers. Red-tailed and Swainson's hawks eat small mammals, rabbits, birds, and snakes, with Swainson's hawks consuming more snakes. Table 3.4 lists the major food items preferred by various species of raptors.

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Table 3.4. Food of Raptors on the Hanford Site (Fi81, Fi79).

Raptor Species	Preferred Food Items	% of Diet
Burrowing Owls	Great Basin Pocket Mouse	10.35
	Other small mammals	6.46
	Reptiles	0.22
	Birds	0.04
	Insects	82.93
Great Horned Owl	Great Basin Pocket Mouse	53.0
	Deer Mouse	14.4
	Other small mammals	9.4
	Rabbits	5.8
	Birds	6.9
	Reptiles	0.6
	Invertebrates	5.6
Long-Eared Owl	Great Basin Pocket Mouse	87.0
	Deer Mouse	6.1
	Other small mammals	4.2
	Rabbits	0.6
	Birds	1.6
	Invertebrates	0.6
Barn Owl	Great Basin Pocket Mouse	68.6
	Deer Mouse	20.0
	Other small mammals	4.4
	Rabbits	3.5
	Birds	2.8
Red-Tailed Hawk	Townsend's Ground Squirrel	31.2
	Other small mammals	3.0
	Black-tailed Hare	11.8
	Cottontail Rabbit	7.7
	Birds	10.1
	Western Yellow Bellied Racer	22.4
	Bullsnake	12.4
	Other reptiles	0.6
	Invertebrates	1.2
Swainson's Hawk	Townsend's Ground Squirrel	14.2
	Northern Pocket Gopher	11.4
	Other small mammals	5.8
	Western Yellow-Bellied Racer	49.5
	Other reptiles	2.5
	Rabbits	0.7
	Insects	14.2

9 3 1 2 8 7 2 0 5 5 2

Table 3.4. Food of Raptors on the Hanford Site (Fi81, Fi79) - cont.

Raptor Species	Preferred Food Items	% of Diet
Prairie Falcon	Cottontail Rabbit	33.3
	Small mammals	54.2
	Birds	16.7
American Kestrel	Small mammals	7.7
	Birds	30.8
	Sagebrush Lizard	38.5
	Short-Horned Lizard	23.1

3.2.2 Diets of Non-Predatory Birds

The diets of birds other than raptors on the Hanford Site are not as well documented as the diets of birds of prey. For the most part, the upland game and passerine bird species occurring in the Hanford shrub-steppe ecosystem consume a variety of seeds, plants, insects, and other invertebrates. A certain amount of grit is also ingested by many species to aid in food digestion. The waterfowl that frequent the riparian habitats at Hanford feed on a variety of green vegetation, fish, insects, and other aquatic invertebrates.

3.3 Reptiles and Amphibians

Reptiles (snakes and lizards) are more abundant than amphibians on the Hanford Site since they are physiologically adapted to the hot, semi-arid environment while amphibians require moisture to survive. Amphibians also require the presence of standing water for reproduction. A listing of the reptiles and amphibians observed on the Hanford Site is presented in Table 3.5.

Table 3.5. Amphibian and Reptile Species at the Hanford Site

	Common Name	Scientific Name
Amphibians	Great Basin Spadefoot	*Scaphiopus intermontanus*
	Western Toad	*Bufo boreas*
	Pacific Treefrog	*Hyla regilla*
Reptiles	Sagebrush Lizard	*Sceloporus graciosus*
	Side-Blotched Lizard	*Uta stansburiana*
	Pigmy Short-Horned Lizard	*Phrynosoma douglassi*
	Western Yellow-Bellied Racer	*Coluber constrictor*
	Gopher Snake (Bullsnake)	*Pituophis melanoleucus*
	Striped Whipsnake	*Masticophis taeniatus*
	Northern Pacific Rattlesnake	*Crotalus viridus*
	Desert Night Snake	*Hypsiglena torquata*

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The dietary habits of reptiles and amphibians at the Hanford Site is not well documented. In general, snakes eat a variety of small mammals, small birds, eggs, insects, and other invertebrates. Lizards feed mainly on insects while amphibians prefer insects and green vegetation.

3.4 Insects

Insects are an important, though little understood, component within the shrub-steppe habitat. Darkling beetles, grasshoppers, and ants are some of the more important insect groups associated with the 100 Areas.

Darkling beetles feed on vegetation and seeds in the 100 Areas. Rabbitbrush is one of the more important food items, occurring with a frequency of 36% in the diet of the darkling beetle species *Eleodes humeralis* (Ro79).

Grasshoppers are also herbivorous. A study of the diets of eight species of grasshoppers (Sh76) indicated that the preferred food items in grasshopper diets include sagebrush (*Artemesia tridentata*), turpentine cymopterus, rabbitbrush, and balsamroot (*Balsamorhiza careyana*). Cheatgrass and Russian thistle were consumed at very low levels and are not a preferred food item.

3.5 Food Webs

To summarize and illustrate much of the diet preference information presented earlier, the food web diagram presented in Figure 3.1 was prepared. This diagram shows the simplified food web that occurs around the 1301-N Facility and 100-N Area.

From the standpoint of radionuclide biotransport, rabbitbrush, Russian thistle, and cheatgrass are the most important plant species at 100-N Area. Rabbitbrush and Russian thistle have deep root systems capable of reaching the contaminated water table while cheatgrass is the most abundant plant species in the 100 Areas. Deer mice and cottontail rabbits are the most important herbivores, obtaining radionuclides through the vegetation they consume and the water they drink from the 1301-N Facility. Hawks and owls are the most important carnivores at 100-N Area. Coyotes are less important since they are fenced out of the 1301-N Facility.

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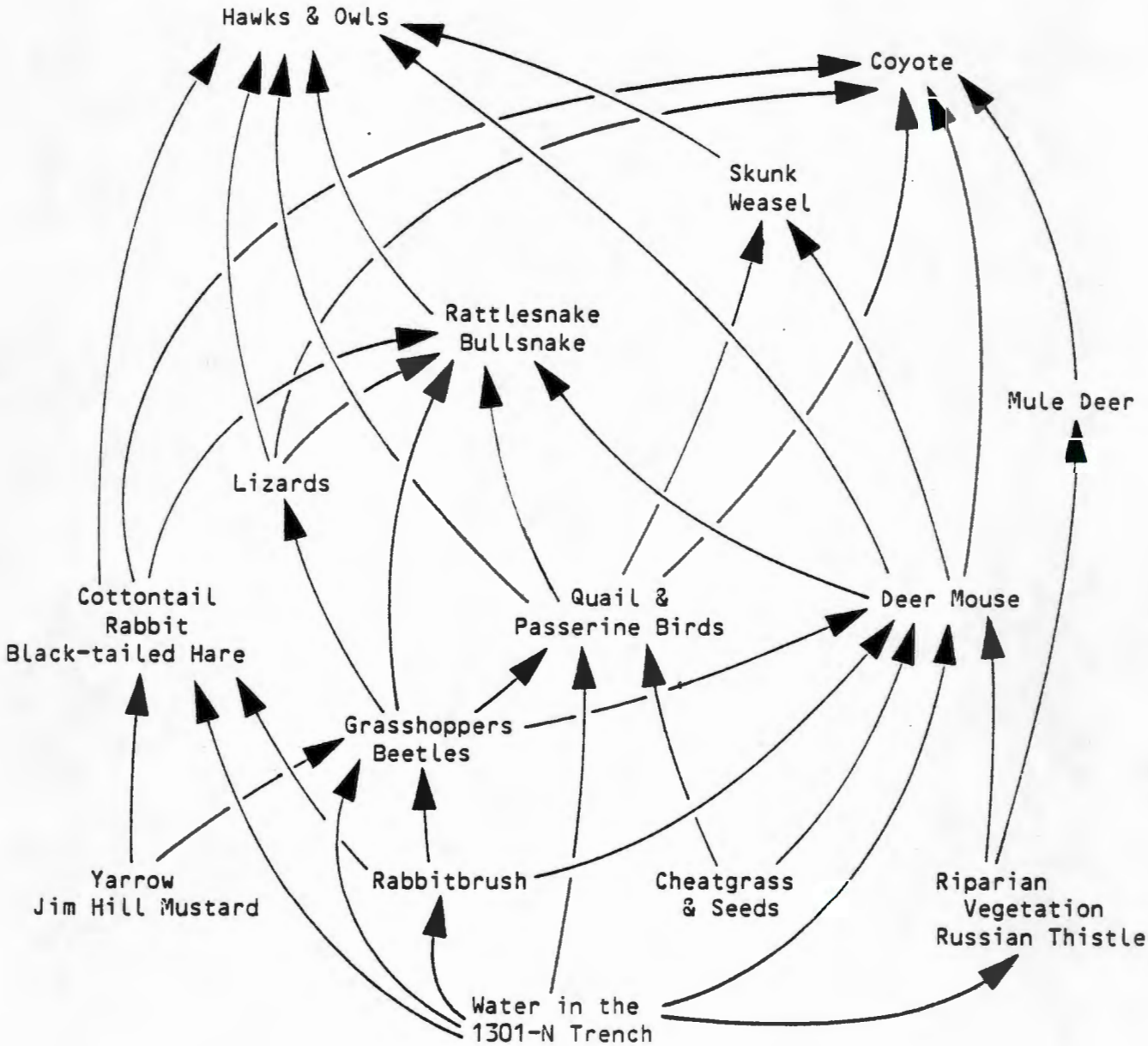

Figure 3.1. Simplified Food Web Occurring Around the 1301-N Facility at 100-N Area.

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4.0 RADIONUCLIDES DETECTED IN 100 AREA ANIMALS

Environmental surveillance of the Hanford environs has been conducted by Battelle Pacific Northwest Laboratory (PNL) for the past several years. Recently, UNC has developed an environmental surveillance program that encompasses the operating 100-N Area and retired 100 Areas.

The PNL Environmental Surveillance Program includes collection of mice, rabbits, waterfowl, upland game birds, and "road killed" deer in the 100 Areas for radioanalysis. Various radioecological studies at Hanford are also performed by PNL. The UNC surveillance program may also include the collection of small animals for radioanalysis.

Radionuclide concentrations detected in tissue samples from animals collected in the 100 Areas have been reported in past environmental surveillance reports. Table 4.1 presents radionuclide data on mice collected in the 100 Areas since 1976. As the table shows, mice collected in the area adjacent the 1301-N trench at 100-N Area contained the highest radionuclide concentrations. The high concentrations result primarily from the mice using the trench as a drinking water source and feeding on the contaminated vegetation growing out of the trench.

Table 4.1. Radionuclides Detected in Mice Collected in the 100 Areas (Ho79, Ho78, Fi77). Concentrations are in pCi/g (wet wt.)

Sample Location	Mn-54	Fe-59	Co-60	Zn-65	Sr-90	Cs-134	Cs-137	Ce-144
100-N trench	362	ND	1,030	35	52	ND	2,920	ND
100-F	ND	ND	ND	0.5	260	ND	1.6	ND
100-F	ND	ND	ND	ND	0.13	ND	ND	ND
100-N	900	ND	2,100	66	300	470	3,400	180
141-F	ND	ND	ND	ND	0.88	ND	ND	ND
100-N trench*	14,000	20,000	20,000	710	180	200	400	9,200
100-N trench	11,000	ND	20,000	640	430	ND	5,600	8,900
100-N trench	1,100	ND	2,300	73	93	ND	1,000	510
100-N	ND	ND	4.1	ND	2.7	ND	ND	ND
100-N	5.1	ND	4.6	ND	2.7	ND	1.7	ND
100-N	960	ND	300	ND	50	80	810	ND

ND = Not Detected

*This sample also contained the following wet weight concentrations: 1300 pCi/g of Co-58, 6100 pCi/g of ZrNb-95, 6400 pCi/g of Ru-103, 3000 pCi/g of Ru-106, and 450 pCi/g of Ce-141.

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Rabbits have also been collected in the 100 Areas. Table 4.2 indicates radionuclide concentrations detected in 100 Area rabbits collected in 1979 and 1980. Table 4.3 presents radionuclide concentrations detected in rabbits collected around the 1301-N Facility at 100-N Area in 1981. As was the case for mice, rabbits collected adjacent the 1301-N trench contained much higher radionuclide concentrations than those rabbits collected farther from the trench or at a different 100 Area.

Radioanalysis of the vegetation growing in or very near the trench (Gr81b) indicated a high uptake of certain radionuclides, for instance, Cs-137 concentrations averaged 740 pCi/g (dry wt.) and Co-60 concentrations averaged 640 pCi/g (dry wt.) Therefore, it appears the high radionuclide concentrations detected in rabbits collected near the trench are due to the rabbits drinking from the trench as well as feeding on the vegetation growing in or very near the trench.

Table 4.2. Sr-90 and Cs-137 Concentrations Detected in Rabbit Tissue Collected in the 100 Areas (Ho-80, Ho-81). Concentrations are in pCi/g (wet wt.).

Sample Location	Sr-90 (bone)	Cs-137 (muscle)
100-N	21	0.006
100-N	72	0.09
100-B	0.51	Not Detected
100-F	0.65	0.07
100-F	0.27	0.06

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Table 4.3. Radionuclides detected in Rabbit Tissue Collected Around the 1301-N Facility at 100-N Area (Gr81b). Concentrations are in pCi/g (wet wt.)

Inside 1301-N Security Fence	Tissue	Mn-54	Co-60	Zn-65	Cs-134	Cs-137	Sr-90	Pu-238	Pu-239/240
#1	Muscle	ND	0.2	ND	0.55	8.9	NA	NA	NA
	Bone	ND	ND	0.46	ND	3.2	73	ND	ND
#2	Muscle	6.1	13	6.2	320	3,700	NA	NA	NA
	Bone	46	13	13	98	1,100	6,000	ND	0.14
	Liver	210	120	ND	160	2,300	5.2	0.07	0.35
#3	Muscle	4.2	2.2	2.1	270	3,400	NA	NA	NA
	Bone	21	5.2	ND	77	1,200	1,300	0.01	0.06
	Liver	330	60	ND	190	3,400	5.6	0.005	0.02
#4	Muscle	1.5	9.0	0.53	9.1	120	NA	NA	NA
	Bone	1.4	0.57	ND	3.0	51	200	ND	0.15
	Liver	11	12	8.7	9.9	160	13	0.13	0.08
#5	Muscle	2.2	3.4	0.42	9.4	140	NA	NA	NA
	Bone	2.5	1.7	ND	3.1	43	180	0.07	0.04
	Liver	26	22	ND	7.8	130	1.4	0.03	0.05
Average	Muscle	2.8	5.6	1.9	120	1,500	NA	NA	NA
	Bone	14	4.1	2.7	36	480	1,600	0.02	0.08
	Liver	140	54	2.2	92	1,500	6.3	0.06	0.13
Rock Pile Outside Fence									
#1	Muscle	ND	0.36	ND	ND	0.07	NA	NA	NA
	Bone	ND	0.29	0.73	ND	0.51	11	ND	ND
	Liver	ND	0.36	ND	ND	0.25	ND	ND	0.005
#2	Muscle	ND	0.06	ND	ND	0.02	NA	NA	NA
	Bone	1.2	0.44	ND	1.9	0.16	1.4	ND	ND
	Liver	ND	0.22	ND	2.7	0.13	ND	ND	ND
#3	Muscle	ND	0.07	ND	ND	ND	NA	NA	NA
	Bone	ND	0.22	0.16	ND	ND	49	*	*
	Liver	ND	0.13	ND	0.33	0.15	ND	*	*
#4	Muscle	2.4	**	0.59	ND	9.5	NA	NA	NA
	Bone	ND	0.72	ND	ND	0.19	1.5	ND	ND
	Liver	ND	0.18	ND	ND	0.17	ND	ND	0.02
Average	Muscle	0.60	0.16	0.15	ND	2.4	NA	NA	NA
	Bone	0.30	0.42	0.22	0.48	0.26	16	ND	ND
	Liver	ND	0.22	ND	0.76	0.18	ND	ND	0.008

ND - Not Detected
NA - Not Analyzed
* - Sample Lost
** - Cross contamination suspected.

In addition, rabbit feces were collected on both sides of the 1301-N trench and analyzed for radionuclide concentrations. All rabbit pellets collected on one side of the trench were composited to form one sample. Results of these analyses are presented in the following table.

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Table 4.4. Radionuclides Detected in Rabbit Feces Collected Around the 1301-N Facility. Concentrations in pCi/g (dry wt.).

	Mn-54	Co-60	Cs-134	CS-137	Ce-144
East of trench	1300	340	63	740	Not Detected
West of trench	650	870	19	270	120

The upland game birds collected in the 100 Areas have generally contained radionuclide concentrations at very low levels that have been attributed to worldwide fallout. Concentrations of both Sr-90 in bone and Cs-137 in muscle tissue have been either non-detectable or in the order of 10^{-2} to 10^{-3} pCi/g wet weight (Fi77, Ho78, Ho79, Ho80, Su81).

A number of "road kill" deer occur every year and PNL collects muscle and bone samples when such an accident occurs. Table 4.5 indicates the radionuclide concentrations that have been detected in deer samples collected in the 100 Areas over the past several years.

Table 4.5. Radionuclide Concentrations Detected in Deer Samples Collected in the 100 Areas (Fi77, Ho78, Ho79, Ho80, Su81). Concentrations are in pCi/g (wet wt.).

Sample Location	Co-60 (muscle)	Zn-65 (muscle)	Cs-137 (muscle)	Sr-90 (bone)	Pu-239/240 (liver)
100-D	0.29	ND	0.73	ND	ND
100-H	ND	ND	ND	0.88	ND
100-N	ND	ND	0.13	18	ND
100-N	ND	ND	0.03	22	ND
100-D	0.02	0.01	0.005	0.38	0.002

ND = Not Detected

A study of I-129 concentrations in forage and deer in the Pacific Northwest (Pr81) indicated that deer collected on the Hanford Site had average I-129 concentrations of 28 pCi/g (dry wt.). Although this I-129 concentration is insignificant from a human dose standpoint, analyses of thyroid glands showed that deer living within 160 Km of Hanford had elevated levels of I-129 compared to deer from more distant Pacific Northwest locations. It should be pointed out that the I-129 concentrations detected in Hanford deer result primarily from past 200 Area operations with a relatively negligible contribution from activities in the 100 Areas.

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A study of raptors at the Hanford Site included radioanalysis of the pellets regurgitated by the birds of prey. The pellets consist of the undigestible portions (bone, hair, etc.) of their prey items and these pellets may be collected near the nesting and roosting areas of the birds.

Since raptors occupy a trophic level of top carnivore, and many raptor species prefer a diet of small mammals and rabbits, radioanalysis of raptor pellets should give some indication of the biotransport of radionuclides through the food chain. There is a limitation to this approach, however, since raptor pellets do not contain the digestible soft tissues of the prey items the nuclides that concentrate in the soft tissues, such as cesium, would not be expected to be present in representative amounts in the pellets. Nonetheless, radioanalysis of raptor pellets is valuable for estimating the biotransport of radionuclides. Table 4.6 and 4.7 present results of raptor pellet radioanalysis.

Table 4.6. Cs-137 Concentrations in 100 Area Raptor Pellet Samples (Fi81). Concentrations are in pCi/g (dry wt.)

Sample Location	Raptor Species	Cs-137 Concentration	
100-D	Barn Owl	0.91	0.37
		5.9	3.9
		4.4	
100-F	Great Horned Owl	0.75	
		0.64	
100-H	Great Horned Owl	1.5	1.37
		1.38	

Table 4.7. Gamma-Emitting Radionuclide Concentrations Detected in 100 Area Raptor Pellet Samples (Fi81). Concentrations are in pCi/g (dry wt.).

Species (Location)	Mn-54	Co-60	Cs-137	Eu-152	Eu-154	Eu-155
Barn Owl (100-D)	5.6	9.0	6.04	64.9	10.1	2.02
Great Horned Owl (100-H)	0.19	0.41	1.68	0.38	ND	0.18

ND = Not Detected

The radionuclide concentrations reported in Table 4.7 are probably related to both the 100 and 200 Areas. The Mn-54 and Co-60 concentrations are most likely due to eating prey species captured around the 1301-N Facility at 100-N Area. However, concentrations of the three europium radioisotopes are probably due to 200 Area operations.

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Radioanalysis of owl pellets collected in the early 1970's (Co72) show radionuclide concentrations six orders of magnitude greater than the concentrations listed in Tables 4.6 and 4.7. The concentrations shown in Table 4.8 are much higher than would be expected. A discussion of these results with a PNL scientist (R. E. Fitzner, 10/7/81) indicated that the high concentrations were the result of mice (predominantly deer mice) using a laboratory feed mixture that had been "spiked" with radionuclides for experiments with laboratory animals. The mice ate the spiked feed and in turn were preyed upon by owls residing near 100-F Area. This resulted in high radionuclide concentrations in the owl pellets and no doubt the owls themselves.

Table 4.8. Radionuclides Concentrations in Owl Pellets (Co72). Concentrations are in pCi/g.

Radionuclide	Concentration
Mn-54	1.0×10^7
Fe-59	1.5×10^6
Co-60	2.6×10^7
Sr-90	6.4×10^5
ZrNb-95	4.5×10^6
Ru-106	1.8×10^6
Sb-124	4.5×10^5
Cs-137	1.7×10^5
Ce-141	3.0×10^5
CePr-144	6.0×10^6
Pu-239	8.5×10^3

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5.0 BIOCONCENTRATION AND RETENTION OF RADIONUCLIDES

Radionuclides present in the food base of a particular organism may be retained and concentrated in various tissues of that organism. In some instances, the bioconcentration may result in predator species containing significantly higher radionuclide concentrations than their prey.

Analyses of potential uptake and transport of radionuclides in vertebrate food chains must consider three steps (Ki75):

(1) identification of critical environmental food-chain pathways,
(2) the assimilation of each link in the pathway, and
(3) turnover rates by the successive receptor populations or trophic levels.

Food-chain transfers to predators from prey species vary according to the feeding habits of the predators. Carnivores such as bobcats and snakes swallow their prey, while raptors regurgitate the indigestible parts such as hair, bone, and teeth. Thus, the radionuclide body burdens in predators will depend greatly on feeding habits of predators and the radionuclide concentrations in various tissues of their prey.

The concentration of radionuclides between one trophic level to the next can be expressed as a bioconcentration factor (BCF). The BCF is the ratio of the radionuclide concentration in an organism to that in its food base:

$$BCF = \frac{\text{concentration in organism}}{\text{concentration in food base}}$$

For the most part, BCF's for mammals have been collected under widely varied habitat conditions so that few generalizations can be made for specific radionuclides. Based on past studies, BCF's for CS-137 show increases from plant to mammalian herbivores and increases at higher trophic levels. The BCF was generally greater than 1.0 for Cs-137. BCF's for Sr-90 ranged from 0.02 - 8.4 while BCF's for H-3, Co-60, and I-131 are generally less than 1.0 (with the exception of Co-60 for quail fed seeds and water). Concentration factors reported by various investigators are listed in Table 5.1.

9 3 1 2 8 7 2 0 5 6 2

Table 5.1. Food-Chain Bioconcentration Factors (Ki75).

Radionuclide	Species	Food Base	Bioconcentration Factor
Cs-134 and Cs-137	Cottontail Rabbit	Grass	1.9
	Quail	Seeds & Water	2.4
	Bobcat	Rabbit	6.1 - 15.9
	Herbivores		0.3 - 2.0
	Omnivores		1.2 - 2.0
	Carnivores		3.8 - 7.0
Sr-90	Cottontail Rabbit	Grass	8.4
	Mule Deer (0-12 mo.)	Grass	0.19
	Mule Deer (12-24 mo.)	Grass	0.16
	Herbivores		0.5 - 4.5
H-3	Deer Mouse	Russian Thistle	1.0
	Herbivores		0.6
Co-60	Quail	Seeds & Water	2.4
	Quail	Seeds, Water, Cricket, Lichen	0.2
	Herbivores		0.3
I-131	Herbivores		0.5
	Omnivores		0.2
	Carnivores		0.1

A study of radionuclide bioconcentration in coastal-plain deer in the southeastern United States (Je73) indicated a BCF of three to five between the deer and their food base.

An investigation of radionuclide concentrations in nestling raptors near a test reactor at the DOE Idaho Site (Cr79) indicated that birds from nests near the facilities contained higher concentratons and a greater variety of radionuclides. However, concentrations of radionuclides encountered in the nestling raptors were lower than those found in potential prey items, indicating that although radionuclides were transferred to higher trophic levels, the concentrations were diluted considerably by the consumption of uncontaminated prey.

Radionuclide retention in organisms is a function of the physical decay (physical half-life = $T_{\frac{1}{2}}$) and the biological half-life (T_B). Thus, retention of radionuclides is related to the characteristics of the specific nuclide and the physiology of the species being examined.

The overall rate at which the radioactivity owing to a radionuclide dimiminshes in an organism can be expressed as the effective half-life (T_{eff}), which can be calculated as follows:

$$T_{eff} = \frac{T_{\frac{1}{2}} \, T_B}{T_{\frac{1}{2}} + T_B}$$

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Table 5.2 lists the physical half-lives of some of the radioecologically more important radionuclides that may be found in samples of soil, vegetation, or wildlife collected in the 100 Areas.

Table 5.2. Physical Half-Lives of Selected Radionuclides (Ei73).

Nuclide	$T_{1/2}$	Nuclide	$T_{1/2}$
H-3	12.36 years	Cs-134	2.5 years
C-14	5730 years	Cs-137	30 years
Mn-54	303 days	Eu-152	14 years
Fe-59	45.6 days	Eu-154	7.8 years
Co-60	5.26 years	Pu-238	86.4 years
Zn-65	245 days	Pu-239	24,400 years
Sr-90	28.1 years		
I-131	8.05 days		

Radionuclide excretion rates are dependent upon species characteristics such as body weight, sex, age, and species biochemistry, along with external environmental factors such as temperature, the chemical form of the nuclide, and the intake rate of stable elements. An investigation of Cs-137 turnover in Great Basin Pocket Mice (Wi70a) concluded that two turnover components existed: (1) a rapid excretion of mostly unassimilated Cs-137 and (2) a slow excretion of the assimilated pool that is distributed throughout the body. T_B values for whole body elimination of Cs-137 in deer mice were found to be 4.97 and 6.29 days (Wi70b). A literature search of T_B values listed a T_B of 3.7 days for I-131 in the thyroid of a deer mouse (Di78).

A study of Zn-65 retention in the Mallard duck (Anas platyrhynchos) determined that the T_{eff} value of this nuclide is affected by sex and season but not the age of the duck (Cu71). Zn-65 retention was significantly greater in males and in October. Egg production accounted for the elimination of 25% of the injected Zn-65 while feather molt accounted for only 2-8% elimination of Zn-65.

Another investigator found that 3% of the Co-60 and 30% of the Cs-137 were retained in Bobwhite Quail (Colinus virginianus) following a 21-day chronic feeding of these two nuclides (An75).

Longer T_B values have been observed for Cs-134 in heavier deer (Ha69). Fawns less than five months old eliminated Cs-134 more rapidly than adults. Additionally, body weight, a sex associated factor, influenced cesium elimination, with a longer T_B in heavier deer.

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6.0 METHODS OF BIOTRANSPORT OF RADIONUCLIDES

Vegetation growing in the 100 Areas may become contaminated by root uptake followed by translocation throughout the plant, and deposition of airborne radionuclides on the plant surfaces. The numerous burial grounds and liquid waste disposal cribs in the 100 Areas, the fact that airborne radionuclide releases occur mainly at 100-N Area (with minor releases from 100-K Area), and the relative absence of broad-leafed vegetation in the 100 Areas all point to root uptake being the more important mechanism by which 100 Area vegetation may be contaminated. At 100-N Area, deposition of radionucides released from the stack and roof vents or from resuspension of radionuclides around the 1301-N Facility may also be important in adding to vegetation radionuclide concentrations.

Perennial plants generally have deeper root systems than annual plants. With a deeper rooting depth, these plants are more capable of invading areas of underground radioactivity and incorporating available radionuclides into their tissues than vegetation wth shallow root systems.

Rabbitbrush has been shown to have strong taproots and few branch roots with one study finding a maximum rooting depth of 2.4 metres for rabbitbrush growing on the Hanford Site (K178). Another study found radiocesium concentrations in rabbitbrush higher in shoots than roots, with leaves having the highest concentrations (K179). This finding is important since herbivores generally eat only the leaves from the rabbitbrush plants.

In the same study (K179) radiocesium concentrations for insects associated with rabbitbrush plants were higher than those collected by hand or from pitfall traps. The eight species of shrub-associated insects averaged 16,300 pCi/g of radiocesium. It should be pointed out that this study was performed at a site in the 200 Areas where the radiocesium concentrations in measured rabbitbrush leaves ranged from 13 to 890,000 pCi/g (dry wt.). Samples of rabbitbrush leaves in the 100 Areas have had relatively lower concentrations of radiocesium, although it does point out that shrub-inhabiting insects will incorporate radionuclides from feeding on rabbitbrush.

Radionuclides from rabbitbrush may also be transferred to the understory plants (such as cheatgrass) or ingested with the leaves by other herbivores. The combination of the deep rooting depth of rabbitbrush, its translocation of radionuclides from roots to leaves, and its ability to invade disturbed land indicates that rabbitbrush is an important plant with the potential to transport radionuclides in the 100 Areas. Other large shrubs, such as bitterbrush and sagebrush, have deep root systems but are not generally found on land that has been disturbed to create burial grounds and liquid waste disposal cribs.

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Another plant in the 100 Areas that is important from a radioecological standpoint is Russian thistle. Although an annual plant, Russian thistle has a relatively deep taproot and therefore has the potential of reaching underground contamination. In addition, when compared with cheatgrass, Russian thistle has a higher affinity for incorporating radionuclides into its tissues (Fi79). In the past, radioactively contaminated tumbleweeds have been found in the 100 Areas. During CY 1973 radiation surveys of retired 100 Area burial grounds, tumbleweeds reading up to 10,000 cpm (EGM with P-11 probe) were observed (Da73). One of these plants was removed and found to have a specific activity of 60,000 pCi/g in the leaves.

Russian thistle may contribute to biotransport of radionuclides by being consumed by herbivores or breaking off at ground level following the growing season and be transported several miles across the Hanford Site with the aid of the wind. The wind may also blow these "tumbleweeds" into the Columbia River, in which case any radionuclides contained within the plants could be transported off-site.

It needs to be pointed out that contaminated tumbleweeds are no longer a significant problem in the retired 100 Areas. Since 1973, herbicides have been applied to the burial grounds, trenches, cribs, and retention basins found in the retired 100 Areas to control weed growth. Surveillance surveys of these waste management areas, which will be discussed in the next section, have also been performed to minimize the potential for biotransport.

Animals residing in the 100 Areas may become radioactively contaminated by three major processes:

(1) ingestion of radioactive food items or water,
(2) inhalation of contaminated particles, and
(3) surface contamination due to dust bathing in radioactive soils.

Ingestion, bioconcentration, and retention of radionuclides has been discussed in previous sections. Animals sustained by a contaminated food base will incorporate radionuclides into their tissues and probably pass these nuclides to their predators.

Burrowing mammals, such as badgers, pocket mice, and ground squirrels, may be very important in the transport of radionuclides. The burrowing animals may dig deep enough to uncover radioactive wastes that then could be ingested by animals or dispersed by the winds.

A good example of radionuclide dispersal at Hanford by a native animal species involves the B-C cribs in the 200 East Area. In the late 1950's, burrowing animals (probably badgers) dug deep enough into the B-C cribs to expose a portion of the solidified radioactive salts. Animals in the area were attracted to the area to use the radioactive

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wastes as a salt lick. The hole was closed and sealed in 1964. A field study using hand-held GM instruments was conducted between 1972-1973 and radioactive fecal pellets from black-tailed hares were found. Most feces with count rates greater than 20,000 counts per minute were found within 400 metres of the B-C cribs, however, jackrabbit feces with count rates in excess of 100,000 counts per minute were found 1.6 km from the cribs (OF75b). Evidence of radioactivity in jackrabbit predators was also found.

The most important animal in the 100 Area that could contribute to the off-site radiation dose is the mule deer. Since they are wanderers, mule deer may migrate off-site and be collected and consumed by hunters. However, the radionuclide concentrations generally found in deer muscle samples collected at Hanford are attributed to worldwide fallout and would result in an insignificant radiation dose to humans.

Waterfowl and upland game birds are also a potential pathway for radionuclides to reach the human population. These birds may incorporate radionuclides while on-site and then migrate off-site and be collected by hunters. In the case of waterfowl, radionuclides may be transported over thousands of miles along migratory routes. The birds may be eaten by humans and other predators, or spread contamination through their feces.

Raptors are also important in transporting radionuclides. As a top carnivore, however, they are not important from a human radiation dose standpoint. Birds of prey may feed on animals that are contaminated and incorporate the nuclides into their tissues. The raptor pellets left at nesting sites may also be contaminated, as was the case of the owl pellets described in Section 3.0 (Co72).

Passerine birds provide relatively little biomass per unit area compared to other kinds of animals and are of less concern than other types of birds. Songbirds may be important in transfering radionuclides from the insects and seeds they feed on to their predators in the higher trophic level. In addition, the blackbilled magpie, robin, barn swallow and cliff swallow all use mud in their nest construction and could transport radionuclides found in mud along pond and ditch margins (Ri76).

Reptiles, particularly lizards, may be the most important carnivorous group associated with the radioactive waste burial sites. Reptiles are more sedentary than mammals or birds, and as such make a good indication of the radionuclides being transported in a particular area.

Insects feeding on contaminated vegetation may contain significant concentrations of radionuclides and pass these along to the insectivores that feed on them. Also, certain insects such as honey bees and wasps, may transport radionuclides when collecting materials to build their hives or nests.

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Ant colonies may also be responsible for the spread of contamination. It was found that harvester ants on the WYE burial ground excavated nests to depths exceeding 1.5 metres (Fi79). It was estimated that harvester ant colonies on this burial ground moved approximately 8.4 kg of soil per year to the surface. Thus, there is a potential for ants to move small particles of contamination to the surface where it could be dispersed by wind and other biota.

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7.0 BIOTRANSPORT OF RADIONUCLIDES IN THE 100 AREAS

Based on the sampling and radioanalysis of vegetation and wildlife that has been conducted, it appears that a limited amount of radionuclide biotransport is occurring in the 100 Areas. As one would expect, the highest potential for biotransport occurs at the last remaining 100 Area in operation, 100-N Area.

The mice and rabbits collected near the 1301-N Facility at 100-N Area show definite uptake and retention of certain radionuclides. As has been previously discussed, radioanalysis of the 1301-N crib influent and plants growing in the 1301-N trench indicate that rabbits and small mammals assimilate the observed radionuclide concentrations by drinking from the crib/trench and eating vegetation growing in or very near the trench.

Vegetation growing around the 1301-N Facility, but outside the chained-off radiation contamination zone, may also become contaminated. The deep-rooted vegetation growing in this area, such as rabbitbrush, are capable of reaching the contaminated water table adjacent the 1301-N Faciltiy and translocating the nuclides to the edible plant leaves. Radionuclides may also be present on plants due to foliar deposition of airborne radionuclides. In the case of the vegetation and soil surrounding the 1301-N Faciltiy, deposition of radionuclides originating from the 116-N stack or 109-N Zone I roof vents may be of some importance, however, it appears that resuspension and deposition of radionucides in the 1301-N Facility is the major source of foliar deposition in that area (Gr79).

Radionuclide concentrations slightly above background levels have also been detected in the riparian vegetation growing along the 1301-N riverbank springs area (Gr80). Animals feeding on this vegetation could therefore assimilate higher than background levels of certain radionuclides.

The major predators of mice and rabbits at 100-N Area are raptors. Hawks and owls have been seen hunting near the 1301-N Facility and raptor nesting sites at Hanford are concentrated in the 100 Areas, mainly between 100-D and 100-F Area. Birds feeding on the contaminated mice and rabbits around the 1301-N Facility would be expected to assimilate certain radionuclides into their tissues, pass radionuclides on to their nestling offspring, and spread contamination by casting the regurgitated pellets from their nests.

Radioanalysis of raptor pellets collected in the 100 Areas indicated levels of Cs-137 above background. It should be remembered that pellets are the undigestible portions of the prey items and, since cesium accumulates mainly in the soft edible tissues, the birds themselves are probably assimilating Cs-137 in concentrations significantly higher than the concentrations found in their pellets.

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It appears, especially in the 100 Areas (since Hanford raptors are most numerous there), that collection and radioanalysis of raptor pellets would be a useful environmental surveillance tool.

Although never collected and analyzed for radionuclide concentrations, rattlesnakes have been seen very near the 1301-N trench. Since mice can be a substantial part of the snake's diet and reptiles are relatively sedentary compared to mammals and birds, the rattlesnakes residing around the 1301-N Facility would be expected to contain significant radionuclide concentrations.

Besides evidence of radionuclide transport from soil, vegetation, mice, and rabbit sampling conducted at 100-N Area, biotransport has also been detected in nest construction. Table 6.1 presents the radionuclide concentrations detected in the nests of swallows and wasps at 100-N Area. The high radionuclide concentrations in the wasp nests were assumed to originate from mud in the 1301-N trench that was used to build the nests. It should be noted that the wasp nests were removed shortly after the contamination was detected.

Table 6.1. Contaminated Nests at 100-N Area (Gr80). Concentrations are in pCi/g (dry wt.).

Sample	Mn-54	Co-60	Cs-137	CePr-144
Swallow Nest	2.5	19	2.9	Not detected
Wasp Nest	1.68×10^5	1.06×10^6	1.55×10^5	5.02×10^4

The major source of radionuclides that accumulate in the biota at 100-N Area is the 1301-N Facility, especially the 1301-N trench. Vegetation growing adjacent the 1301-N Facilty and along the riverbank springs also contributes to biotransport of radionuclides, but probably to a lesser extent.

To greatly reduce the potential for radionuclide transport from the 1301-N Facility, a project to provide a cover for the 1301-N trench is scheduled to be completed in FY 1982. The cover will consist of pre-cast, lightweight concrete which will extend into the bank of the trench to preclude burrowing animals digging beneath the cover and gaining access to the trench. The cover will be provided with sampling ports to obtain the routine environmental surveillance samples from the trench. The trench cover is expected to be very beneficial in reducing biotransport of radionuclides at 100-N Area.

The potential for biotransport of radionuclides is lower at the 100 Areas other than 100-N Area. Mice and rabbit samples collected in the retired 100 Areas have generally contained much lower radionuclide concentrations than those collected at 100-N Area, although some samples have contained concentrations above background levels. Based on this and the vegetation sampling performed in the retired 100 Areas for the 1981 UNC Environmental Surveillance Report (Gr81b), it appears a potential for radionuclide biotransport exists in these areas, however, the potential is lower compared to the operating 100-N Area.

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All burial grounds and radioactive liquid waste disposal facilities in the retired 100 Areas have been covered with clean soil fill. Contaminated soil columns generally have at least 5 to 20 feet of uncontaminated soil cover (sand and gravel).

Radiological control of these facilities is maintained through a Site Surveillance Program, the scope of which is defined in DUN-7805, Rev 3, "Surveillance Program for 100 Area Deactivated Facilities." Bi-monthly surveillance surveys are made during the period from May 1 through November 1. The surveys are of covered and terminated burial grounds, trenches, retention basins, effluent lines, cribs, trenches and outfalls for tumbleweeds and any other unusual radiological conditions. Surveillance of the facilities is directed at the identification of potential contamination spreads from soil erosion, wind, rodents digging holes, weed growth, etc. Corrective actions related to radiological control taken as the result of the site surveillance program are generally the application of soil sterilant on earth cover over contaminated soil columns, and covering or removing any identified surface contaminated areas to prevent the direct release of any radioactive materials.

Application of soil sterilant has greatly minimized the potential of biotransport from deactivated radioactive liquid and solid waste disposal facilities. Experience has shown that soil sterilant must be applied every couple of years. This program has been effective in preventing significant biotransport from vegetation. Prior to the introduction of the soil sterilant program in 1973, contaminated tumbleweeds had been a recurring problem.

Site surveillance and site cleanup programs have been fairly effective in reducing potentials for biologic transport of radioactive materials from the deactivated 100 Areas. Minor potential problems identified as part of the site surveillance program, are also corrected as part of the same program; such as the need to reapply soil sterilant or add more soil fill to an area as the result of settling over a burial trench.

Cyclone fencing has been installed around the retention basins at the retired 100 Areas. Prior to this fencing project, deer were known to occasionally enter these basins using existing access ramps. These fences prohibit the entry of deer and other large, non-burrowing animals into the retention basins. The combination of fencing and soil sterilant used inside and adjacent to the basins should minimize the biotransport of radionuclides from these retention basins.

Although biotransport of radionuclides is occurring to some extent in the 100 Areas, this biotransport would not result in any significant radioactive dose to the off-site human population. Samples of deer, waterfowl, and upland game birds collected in the 100 Areas have generally contained insignificant radionuclide concentrations,

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especially in the edible tissues. Off-site hunters could be exposed to insignificant radionuclide concentrations if they were to consume these types of animals. Cottontail rabbits are frequently consumed by humans and the rabbits collected around the 1301-N Facilty had high concentrations of Cs-137. However, cottontails generally have a relatively limited home range compared to deer and it would be highly unlikely for these rabbits in the 100 Areas to wander off-site where they could be collected by hunters.

The most significant biotransport of radionuclides in the 100-Areas appears to be between small mammals and rabbits to their natural predators, especially raptors. Small mammals and rabbits are capable of gaining access to areas of contamination that other larger mammals may not be able to reach. An example of this is the 1301-N Facility which is surrounded by an eight foot security fence and the trench itself which is covered with 2-inch by 4-inch wire mesh. Radionuclides incorporated into prey species may be passed to higher trophic levels and concentrated in the carnivorous animals, which may result in a significant concentration of radionuclides in the tissues of predatory animals.

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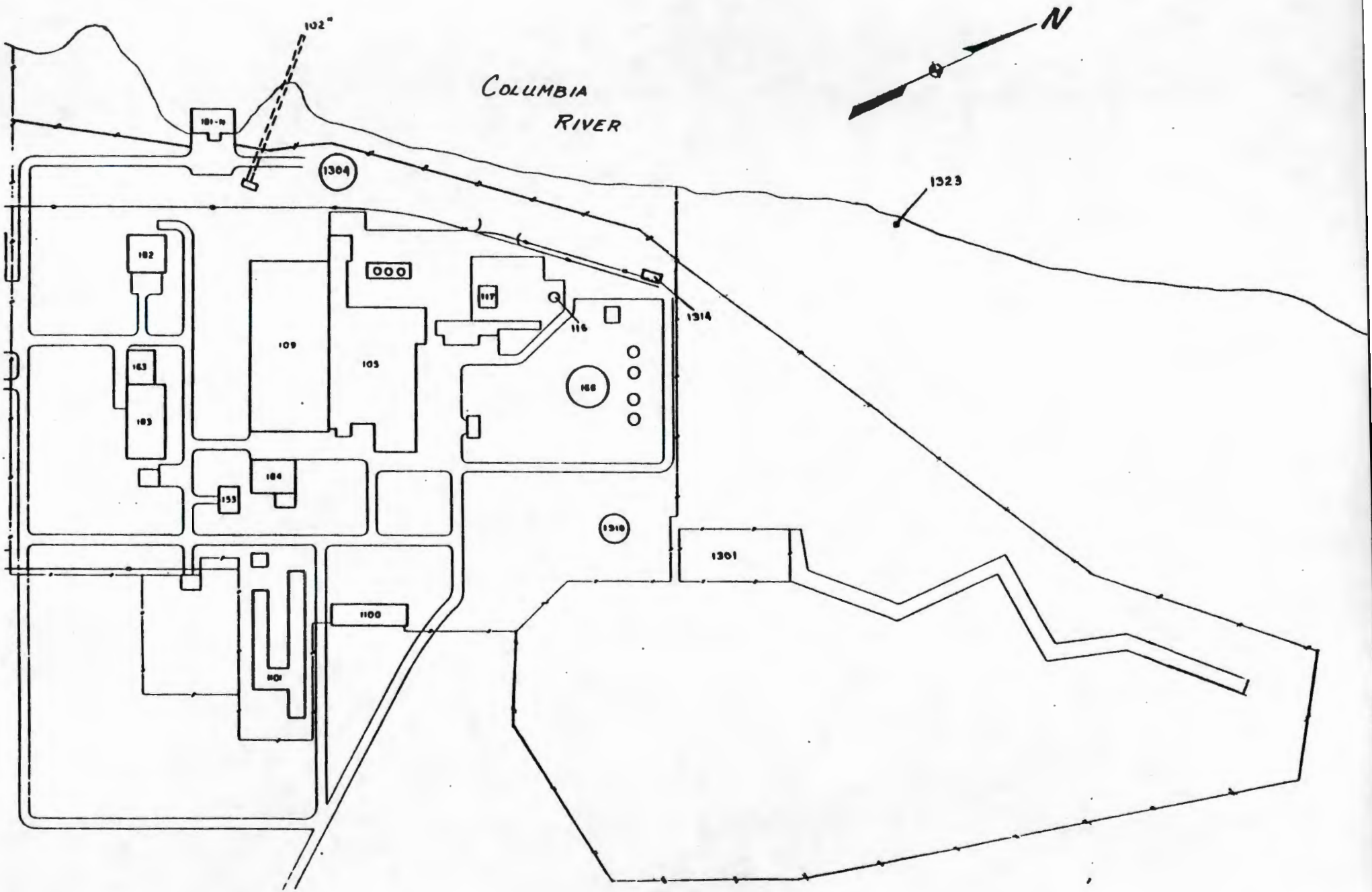

Appendix A - Maps of the 100 Areas - 100-N Area

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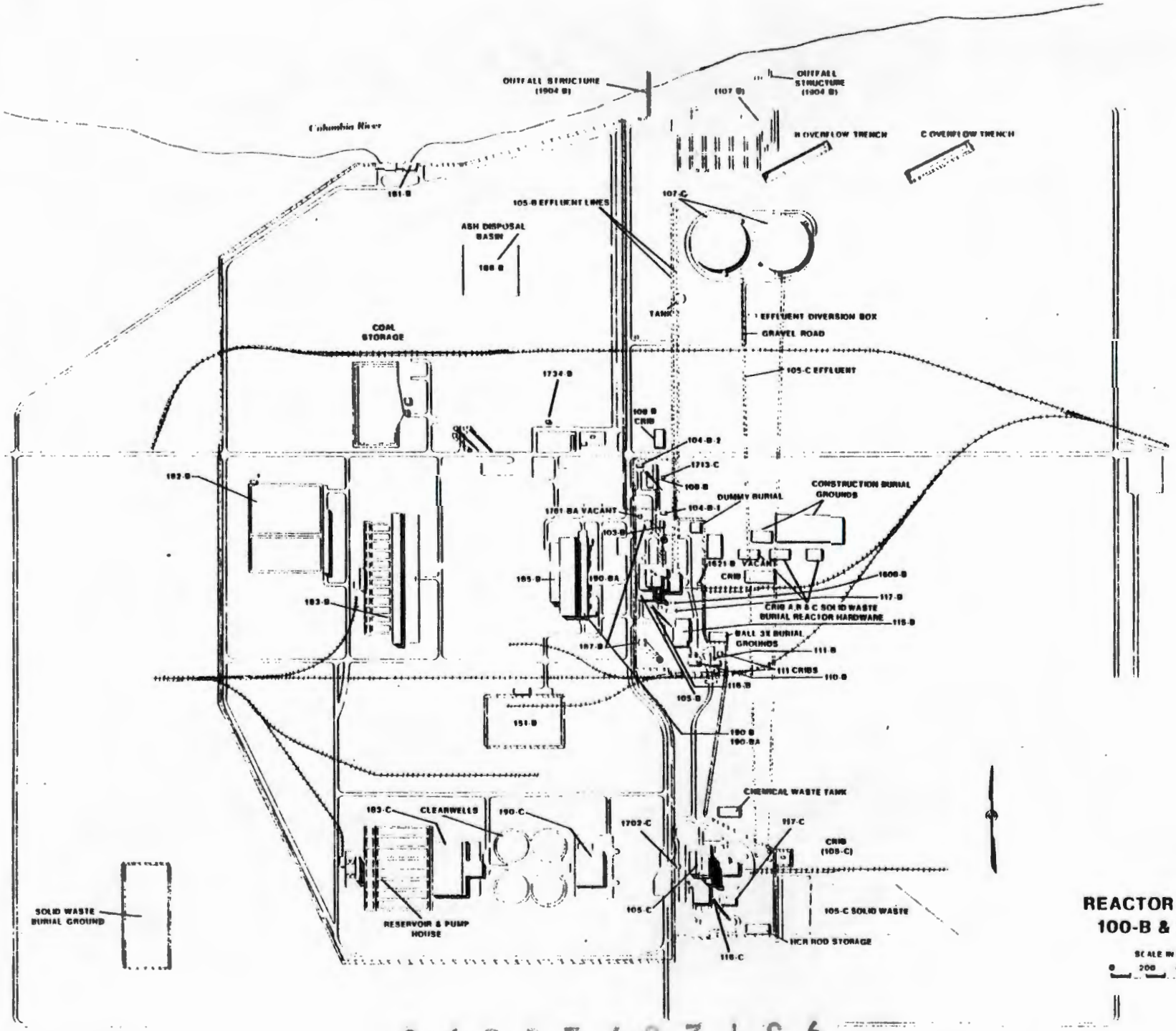
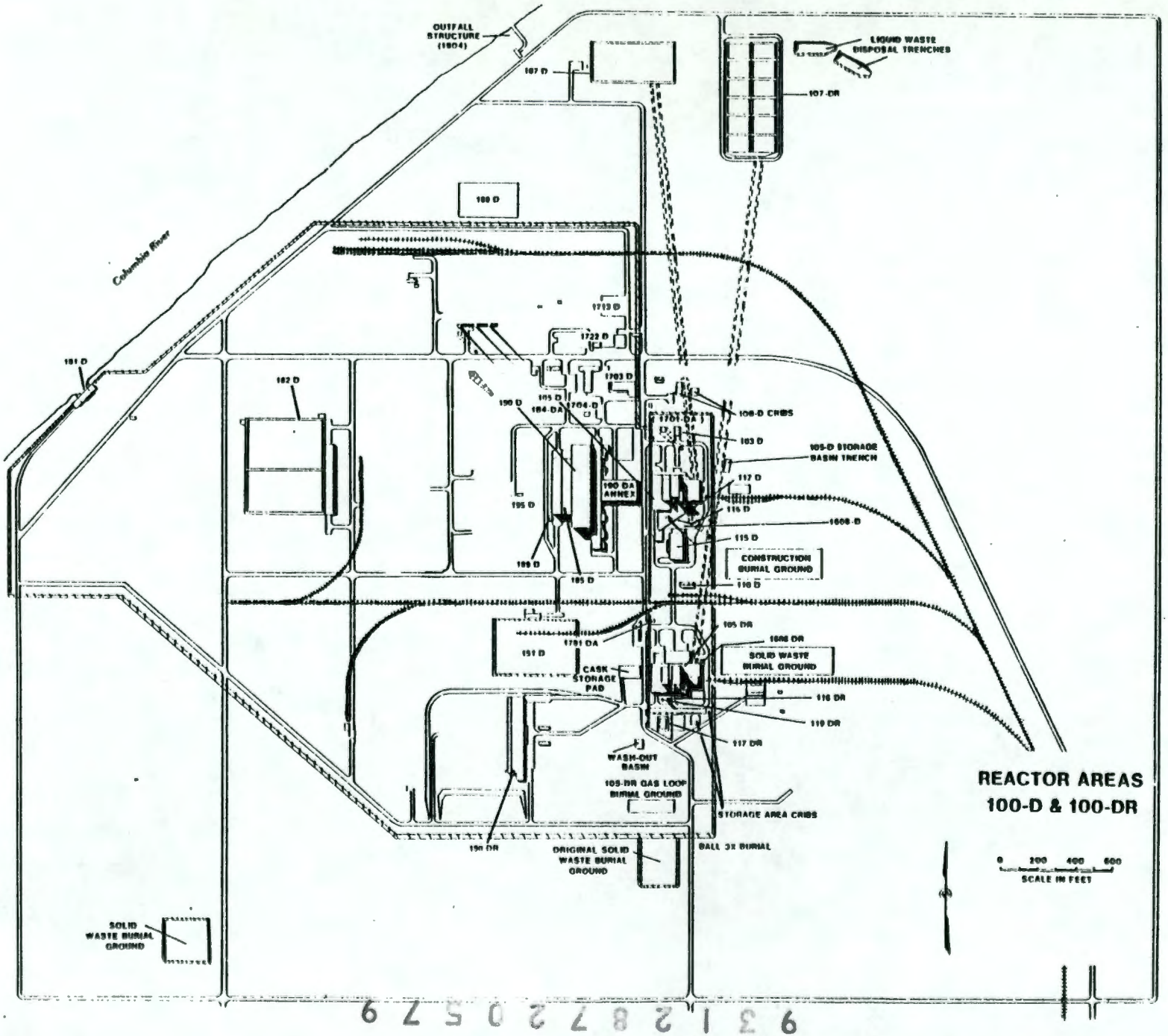
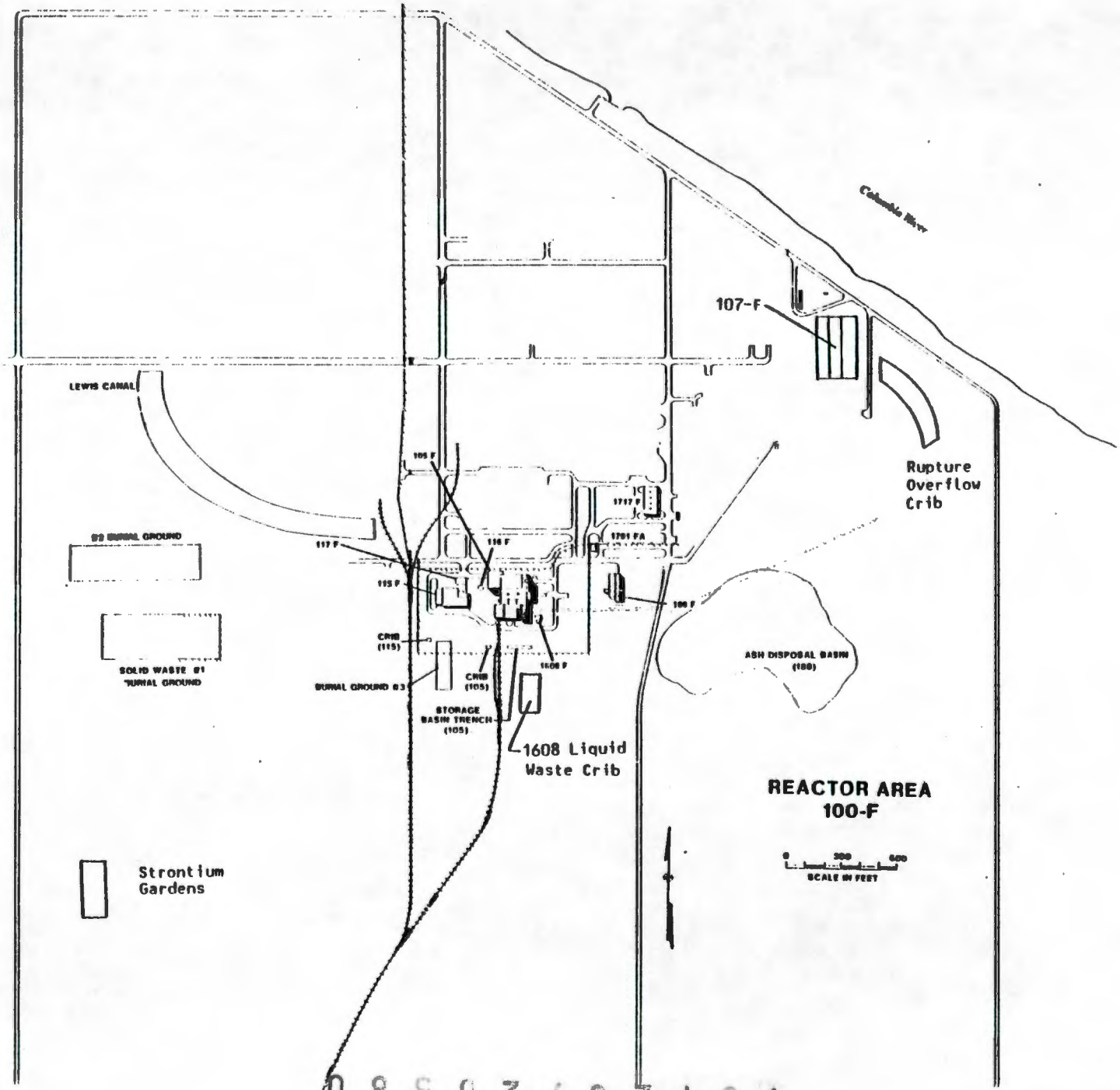
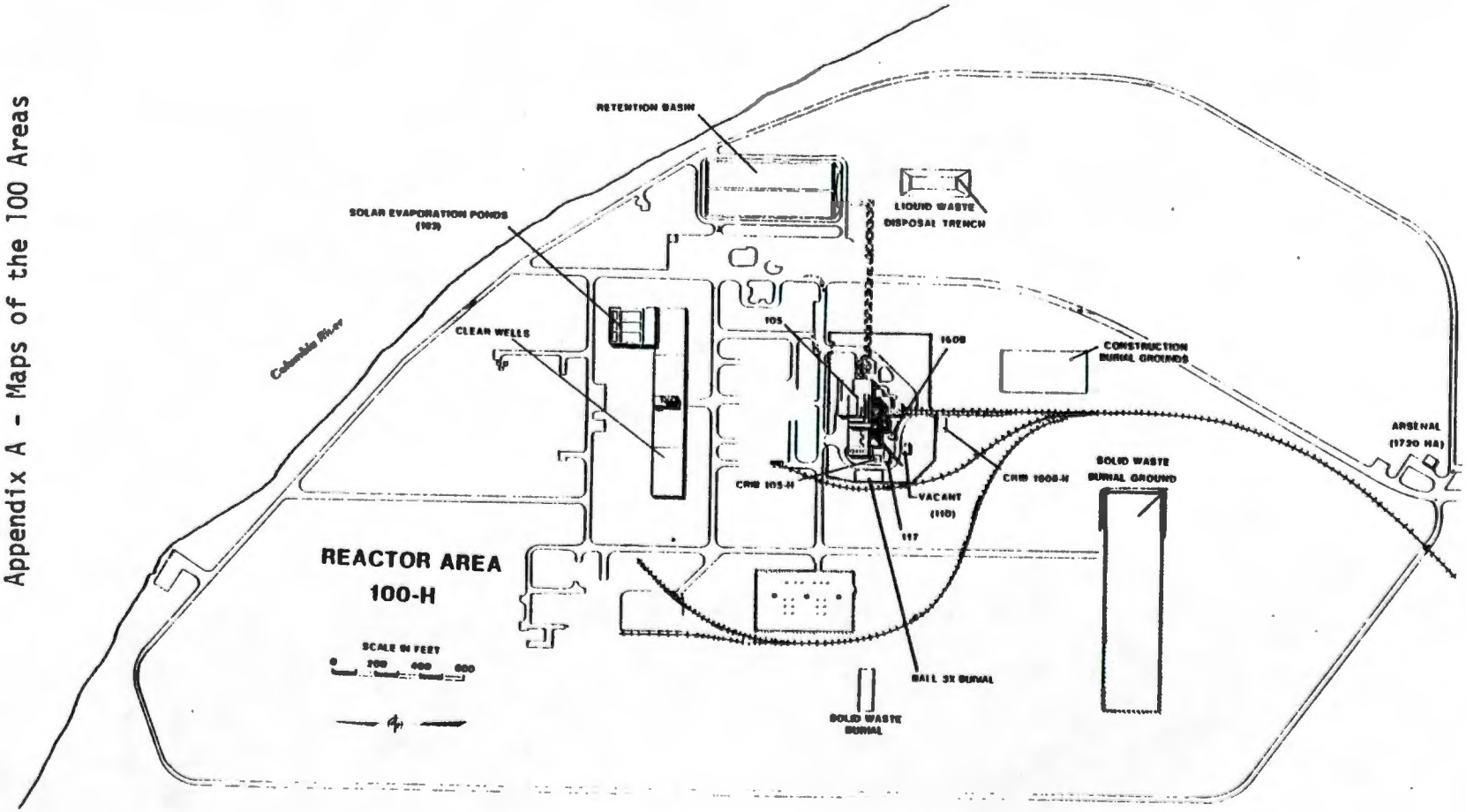

OUTFALL STRUCTURE (1904 B)
OUTFALL STRUCTURE (1904 B)
(107 B)
Columbia River
N OVERFLOW TRENCH
C OVERFLOW TRENCH
181-B
105-B EFFLUENT LINES
107-C
ASH DISPOSAL BASIN
188-B
TANK
EFFLUENT DIVERSION BOX
GRAVEL ROAD
COAL STORAGE
105-C EFFLUENT
1734-B
108-B CRIB
104-B-2
1713-C
108-B
CONSTRUCTION BURIAL GROUNDS
DUMMY BURIAL
1701-BA VACANT
104-B-1
103-B
182-B
1621-B VACANT
CRIB
1606-B
185-B
190-BA
117-B
183-B
CRIB A, B & C SOLID WASTE BURIAL REACTOR HARDWARE
115-B
BALL 3X BURIAL GROUNDS
187-B
111-B
111 CRIBS
110-B
116-B
105-B
151-B
190-B
190-BA
CHEMICAL WASTE TANK
183-C
CLEARWELLS
190-C
1702-C
117-C
CRIB (105-C)
105-C
105-C SOLID WASTE
SOLID WASTE BURIAL GROUND
RESERVOIR & PUMP HOUSE
HCR ROD STORAGE
116-C
REACTOR AREAS
100-B & 100-C
SCALE IN FEET
0 200 400 600

Appendix A - Maps of the 100 Areas

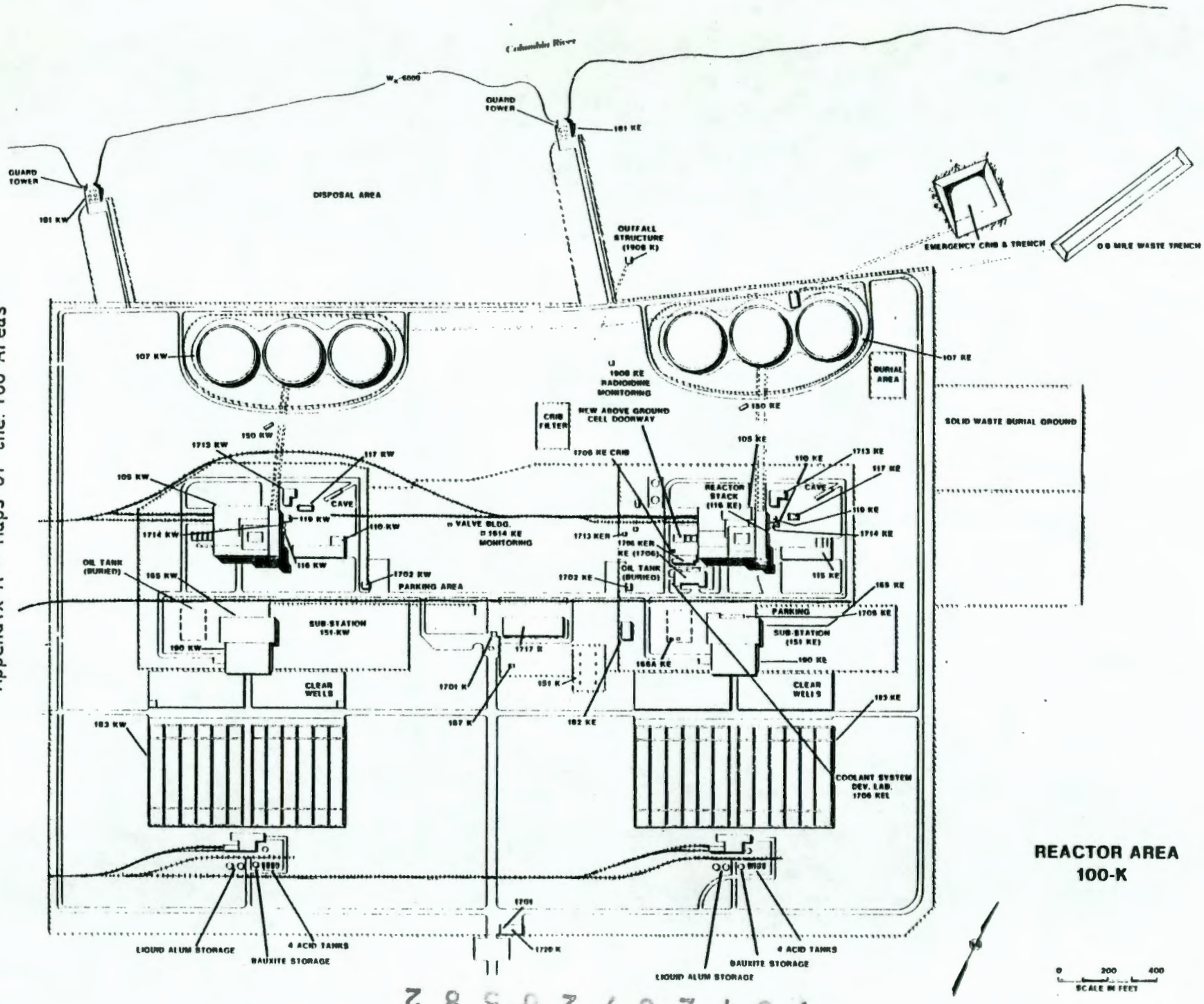



Columbia River
107-F
Rupture
Overflow
Crib
LEWIS CANAL
105 F
1717 F
1701 FA
117 F
116 F
115 F
106 F
CRIB
(115)
1608 F
CRIB
(105)
BURIAL GROUND 03
STORAGE
BASIN TRENCH
(105)
1608 Liquid
Waste Crib
ASH DISPOSAL BASIN
(100)
SOLID WASTE #1
BURIAL GROUND
REACTOR AREA
100-F
SCALE IN FEET
Strontium
Gardens

Appendix A - Maps of the 100 Areas



9 3 1 2 8 7 2 0 5 8 1



REACTOR AREA
100-K