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3.0 DESCRIPTION OF AFFECTED ENVIRONMENT

This chapter provides information and data for the affected environment at the proposed Eagle Rock Enrichment Facility (EREF) and surrounding vicinity. Topics include land use (3.1), transportation (3.2), and geology and soils (3.3), as well as various resources such as water (3.4), ecological (3.5), historic and cultural (3.8), and visual/scenic (3.9). Other topics included in this chapter are meteorology, climatology, and air quality (3.6), environmental noise (3.7), socioeconomic information (3.10), public and occupational health (3.11), and waste management (3.12).

3.1 LAND USE

This section describes land uses on the proposed Eagle Rock Enrichment Facility (EREF) site and within 8 km (5 mi) of the proposed site. It also provides a discussion of land uses in the general region within 80 km (50 mi) of the proposed site. Figure 3.1-1, Land Ownership Within 80-km (50 mi), shows the site in relation to regional lands. Major transportation corridors are identified in Section 3.2, Transportation.

3.1.1 Description of the Proposed Property

The proposed site is situated within Bonneville County, Idaho, on the north side of U.S. Highway 20, about 113 km (70 mi) west of the Idaho/Wyoming state line. Portions of Bonneville, Jefferson, and Bingham counties are within 8 km (5 mi) of the proposed site. The approximately 1,700 ha (4,200 ac) property is currently under private ownership by a single landowner. There is a 16-ha (40-ac) parcel within the proposed site, which is administered by the Bureau of Land Management (BLM). The privately held land will be purchased by AREVA Enrichment Services, LLC (AES).

There are no right-of-ways on the property with the exception of the right-of-way for U.S. Highway 20, which forms part of the southern boundary of the proposed site. Otherwise, the site is in native rangeland, non-irrigated seeded pasture, and irrigated cropland. A dirt road provides site access from U.S. Highway 20, while other dirt roads provide access throughout the proposed site.

There are no mineral or oil and gas leases on or near the proposed site. However, the Federal government has uranium land patents for two, 16-ha (40-ac) parcels located within the proposed site (Figure 3-1.2, Location of U.S. U308 Uranium Patents). The land patents are not subject to the 1872 Mining Law (USC, 2008f) and, therefore, are not available to mining claims. Although the U.S. government can exploit uranium under the patent if present, the geologic setting at the site is not consistent with the occurrence of uranium deposits because the proposed site is underlain by basaltic lava flows that range up to a few thousand feet in total thickness. Basaltic lavas are not known to host any significant uranium deposits anywhere in the world (Nash, 1981). At the current time, no exploration activity for uranium or active uranium mining is reported to be occurring anywhere in Idaho (Gillerman, 2008a). Based on these geological characteristics and associated information, AES concludes that there are no significant uranium deposits at the proposed site and the patents will not interfere with the safe operation of the facility. Refer to Section 3.3, Geology and Soils, for further discussion on mineral resources in the site vicinity.

3.1.2 Local and Regional Setting

Grazing and cropping are the main land uses within 8 km (5 mi) of the proposed site (Table 3.1-1a, Land Use Within 8 km (5 mi) of the Proposed Eagle Rock Enrichment Facility Classification and Area). State land immediately west of the proposed site and BLM land immediately east of the site are grazed. The nearest croplands are within 0.8 km (0.5 mi) of the southeast corner of the proposed site. The nearest feedlot and dairy operations are about 16 km (10 mi) east of the proposed site. The Department of Energy's Idaho National Laboratory (INL) eastern boundary is 0.8 km (0.5 mi) west of the proposed site. The INL property near the site is undeveloped rangeland (Anderson, 1996a). The closest facility on the INL property is the Materials and Fuels Complex (MFC), located approximately 16 km (10 mi) west of the proposed site boundary. The lands north, east, and south of the site are a mixture of private-, State-, and

Federal-owned parcels as shown in Figure 3-1.3, Land Ownership Map Within 8 km (5 mi). (Inside Idaho, 2008) (USCB, 2008a)

The city of Idaho Falls is located about 32 km (20 mi) east southeast from the site. Land uses surrounding Idaho Falls include residential, recreational, agricultural, and commercial (Inside Idaho, 2008, USCB, 2008a). Several lines and branches of the Union Pacific Railroad pass through Idaho Falls. The Union Pacific Railroad Aberdeen Branch runs parallel to U.S. Highway 26, about 40 km (25 mi) south of the proposed site, with the Scoville Branch leading onto the Idaho National Laboratory and ending at Scoville Siding. In addition, the Eastern Idaho Rail Road operates short line tracks connecting towns north and east of Idaho Falls to the Union Pacific Line (USCB, 2008a).

The towns of Rigby and Rexburg are located approximately 23 km (14 mi) and 42 km (26 mi) north of Idaho Falls, respectively. Atomic City is about 32 km (20 mi) west of the site. South of the proposed site are the towns of Blackfoot at 40 km (25 mi) and Pocatello at 76 km (47 mi). The Fort Hall Indian Reservation comprises about 220,150 ha (544,000 ac) and also lies to the south. The nearest boundary of the reservation is about 44 km (27 mi) from the proposed site (Inside Idaho, 2008). The town of Fort Hall is located at a distance of approximately 60 km (37 mi).

The nearest residence is 7.7 km (4.8 mi) east of the proposed site boundary. Temporarily occupied structures in the 8-km (5-mi) radius include two potato cellars, one 3.2 km (2 mi) west of the proposed site boundary, and one about 7.7 km (4.8 mi) to the east of the site boundary (next to the nearest residence). In addition, a powerline transformer is adjacent to the proposed site boundary to the east. Public use areas include a hiking trail south of the proposed site in Hell's Half Acre Wilderness Study Area (WSA) and a small lava tube cave located approximately 8 km (5 mi) east and south (BLM, 2008a). There are landfills in Jefferson, Bonneville, and Bingham counties and two waste transfer stations in Bonneville County. However, none of the facilities are within the 8-km (5-mi) area surrounding the proposed site. U.S. Highway 20 is immediately south of the proposed site and Interstate 15 runs through Idaho Falls about 32 km (20 mi) east of the proposed site. Additional discussion of transportation is presented in Section 3.2, Transportation. A discussion of schools and hospitals is included in Section 3.10, Socioeconomic.

3.1.3 Geology and Soils

The proposed site is located in the eastern portion of the Snake River Plain geologic province (NRCS, 2008a). The Snake River Plain is a crescent-shaped area of topographic depression that is bounded on three sides by mountain ranges and extends across much of the southern portion of Idaho, covering about 40,400 km^2 (15,600 mi^2). The geology of the Snake River Plain has experienced extensive volcanism that has deposited a thick sequence of rhyolitic and basaltic rocks, ranging up to 1,676 m (5,500 ft) thick. On-site soils are primarily of the Pancheri series and consist of deep silt loams (NRCS, 2008b), that commonly support crops, grazing, and wildlife. Refer to Section 3.3.2, Geology at the Proposed Site, for further discussion.

3.1.4 Land Use Within 8 km (5 mi)

Referring to Table 3.1-1a, Land Use Within 8 km (5 mi) of the Proposed Eagle Rock Enrichment Facility Classification and Area, Table 3.1-1b, Land Use Within 8 km (5 mi) of the Proposed Eagle Rock Enrichment Facility Site Classification Descriptions, and Figure 3.1-4, Land Use Map Within 8 km (5 mi), rangeland comprises 53% of the area within an 8-km (5-mi) radius of the proposed site, including 10,161 ha (25,108 ac) within Bonneville County, 4,442 ha (10,977 ac) in Bingham County, and 6,527 ha (16,130 ac) in Jefferson County, Idaho (Bonneville County, 2008) (Jefferson County 2008) (Inside Idaho, 2008) (USCB, 2008a) The rangeland, typical of that found in southeastern Idaho, is composed of shrub and herbaceous vegetation and supports livestock grazing and wildlife.

Non-irrigated seeded pasture comprises 10% of the area within the 8-km (5-mi) radius, all 3,914 ha (9,673 ac) of which is located within Bonneville County. Non-irrigated seeded pastures are areas where native rangelands have been cleared to create improved pasture for livestock grazing.

Agricultural land comprises 18% of the area within an 8-km (5-mi) radius of the proposed site, including 5,063 ha (12,510 ac) within Bonneville County, and 1,931 ha (4,771 ac) in Jefferson County. There are no agricultural lands in Bingham County. The agricultural lands are used primarily for production of food and fiber.

Barren land, comprised of bare exposed rock and volcanic flows constitutes the other land use classification in the proposed site vicinity, is 19% of land area.

3.1.5 Special Land Use Classifications

Special land use classifications (e.g., Native American reservations, national parks, prime farmland) within the vicinity of the site include the following:

- Two Wildlife Management Areas (WMAs), Mud Lake WMA, approximately 35 km (22 mi) to the north, and the Market Lake WMA, approximately 32 km (20 mi) to the northeast (IFG, 2008);
- Camas National Wildlife Refuge (NWR), approximately 44 km (27 mi) to the north (USFWS, 2008b);
- Hell's Half Acre WSA, located on the south side of Highway 20 (BLM, 2008a), adjacent to the proposed site, and;
- Fort Hall Indian Reservation, about 60 km (37 mi) to the south.

The soil in the northeast portion of the proposed site where the irrigated farmland occurs is classified by the U.S. Natural Resources Conservation Service (NRCS) as prime farmland, if irrigated (NRCS, 2008b). The NRCS is responsible for the preservation of prime or unique farmlands as outlined in the Farmland Protection Policy Act (FPPA) (USC, 2006a). Although the proposed enrichment facility will occupy soils identified as prime farmland, private actions on private lands and Federal permitting and licensing involving prime farmland are not subject to protection under FPPA. Therefore, no NRCS formal land evaluation and site assessment are required for the proposed enrichment facility.

3.1.6 Ecological Use

Wildlife observed on and near the proposed site during field visits in May, June and October 2008 were species common to the area. Mammals observed included Pronghorn (*Antilocapra americana*), jack rabbit (*Lepus spp.*), and coyote (*Canis latrans*).

Common bird species observed included horned lark (*Eremophila alpestris*), western meadowlark (*Sturnella neglecta*), Brewer's sparrow (*Spizella breweri*), sage thrasher (*Oreoscoptes montanus*), northern harrier (*Circus cyaneus*), mourning dove (*Zenaida macroura*), killdeer (*Charadrius vociferus*), brown-headed cowbird (*Molothrus ater*), crow (*Corvus brachyrhynchos*), and long-billed curlew (*Numenius americanus*). A single greater sage grouse (*Centrocercus urophasianus*) was observed in May about 1.6 km (1 mi) north of the proposed site, and multiple roost sites were observed in three areas of the proposed site during June 2008 surveys.

See Section 3.5, Ecological Resources, for a detailed discussion of other animals that may be found near the site.

3.1.7 Water Resources

Known sources of water in the vicinity of the proposed site include Mud Lake, Market Lake WMA, the Snake River, Camas NWR, and American Falls Reservoir (American Falls Chamber of Commerce, 2008) (IFG, 2008) (USFWS, 2008b). Both Mud Lake and Market Lake are designated as Wildlife Management Areas dedicated to primary uses such as big game, waterfowl, fishing and general public use (IFG, 2008).

The Snake River is located 32 km (20 mi) east of the proposed site and runs north to south through the town of Idaho Falls and is used for recreational activities as well as providing wildlife habitat along its extensive corridor in the surrounding area (Idaho Falls Chamber of Commerce, 2008). Camas NWR located 44 km (27 mi) to the north of the proposed site is comprised of over 4,050 ha (10,000 ac) of marshes, meadows, and uplands used for wildlife observation, waterfowl, and upland game bird hunting (USFWS, 2008b).

American Falls Reservoir, located 68 km (42 mi) southwest of the proposed site is the largest reservoir on the Snake River and is used for a variety of outdoor sporting and recreational activities (RecreationGov, 2008). Although commercial fishing for some species is permitted at Mud Lake and along designated reaches of the Snake River, there are no commercial fishing operations on or near the proposed site.

3.1.8 Agricultural Use

Various crops are grown in Bonneville, Bingham and Jefferson Counties. About 389 ha (962 ac) of irrigated land on the proposed site are used to grow potatoes and grains. The crop land stubble is grazed in the winter and the remainder of the property is grazed in the spring. Within the vicinity of the proposed site, agricultural activity is comprised mainly of corn, wheat, oats, barley, potato, and hay farms; small dairy and feedlot operations, and; cattle and sheep grazing. See Table 3.1-2, USDA Agriculture Census, Crop, and Livestock Information (USDA, 2008a). No leafy vegetable crops are grown within 8 km (5 mi) of the proposed site. Potato production in the area loses approximately 6 to 8% of the crop to disease damage, with the remaining portion going to direct consumption, processing, or as future seed source. For grazing animals in the vicinity of the proposed site, the fraction of daily intake from pasture varies by the animal as noted in Table 3-1.3, Estimated Fraction of Daily Intake from Pasture.

The principal livestock for Bonneville, Bingham and Jefferson counties is cattle. Milk cows comprise a small portion of the number of cattle in the three counties, with the nearest feedlot and milking operation located about 16 km (10 mi) east of the proposed site. A small farm that raises dairy cows is located about 19 km (12 mi) east of the proposed site. The largest dairy operation near the proposed site is Reed's Dairy, located 32 km (20 mi) east, near the city of Idaho Falls, Idaho.

Cattle and sheep grazing occur both east and west of the proposed site. The State-owned L-shaped land adjacent to the property to the west (Figure 3.1-3, Land Ownership Map Within 8 km (5 mi)), is currently leased to the Siddoway Sheep Company until 2012. The parcel is used in conjunction with other BLM lands as part of the Twin Butte Allotment and is used by BLM for sheep grazing and trailing use from early spring to late fall. Cattle grazing from early spring to late June, and again in November on the BLM lands immediately adjacent to the property boundary to the east, is part of the Kettle Butte Allotment.

There are no unusual animals, facilities, agricultural practices, game harvests, or food processing operations within the vicinity of the proposed site. As listed in Table 3.1-2, USDA Agriculture Census, Crop, and Livestock Information, between 1997 and 2002, the number and total acreage in farms has increased in Bonneville County. Bingham County has shown a decrease in the number of farms, but an increase in total acreage in farms, while Jefferson County has shown a slight decrease in both acreage and number of farms (USDA, 2008a).

3.1.9 Proposed Development

Multiple agencies were contacted to determine if there were any known current, future, or proposed plans for development in the 11 counties located within 80 km (50 mi) of the proposed site.

In Bonneville County, which includes the proposed site, there are several development projects within or near Idaho Falls. These projects include mixed residential, office, retail developments, and hotel developments. There are no industrial developments planned within Bonneville County; however, Idaho National Laboratory, a small portion of which is located in Bonneville County, has started preliminary planning for a Component Test Facility supporting the High Temperature Gas Reactor.

The largest development plan within the region is the Power County Energy Center, located in Power County. The project will include 182 ha (450 ac) of land near American Falls, with construction proposed to start in 2009 and lasting at least five years. The project is for a facility to gasify coal and petroleum coke to produce nitrogenous fertilizers and sulfuric acid (IDEQ, 2008e). Major components of the project are to 1) gasify ~1,814 to 2,087 MT (~2,000 to 2,300 tons) per day of coal and coal/petroleum coke blends, 2) install two GE gasifiers (one for production, one in hot standby as backup), and 3) produce ammonia, urea, urea ammonium nitrate (UAN), sulfuric acid, and slag/frit products for sale for road mix or other uses. The proposed site is about 9.7 km (6.0 mi) southwest of American Falls, just south of the Lamb Weston Potato Processing Plant. Power for the proposed facility operations will be supplied by the local utility.

Smaller projects within the region include a 90-home subdivision in Clark County, a mixed-use 364-ha (900-ac) development in Madison County, a 370-unit development and two large hotels in Blaine County, construction of several cell towers, and a potential 150-unit windmill farm in Bingham County.

Of the projects listed above, there are no known potential conflicts of land use plans, policies, or controls.

TABLES

Table 3.1-1a Land Use Within 8 km (5 mi) of the Proposed Eagle Rock Enrichment Facility Classification and Area

(Page 1 of 1)

Classification	Area							
	(Hectares)				(Acres)			
	Bonneville	Bingham	Jefferson	Total	Bonneville	Bingham	Jefferson	Total
Agricultural Land	5,063	0	1,931	6,994	12,510	0	4,771	17,281
Rangeland	10,161	4,442	6,527	21,130	25,108	10,977	16,130	52,215
Non-irrigated Seeded Pasture[a]	3,914	<1	0	3,914	9,637	0	~1	9,673
Barren	7,685	0	0	7,685	18,990	0	0	18,990
Total[b]	26,823	4,442	8,458	39,723	66,281	10,997	20,901	98,159

Notes:

a. Pasture is identified as part of agriculture in USGS land use categories. However, these areas are used for seasonal grazing similar to rangelands but are not native rangelands. Therefore, this category has been identified separately from agriculture and rangeland.

b. The number of hectares (acres) in a circle with an 8 km (5 mi) radius is 20,342 (50,265). The total acres listed reflects an integration of 8 km (5 mi) radius circles originating from the site boundary.

Table 3.1-1b Land Use Within 8 km (5 mi) of the Proposed Eagle Rock Enrichment Facility Site Classification Descriptions

(Page 1 of 1)

Classification	Description
Agricultural Land	Cropland, Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas; Confined Feeding Operations; and Other Agricultural Land.
Rangeland	Herbaceous Rangeland, Shrub and Brushland; Mixed Rangeland, and Non-irrigated Seeded Pasture
Barren	Bare Exposed Rock; Volcanic Flows

Table 3.1-2 USDA Agriculture Census, Crop, and Livestock Information (Page 1 of 2)

Information	County					
	Bonneville		Bingham		Jefferson	
Census Data	**1997**	**2002**	**1997**	**2002**	**1997**	**2002**
Number of Farms	909	963	1,339	1,273	888	784
Total Land in Farms Hectares (acres)	187,611 (463,598)	193,352 (477,784)	328,961 (812,881)	332,313 (821,163)	136,335 (336,891)	123,553 (305,305)
Ave. Farm Size Hectares (acres)	206 (510)	201 (496)	246 (607)	261 (645)	153 (379)	157 (389)
Crop Annual Average Yields (Most Current)	**Area Harvested Hectares (Acres) in 2002**	**Yield per Hectare (Acre) in 2002**	**Area Harvested Hectares (Acres) in 2002**	**Yield per Hectare (Acre) in 2002**	**Area Harvested Hectares (Acres) in 2002**	**Yield per Hectare (Acre) in 2002**
All Corn	966 (2,387)	59.31 MT/ha (26.45 tons/ac)	1,208 (2,986)	55.34 MT/ha (24.68 tons/ac)	1,233 (3,047)	44.86 MT/ha (20.01 tons/ac)
All Wheat	33,709 (83,296)	3.59 m^3/ha (41.25 bu/ac)	5,308 (13,117)	8.13 m^3/ha (93.33 bu/ac)	9,833 (24,298)	7.55 m^3/ha (86.67 bu/ac)
Oats	233 (576)	4.04 m^3/ha (46.46 bu/ac)	247 (611)	6.52 m^3/ha (74.85 bu/ac)	230 (567)	5.41 m^3/ha (62.09 bu/ac)
Barley	25,348 (62,636)	5.36 m^3/ha (61.65 bu/ac)	9,118 (22,531)	7.66 m^3/ha (87.97 bu/ac)	15,117 (37,356)	8.49 m^3/ha (97.45 bu/ac)
Potatoes	11,912 (29,436)	9,640 kg/ha (8,601 lbs/ac)	27,829 (68,767)	37,241 kg/ha (33,226 lbs/ac)	11,245 (27,788)	39,838 kg/ha (35,543 lbs/ac)
All Hay	14,775 (36,510)	774.49 MT/ha (316.62 tons/ac)	29,530 (72,969)	9.08 MT/ha (4.05 tons/ac)	39,642 (97,958)	10.29 MT/ha (4.59 tons/ac)
Sugarbeets	0	0	10,350 (25,574)	56.15 MT/ha (25.04 tons/ac)	0	0

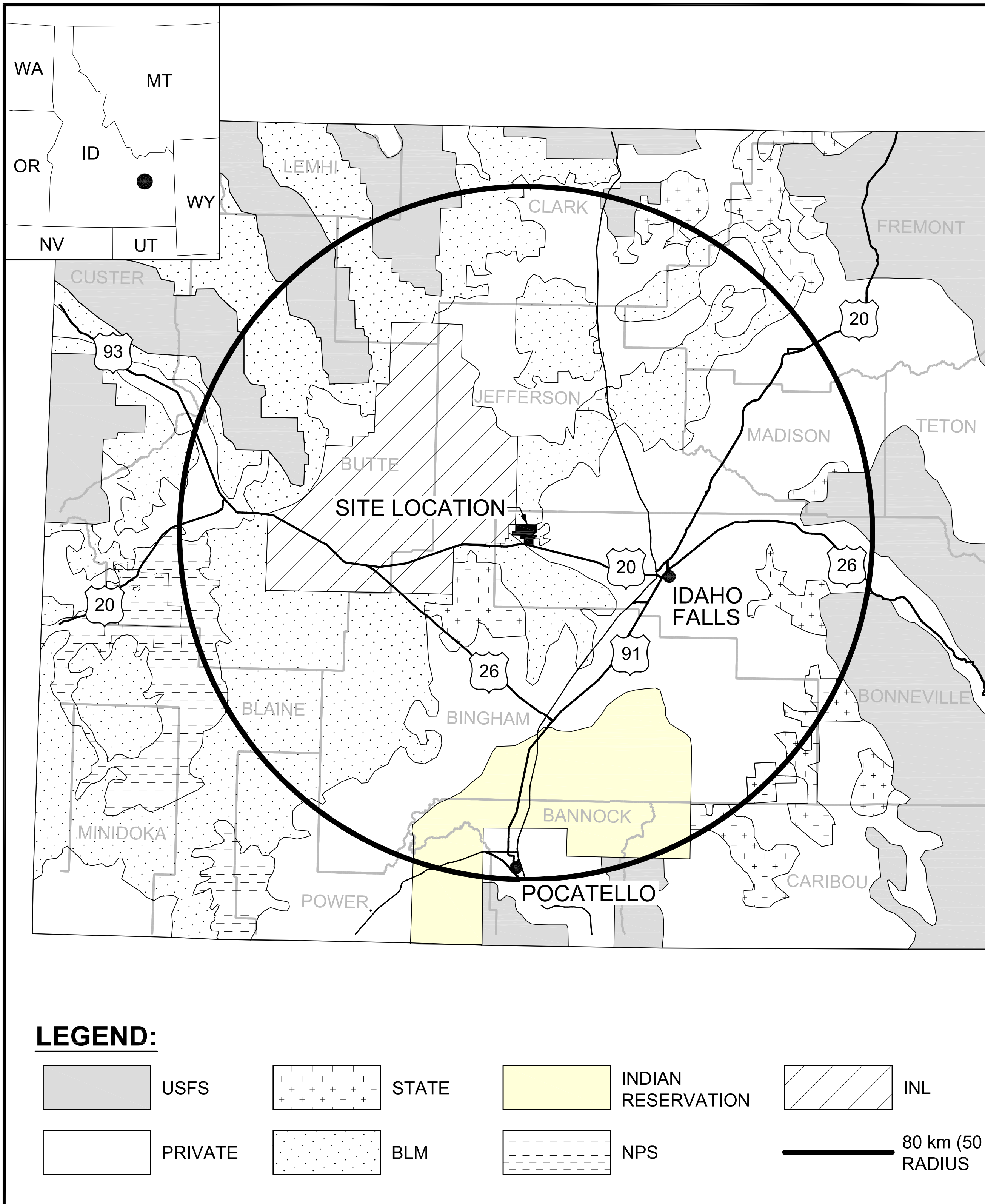
Table 3.1-2 USDA Agriculture Census, Crop, and Livestock Information (Page 2 of 2)

Information	County		
	Bonneville	Bingham	Jefferson
Livestock (Most Current)	Number in 2002	Number in 2002	Number in 2002
All Cattle	50,847	84,096	65,844
Beef Cows	16,518	27,298	17,774
Milk Cows	1,023	10,783	4,266
Other Cattle (Includes cattle on feed)	33,306	46,015	43,804
Sheep and Lambs	3,272	10,329	14,531

Table 3.1-3 Estimated Fraction of Daily Intake from Pasture

Grazing Animal	Estimated Fraction of Daily Intake from Pasture (% dry matter)
Idle Horse	2.0
Yearling Animal	2.0
Pregnant Cow	2.5
Cow	2.0
Lactating Dairy Cow	3.0

FIGURES



NOTE:

1. SMALL PRIVATE AND STATE LANDS EXISTING WITHIN LARGE FEDERAL LAND BLOCKS ARE NOT SHOWN DUE TO SCALE.

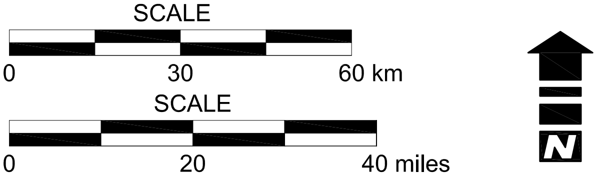
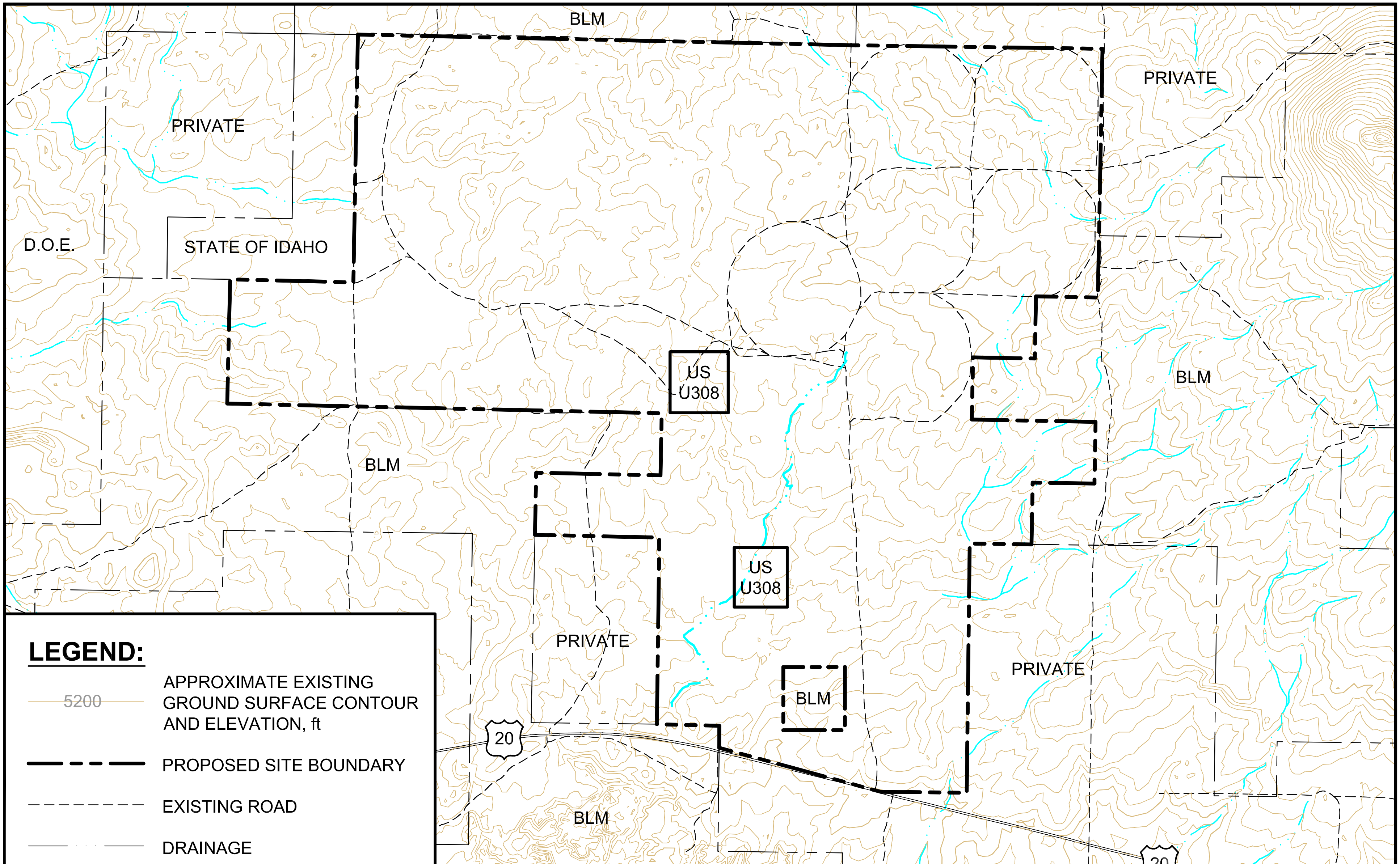


Figure 3.1-1 **Rev. 0**

Land Ownership within 80-km (50-mi)

EAGLE ROCK ENRICHMENT FACILITY ENVIRONMENTAL REPORT



NOTES:

1. GROUND SURFACE CONTOUR ELEVATIONS ARE SHOWN IN FEET. METRIC CONVERSION IS 1 m = 3.281 ft.

SCALE
0 800 1600 m

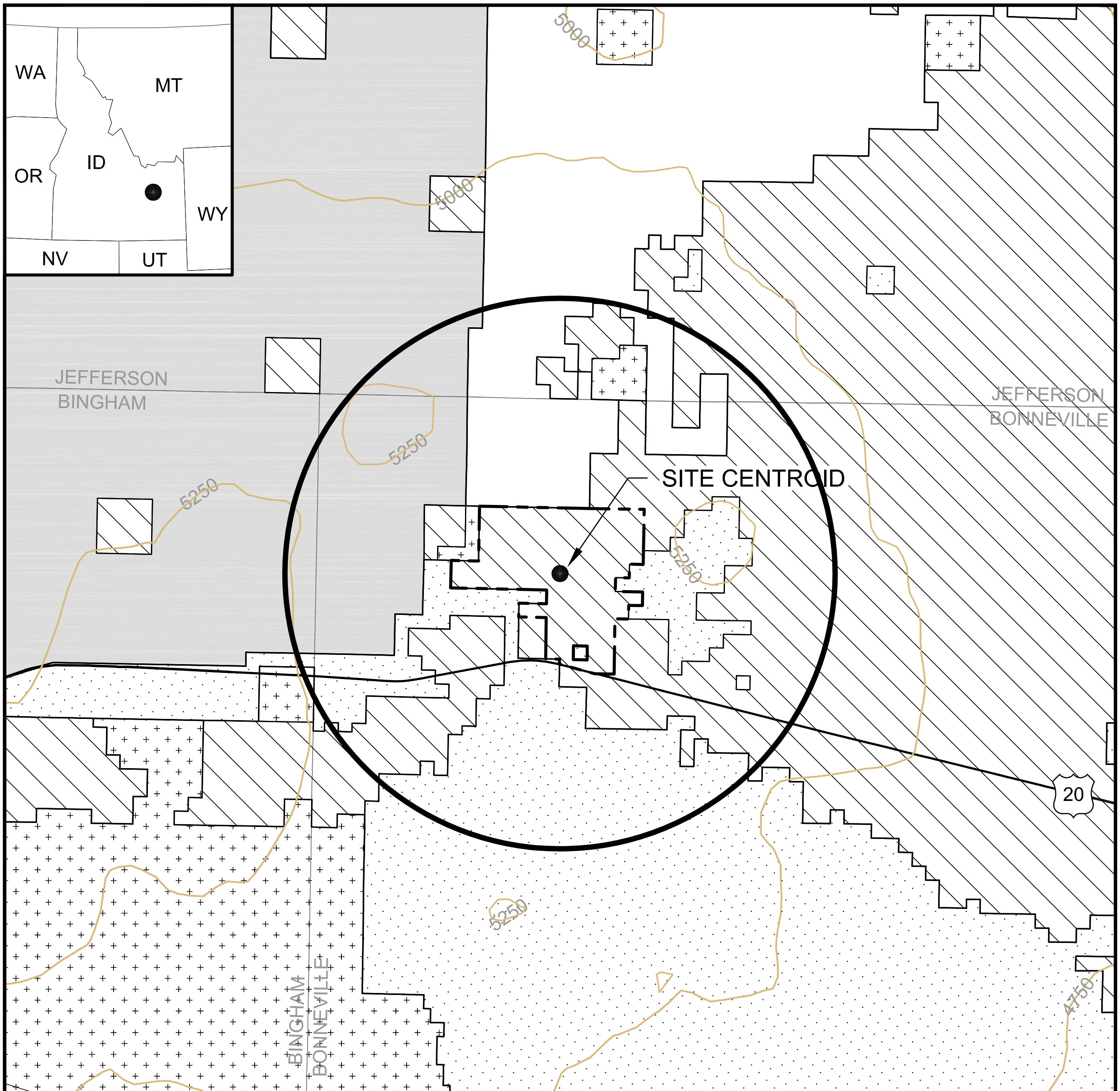
SCALE
0 2500 5000 ft

N

Figure 3.1-2 **Rev. 0**

Location of U.S. U308 Uranium Patents

EAGLE ROCK ENRICHMENT FACILITY
ENVIRONMENTAL REPORT



LEGEND:

D.O.E. (INL)

STATE

5250 APPROXIMATE EXISTING GROUND SURFACE CONTOUR AND ELEVATION, ft

PRIVATE

BLM

PROPOSED SITE BOUNDARY

8 km (5 mi) RADIUS

NOTES:

1. GROUND SURFACE CONTOUR ELEVATIONS ARE SHOWN IN FEET. METRIC CONVERSION IS 1 m = 3.281 ft.

SCALE

0 4 8 km

SCALE

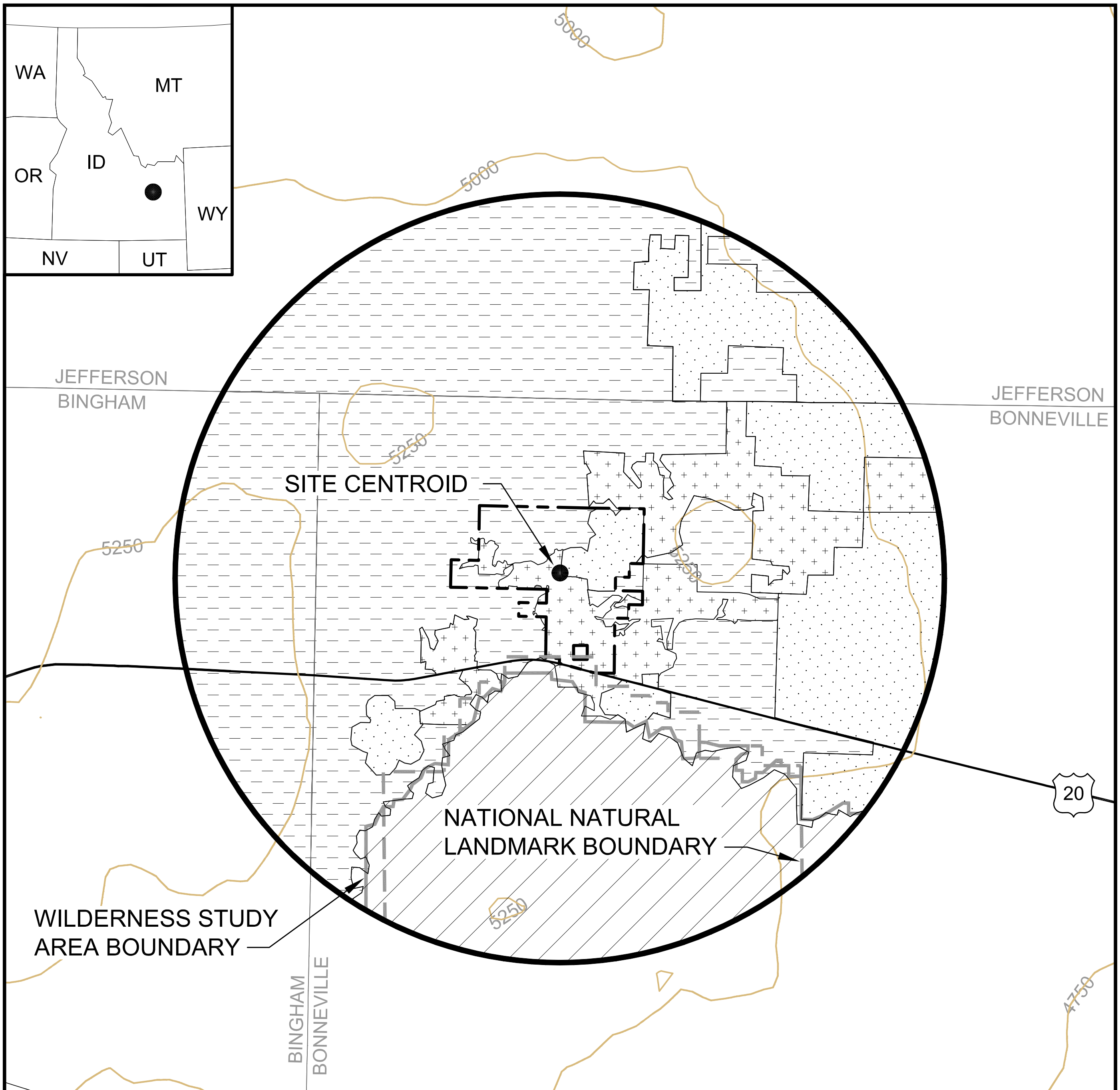
0 2 4 miles

N

Figure 3.1-3 **Rev. 0**

Land Ownership Map Within 8 km (5 mi)

EAGLE ROCK ENRICHMENT FACILITY ENVIRONMENTAL REPORT



LEGEND:

- BARREN
- NATIVE RANGELAND
- NON-IRRIGATED SEEDED PASTURE
- AGRICULTURE
- 5000 — APPROXIMATE EXISTING GROUND SURFACE CONTOUR AND ELEVATION, ft
- PROPOSED SITE BOUNDARY
- 8 km (5 mi) RADIUS

NOTES:

1. GROUND SURFACE CONTOUR ELEVATIONS ARE SHOWN IN FEET. METRIC CONVERSION IS 1 m = 3.281 ft.

N

Figure 3.1-4 **Rev. 0**

Land Use Map Within 8 km (5 mi)

EAGLE ROCK ENRICHMENT FACILITY ENVIRONMENTAL REPORT

3.2 TRANSPORTATION

This section describes transportation facilities at or near the proposed Eagle Rock Enrichment Facility (EREF) site. The section provides input to various other sections such as Section 3.11, Public and Occupational Health and Section 3.12, Waste Management, and includes information on access to and from the site, proposed transportation routes, and applicable restrictions.

3.2.1 Transportation Access

The proposed site is located in eastern Idaho about 32 km (20 mi) west northwest of Idaho Falls, Idaho and immediately east (0.8 km (0.5 mi))of the Department of Energy Idaho National (INL) Laboratory in Bonneville County, Idaho. The site lies immediately north of U.S. Highway 20, which is a two-lane highway with 12.5-m (41.0-ft) driving lanes, and shoulders centered on a right-of-way easements of 122–m (400-ft). U.S. Highway 20 provides direct access to the site. To the east, U.S. Highway 20 intersects with Interstate 15 on the west side of Idaho Falls, Idaho. To the west, U.S. Highway 20 intersects with U.S. Highway 26 northwest of Atomic City and ultimately intersects with Interstate 84 outside the town of Mountain Home, Idaho, southeast of Boise. Refer to Figure 2.1-1, 80-Kilometer (50-Mile) Radius with Cities and Roads. Current traffic volume for the nearby road systems is shown in Table 3.2-1, Current Traffic Volume for the Major Roads in the Vicinity of the Proposed EREF site. Additional information regarding corridor dimensions, corridor uses, and traffic patterns and volumes is provided in Section 4.2, Transportation Impacts.

Several lines and branches of the Union Pacific Railroad run through Idaho Falls. These branches are about 32 km (20 mi) from the proposed site at their nearest point. The Montana Main Branch averages up to sixteen train operations (through trains plus switching) each day (FRA, 2008), while the Yellowstone Branch averages four train operations each day. A Union Pacific Railroad line (Aberdeen Branch) runs parallel to U.S. Highway 26 about 40 km (25 mi) south of the proposed site. This branch averages about two train operations each day. The Scoville Branch leads onto the Idaho National Laboratory ending at the Scoville Siding. The Scoville Branch and Siding are about 40 to 45 km (25 to 28 mi) west of the proposed EREF site, with the siding closer. The Scoville Branch and Siding averaged 26 trains per year from 1993 through 1997 (DOE, 2002b). Likely, this number of rail shipments will continue during construction and operation of the proposed EREF. In addition, up to 20 rail shipments per year of naval spent fuel are permitted from 1997 through 2035 (DOE, 2002b). Therefore, about 46 rail shipments will be received on the Scoville Siding per year during construction, operation, and decommissioning of the proposed EREF. In addition, the Eastern Idaho Rail Road operates short line tracks connecting towns north and east of Idaho Falls to the Union Pacific Line and averages up to six train operations each day. The nearest distance of this railroad line to the proposed site is about 32 km (20 mi).

The nearest airports are in Idaho Falls, approximately 32 km (20 mi) east of the site and in Atomic City, approximately 32 km (20 mi) southwest of the site. The Idaho Falls Regional Airport is used by commercial and privately-owned planes with approximately 8,500 to 9,800 aircraft operations each year (IFRA, 2008). The Midway Airport in Atomic City is used by private planes and averages about 400 aircraft operations each year (AIRNAV, 2008).

3.2.2 Transportation Routes

3.2.2.1 Plant Construction Phase

The transportation route for conveying construction material to the site is via Interstate 15 to U.S. Highway 20, which leads directly to the site. The mode of transportation will consist of over-the-road trucks, ranging from heavy-duty 18-wheeled delivery trucks, concrete mixing trucks and dump trucks, to box and flatbed type light-duty delivery trucks.

3.2.2.2 Plant Operation Phase

All radioactive material shipments will be transported in packages that meet the requirements of 10 CFR 71 (CFR, 2008e) and 49 CFR 171-173 (CFR, 2008j; CFR, 2008w; CFR 2008k). Uranium feed, product, associated low-level radioactive waste, depleted uranium, and empty cylinders will be transported to and/or from the facility. The following distinguishes each of these conveyances and associated routes.

Uranium Feed

The uranium feed for the facility is natural uranium in the form of uranium hexafluoride (UF_6). The UF_6 is transported to the facility in 48Y cylinders. These cylinders are designed, fabricated and shipped in accordance with American National Standard Institute (ANSI) N14.1, Uranium Hexafluoride - Packaging for Transport (ANSI, applicable version). Feed cylinders are transported to the site by 18-wheeled trucks, one per truck. Since the facility has an operational capacity of 712 feed cylinders per year, up to 712 shipments of feed cylinders per year will arrive at the site.

Uranium Product

The enriched uranium from the facility is transported in 30B cylinders. These cylinders are designed, fabricated and shipped in accordance with ANSI N14.1, Uranium Hexafluoride - Packaging for Transport (ANSI, applicable version). Product cylinders are transported from the site to fuel fabrication facilities by modified flat bed truck. Product cylinders contain up to 2,300 kg (5,071 lbs) of enriched product. Typically, two product cylinders are shipped per truck although up to five product cylinders could be transported on the same truck resulting in a maximum of 11,500 kg (25,355 lbs) per truck shipment. There will be approximately 516 product cylinders shipped per year, which will typically result in a shipment frequency of approximately one shipment per 1½ days (258 shipments per year).

Low-Level Radioactive Wastes

Waste materials are transported in packages by truck via highway in accordance with 10 CFR 71 (CFR 2008e) and 49 CFR 171-173 (CFR, 2008j; CFR, 2008w; CFR 2008k). Detailed descriptions of radioactive waste materials which will be shipped from the facility for disposal are presented in Section 3.12, Waste Management. Table 3.12-1, Estimated Annual Radiological and Mixed Wastes, presents a summary of these waste materials. Based on the expected generation rate of low-level radioactive waste (see Table 4.2-5, Annual Radioactive material Quantities and Shipments), an estimated 477, 55-gallon drums of solid waste are expected annually. Using a nominal 60 drums per radiological waste truck shipment, approximately eight low level waste shipments per year are anticipated.

Depleted Uranium Tails

Depleted Uranium tails will be shipped to conversion facilities via truck in 48Y cylinders similar to feed cylinders. These cylinders are designed, fabricated and shipped in accordance with

ANSI N14.1, Uranium Hexafluoride - Packaging for Transport (ANSI, applicable version). Depleted Uranium tails will be transported from the site by 18-wheeled trucks, one per truck (48Y). Since the facility has an operational capacity of approximately 611 cylinders containing Depleted Uranium tails per year, approximately 611 shipments of Depleted Uranium tails per year will leave the site. At present, Depleted Uranium tails will be temporarily stored on site until shipment to conversion facilities.

Empty Cylinders

The number of empty cylinders to be transported annually is as follows: empty feed cylinders (712), empty product cylinders (516), and empty depleted uranium tails cylinders (611). These cylinders are included because they contain decaying residual material (heel) and produce a higher dose equivalent than full 48Y cylinders due to the absence of self-shielding. The empty feed cylinders (with heel) are assumed to be shipped two per truck, totaling 356 shipments per year. The empty product cylinders (with heel) are assumed to be shipped two per truck, totaling 258 shipments per year. The empty depleted uranium tails cylinders (with heel) are assumed to be shipped two per truck, totaling 306 shipments per year.

3.2.3 Transportation Modes, Routes and Distances

Construction material will be transported by truck from areas north and south of the site via Interstate 15 and then west via U.S. Highway 20.

The feed and product materials of the facility will be transported by truck via highway travel only. Most of the feed material is expected to be obtained from UF_6 conversion facilities near Port Hope, Ontario and Metropolis, IL, although a small amount could come from other non-domestic sources. Empty feed cylinders (with heel) are assumed to be returned from the EREF to the UF_6 conversion facilities near Port Hope, Ontario and Metropolis, IL, as well as to ports for overseas shipping near Portsmouth, VA, and Baltimore, MD. The product could be transported to fuel fabrication facilities near Richland, WA, Columbia, SC, and Wilmington, NC, and to ports for overseas shipment near Portsmouth, VA, and Baltimore, MD. Empty product cylinders (with heel) are assumed to be returned to the EREF from the fuel fabrication facilities near Richland, WA, Columbia, SC, and Wilmington, NC. The designation of the supplier of UF_6 and the product receiver is the responsibility of the utility customer. Waste generated from the enrichment process may be shipped to a number of disposal sites or processors depending on the physical and chemical form of the waste. Potential disposal sites or processors are located near Richland, WA; Clive, UT; Oak Ridge, TN; Paducah, KY; and Portsmouth, OH. Refer to Section 3.12.2.1, Radioactive and Mixed Wastes, for disposition options of other wastes.

The primary transportation route between the site and the conversion, fuel fabrication and disposal facilities is via U.S. Highway 20 to Interstate 15 on the west edge of Idaho Falls, about 32 km (20 mi) east of the site. Table 3.2-2, Possible Radioactive Material Transportation Routes and Estimated Distances from the Proposed EREF, lists the approximate highway distances from the site to the respective conversion facilities site, fuel fabrication facilities, and radioactive waste disposal sites.

U.S. Highway 20 serves as the primary commuting route for workers and delivery route from Idaho Falls to the INL. Traffic volume on this highway varies greatly during the day. Commuter traffic is heavy in the early morning and evenings. Traffic volume is low at other times. The condition and design basis for this highway is adequate to meet current traffic flow requirements. There are no improvements funded at this time; however, proposals have been discussed to develop additional passing lanes or expand U.S. Highway 20 to a four-lane highway from Idaho Falls to the INL.

3.2.4 Land Use Transportation Restrictions

The proposed site is on land that will be purchased by AREVA Enrichment Services (AES) from a private owner. There are no restrictions on the types of materials that may be transported along this transportation corridor. AES is working with the Idaho Transportation Department to design and receive permit approval for access to U.S. Highway 20.

TABLES

Table 3.2-1 Current Traffic Volume for the Major Roads in the Vicinity of the Proposed EREF Site

(Page 1 of 1)

Road Name	Average Traffic Volume Vehicles Per Day	Average Traffic Volume Vehicles Per Year [(c)]
U.S. Highway 20	2,282 [(a)]	832,930
Interstate-15 south side of Idaho Falls	20,041[(a)]	7,314,965
U.S. Highway 26	1,100 [(b)]	401,500
U.S. Highway 20 at the U.S. Highway 26 intersection	1,900 [(b)]	693,500
U.S. Highway 20 at the I-15 intersection	21,000 [(b)]	7,665,000

Notes:

(a) Source: (ITD, 2008c).

(b) Source: (ITD, 2007).

(c) Assumes 365 travel days in a year.

Table 3.2-2 Possible Radioactive Material Transportation Routes and Estimated Distances from the Proposed EREF Site

(Page 1 of 1)

Facility	Description	Estimated Distance, km (mi)
UF_6 Conversion Facility Port Hope, Ontario	Feed/Empty Feed/Empty Depleted Uranium Tails	3,547 (2,204)
UF_6 Conversion Facility Metropolis, IL	Feed/Empty Feed/Empty Depleted Uranium Tails	2,580 (1,603)
UF_6 Conversion Facility Overseas Port: Portsmouth, VA	Feed/Empty Feed Empty Depleted Uranium Tails	3,789.1(2,354.5)
UF_6 Conversion Facility Overseas Port: Baltimore, MD	Feed/Empty Feed/Empty Depleted Uranium Tails	3,557.0 (2,210.3)
Fuel Fabrication Facility Richland, WA	Product/Empty Product	948 (589)
Fuel Fabrication Facility Columbia, SC	Product/Empty Product	3,744 (2,326)
Fuel Fabrication Facility Wilmington, NC	Product/Empty Product	4,109 (2,554)
U.S. Ecology Richland, WA	LLW Disposal	871 (541)
Fuel Fabrication Facility Overseas Port: Portsmouth, VA	Product	4021.9 (2,499.1)
Fuel Fabrication Facility Overseas Port: Baltimore, MD	Product	3,760.5 (2,336.8)
Energy*Solutions* Clive, UT	LLW & MLW Disposal	475 (295)
Energy Solutions [(a)] Oak Ridge, TN	Waste Processor	3,068 (1,907)
Depleted UF_6 Conversion Facility [(b)] Paducah, KY	Depleted UF_6 Disposal/Empty Depleted Uranium Tails	2,610 (1,622)
Depleted UF_6 Conversion Facility [(b)] Portsmouth, OH	Depleted UF_6 Disposal/Empty Depleted Uranium Tails	3,002 (1,865)

Notes:

(a) Other off-site waste processors may also be used.

(b) To be operational in approximately two to three years.

3.3 GEOLOGY AND SOILS

This section provides a description of the regional and local geologic setting and soil characteristics of the proposed site for the proposed Eagle Rock Enrichment Facility (EREF). Summaries of the volcanism, mineral resource potential, and seismology of the area are also provided. In addition, the results of field investigations to determine site-specific conditions are presented. The geologic overview presented below is a brief synopsis based on published scientific literature that is cited in subsequent sections of this report.

Geologic Overview

The proposed EREF site lies within the Snake River Plain volcanic field of southeast Idaho approximately 32 km (20 mi) west northwest of Idaho Falls, Idaho. Location of the site within the Snake River Plain (SRP) and locations of regional physiographic features are shown on Figure 3.3-1, Regional Shaded-Relief Topographic Map of Snake River Plain and Surrounding Physiographic Regions. The Snake River Plain is an arc shaped (convex south) belt of topographically subdued volcanic and sedimentary rocks. The SRP crosses southern Idaho, transecting the high-relief mountain ranges of the surrounding Basin and Range province. Volcanic and sedimentary rocks of the SRP occur in a 50-km (31-mi) to 100-km (62-mi) wide belt, spanning 600 km (373 mi) (Kuntz, 1979) from the Oregon-Idaho border, and northeastward to the Yellowstone Plateau. The total area of the SRP (Figure 3.3-1, Regional Shaded-Relief Topographic Map of Snake River Plain and Surrounding Physiographic Regions) is about 40,400 km^2 (15,600 mi^2). The SRP slopes upward from an elevation of about 750 m (2,500 ft) at the Oregon border to more than 1,500 m (5,000 ft) at Ashton, Idaho located northeast of the proposed site. The SRP is a relatively recent geologic feature that is superimposed on older and semi-contemporaneous geologic features of the Cordilleran Mountain Belt of western North America. Early volcanism of the SRP involved violent, voluminous eruptions of silicic rhyolite tuffs and lava flows, many of them associated with volcanic centers known as calderas. The nature of the volcanic activity changed over time to less violent, relatively lower volume eruptions of predominantly basaltic lavas. The older calderas and associated rhyolitic materials were buried beneath younger basaltic volcanic and sedimentary deposits.

Geologists have divided the Snake River Plain into eastern (ESRP) and western (WSRP) segments, based on physiographic features described above and tectonic characteristics. The EREF site is located close to the center of the ESRP, near the southeastern corner of the Idaho National Laboratory (INL). The ESRP has been structurally and volcanically active since approximately 17 million years ago (Ma) when this portion of the North American Plate began passing over a feature known as the Yellowstone hotspot. Radiometric age dating (Armstrong, 1975) indicates that the early silicic volcanism of the SRP becomes systematically younger from southwest to northeast (Figure 3.3-2, Age–Distance Plot Of Late Cenozoic, Bimodal Volcanism in Snake River Plane–Yellowstone Province). The northeastward progression of age dates supports the interpretation that the older silicic volcanic rocks of WSRP in southwest Idaho (Idavada volcanics and older rhyolites) and the younger silicic rocks of the ESRP in southeast Idaho (Heise volcanics) represent the track of a mantle plume (Pierce and Morgan, 1992) hotspot. The ESRP topographic depression resulted from subsidence behind the Yellowstone hotspot as it tracked towards its present location in northwest Wyoming (Hughes, 1999).

The igneous, metamorphic, and sedimentary rocks exposed in the mountainous areas adjacent to the ESRP range in age from Precambrian to Holocene. A geologic time scale is shown on Figure 3.3-3, Geologic Time Scale. Given their ages and position within the Central Cordillera of North America, these rocks have a highly varied yet common geological heritage that is tied to the development of western North America. Precambrian, Paleozoic, Mesozoic, and Early Cenozoic sedimentary formations were deposited along the western North American continent during several episodes of mountain building and erosion. Deformation of the Cordillera culminated during the Early Cenozoic with the formation of the easternmost thrust faults that can be observed in the Caribou and Snake River Mountain Ranges, east of Idaho Falls. Volcanic and intrusive igneous rocks were extruded/emplaced during and after the destruction of the continental margin basins and are exposed in the Challis Volcanic Field and Idaho Batholith, Owyhee Plateau (north and west of the ESRP), and in the Basin and Range fault block mountains that generally surround the ESRP. The Basin and Range, fault block mountains formed in response to crustal extension during the Late Cenozoic.

The following sections provide general descriptions of the regional and local geology in the vicinity of the EREF site.

3.3.1 Regional Geology

Idaho-Wyoming Thrust Belt

The ESRP is bounded to the east by a physiographic region known as the Idaho-Wyoming Thrust Belt. The rocks and associated thrust faults of this region were the culmination of sedimentary deposition and deformation along the western margin of North America. Approximately 11,000 m (36,090 ft) of Paleozoic and Mesozoic sedimentary rocks were deposited near the shelf- basin boundary that ran the length of the North American craton (Momley, 1971; Blackstone, 1977).

Destruction of the continental margin began in late Jurassic moved eastward, and culminated in the east during Early Eocene time (Armstrong, 1965). Structural features associated with the Idaho-Wyoming Thrust Belt include low-angle thrust faults and folds. Armstrong and Oriel (Armstrong, 1965) determined the stratigraphic throw of the thrusts to be near 6,100 m (20,013 ft) and lateral displacements near 16 and 25 km (10 to 16 mi). Younger tectonic features of the Basin and Range and SRP have been superimposed on the Thrust Belt.

Idaho Batholith

The Idaho Batholith is a large region of multiple granitic plutons covering over 38,850 km^2 (15,000 mi^2) in central portions of Idaho. The batholith formed during two stages of activity in the Cretaceous Period, 105 to 75 million years ago (Ma) and 85 to 65 Ma. The batholith formed beneath the surface as the Cretaceous oceanic Farallon Plate was subducted beneath the North American Plate (Hyndman, 1983). The southern portion of the Idaho Batholith is known as the Atlanta Lobe and it occurs north of the western end of the ESRP. As the plutons of the Idaho Batholith were emplaced, the older overlying rocks decoupled along low angle faults and moved laterally away from the uplifted area (Hyndman, 1983)

Challis Volcanic Field

The Challis volcanic field is an area of volcanism dating from approximately 34 to 56 Ma northwest of the ESRP. Three stages of eruptive activity occurred during this time (Sanford, 2005). The first stage was the eruption of andesite and dacite lava flows. Up to 1,524 m (5,000 ft) of andesitic and dacite volcanic deposits cover the area. The second eruption stage consisted of explosive ash- flow tuff eruptions of rhyolite and dacite from calderas. The last stage was the formation of dacite dome complexes. Basin and Range extensional caused faulting in the area (Sanford, 2005).

Owyhee Plateau

The Owyhee Plateau is an area of volcanic rocks located southwest of the ESRP. Volcanic activity in this area began approximately 17.5 Ma near the intersection of the Oregon-Idaho-

Nevada borders, as the North American Plate passed over the Yellowstone (hotspot) mantle plume (Shoemaker, 2002). Initial activity was synchronous with flood basalts that were erupted onto the Columbia and Oregon Plateaus. Younger silicic volcanism in this area is related to large cataclysmic eruptive centers (Shoemaker, 2002).

Basin and Range

Extensional tectonism in the Basin and Range province began around 30 Ma in present day Nevada (Kuntz, 1979). In Idaho, physiographic features that are typical of the Basin and Range province can be found north and south of the ESRP. Folded and thrust faulted Paleozoic and Mesozoic rocks that have been affected by extensional tectonics are found throughout the Idaho portion of the Basin and Range province (Kuntz, 1979). Reactivation of Late Mesozoic and Early Cenozoic thrust fault surfaces, and normal faulting occurred during Tertiary and Quaternary time, uplifting the block faulted mountain ranges (Link, 1999). Movement along range front normal faults has been observed throughout the province as crustal extension continues. The Lost River Range, Lemhi Range, and Beaverhead Range are three mountain ranges that developed along Basin and Range structures located north-northwest of the EREF site area. The tectonic setting of these areas and their apparent relationship with the ESRP volcanic rift zones will be discussed later in this section.

Western Snake River Plain

The Western Snake River Plain (WSRP) is a large structural graben that formed between 10 and 12 Ma (Shervais, 2005) and is filled with sediments and basalts. Extensive rhyolite deposits were extruded coincident within and adjacent to the WSRP graben (Shervais, 2005). Rhyolitic volcanic activity in the WSRP occurred between 11.8 to 9.2 Ma as the North American Plate passed over the Yellowstone hotspot mantle plume. Basaltic lava flow eruptions occurred between 9.0 and 7.0 Ma, and are interspersed within the graben with Miocene sediments (Vetter, 2005). A later phase of basaltic activity, shield volcanoes and cinder cones, began approximately 2.2 Ma and continued until approximately 0.7 Ma. The later basaltic volcanic deposits are also intermitted with fluvial and lacustrine sediments (Vetter, 2005). West of Twin Falls, the Snake River has cut a valley through the tertiary basin fill sediments and interbedded volcanic rocks. The stream drainage is well developed, except in areas covered by recent thin basalt flows.

Yellowstone Plateau

The Yellowstone Plateau is an area of contemporary seismicity, hydrothermal activity, and recent volcanismic activity in northeastern Idaho, southwestern Montana, and northwestern Wyoming. Volcanic activity in this plateau occurred during three eruptive cycles (Christiansen, 1987a). Initial activity for each cycle began as small scale bimodal basaltic and rhyolitic eruptions. Rhyolitic eruptions are believed to have continued for several hundred thousand years during each eruptive cycle as the magma chamber continued to grow beneath the plateau. Each cycle ended in a large cataclysmic explosive eruption that dispersed ejecta hundreds of kilometers (miles) away from the Plateau. The three large caldera-forming eruptions that occurred at the end of each eruptive cycle were approximately 700,000 years apart, 2.0, 1.3, and 0.6 Ma (Christiansen, 1987a). The middle eruptive phase was associated with feature known as the Island Park Caldera near West Yellowstone, Montana and forms the northeastern boundary of the ESRP (Christiansen, 1987a). The mantle plume hotspot responsible for the formation of the SRP is now considered to underlie the Yellowstone Plateau, accounting for the geothermal features and the more than 6,000 km^3 (1,440 mi^3) of late Pliocene and Quaternary silicic volcanic rocks in the Yellowstone Plateau Volcanic Field (Christiansen, 2000). Hydrothermal activity at Yellowstone in the form of geysers, fumaroles, hot springs, and mud pots are present today.

Sedimentary Deposition

During the late Pleistocene, the geomorphology of the ESRP was affected by continued eruptions of basaltic lava flows and also by glaciation particularly in the mountains on the northern side of the ESRP (Hughes, 1999). Important processes associated with glaciation were outburst flooding that deposited gravels and granitic boulders on top of the basaltic lavas in the ESRP and drainages eroded into the basaltic lavas. Extensive eolian (wind) erosion of glacial silts and sands resulted in deposition of loess of variable thicknesses throughout the ESRP. Lacustrine deposits from the formation of lakes and ponds are found in some areas of the ESRP. In recent times, range fires, subsequent wind erosion and re-deposition of soils and sands have been the dominant processes affecting the surface of the ESRP (Hughes, 1999).

Eastern Snake River Plain

The Eastern Snake River Plain (ESRP) is an east-northeast trending topographic depression that extends approximately 100 km (62 mi) by 300 km (186 mi) through southeastern Idaho (Kuntz, 1979). Most of the ESRP has a gently rolling topography at elevations from about 1,830 m (6,000 ft) above sea level in the northeastern portion to about 1,070 m (3,500 ft) at the southeastern edge along the Snake River (Figure 3.3-4, General ESRP Geology and Stratigraphy). Several prominent buttes are scattered along the central part of the ESRP, including Big Southern Butte, Middle Butte, East Butte, and Menan Buttes (Figure 3.3-5, Regional Shaded-Relief Topographic Map of Eastern Snake River Plain (ESRP) and Local Geology). Big Southern Butte is the largest, rising 760 m (2,493 ft) above the plain. The topographic features of the ESRP of volcanic origin may be associated with geologic structures that are oriented both perpendicular and parallel to its axis. The general trends of structures in the adjacent Basin and Range province are also perpendicular to the ESRP axis and fault block mountain ranges occur to the north, east, and south as shown on Figure 3.3-1, Regional Shaded-Relief Topographic Map of Snake River Plain and Surrounding Physiographic Regions. To the northeast and west, the ESRP is bounded by the Yellowstone and Owyhee Volcanic Plateaus, respectively.

The well preserved volcanic features and associated deposits of the ESRP have been the subject of numerous studies and technical papers. Additionally, many of the ESRP studies have been associated with the Idaho National Laboratory (INL) property located immediately west of the EREF site. Many of the published sources that are cited in this section are part of the geologic literature associated with the INL. The geologic history of the ESRP is dominated by late Tertiary to Quaternary events that deposited a thick sequence of volcanic rocks of rhyolitic and basaltic composition. The general order of major geologic events from early to most recent is as follows (Hughes, 1999):

1. Miocene to Pliocene age rhyolitic volcanism associated with Yellowstone mantle plume hotspot,
2. Miocene to Recent age crustal extension associated with the Basin and Range province,
3. Quaternary eruptions of basalts and associated buildup of elongated, intermingled lava fields, small shield volcanoes, and cinder cones,
4. Quaternary glaciation and associated eolian, fluvial, and lacustrine sedimentation.

At the land surface, Quaternary basaltic lava flows, monogenetic shield volcanoes, rhyolite domes, and accumulations of unconsolidated sediments of variable thickness dominate the regional physiography (Hughes, 1999). Scoria cones, pyroclastic deposits near the volcanic vents, dikes, and less chemically evolved basaltic rocks are found to a lesser extent within the ESRP (Hughes, 1999) than in the WSRP. Most of the surface (Kuntz, 1994) and subsurface basalt lava flows (Champion, 2002) of the INL area have normal magnetic polarity associated with the Brunhes Normal Polarity Chron, and are therefore younger than 780 thousand years ago (ka).

Thermal contraction and subsidence in the ESRP occurred after the cessation of rhyolitic activity from the Yellowstone mantle plume (Christiansen, 1987b). The effects of the Yellowstone mantle plume persist to the present day and the heat flux (~110 mW/m^2) beneath the ESRP is the highest found in the region. Recent volcanic activity has been the greatest beneath the northeastern ESRP where most of the heat is concentrated (Smith, 2004). Tectonic processes, including uplift of the Yellowstone plateau above the mantle hotspot and normal faulting in the adjacent Basin and Range province, maintain the high elevations and mountainous character of the region surrounding the ESRP.

Yellowstone Hotspot

The Yellowstone hotspot is considered to be responsible for formation of the ESRP. As the North American Plate passed over the Yellowstone hotspot beginning approximately 17 Ma, melting above the hotspot produced (Pierce and Morgan, 1992; Smith, 2004) thick rhyolitic ash flows, tuffs, and lavas. The hot spot has left a trail of volcanism that records the southwestward relative motion of the North American plate over a fixed mantle plume, at a rate of about 3 cm per year.

Miocene and Pliocene rhyolitic calderas are believed to be buried under younger Pleistocene volcanic deposits. Subsidence within the ESRP began approximately 4 Ma, as the hotspot track continued to the northeast beneath and relative to the North American plate, to its present day location in northwest Wyoming. Cooling of the crust, crustal extension, increased loads from denser magmatic rocks, and isostatic adjustment were other factors contributing to subsidence. Approximately 1.5 to 2 km (0.9 to 1.2 mi) of subsidence has occurred within the ESRP continues today as the crust continues to reach isostatic equilibrium (Smith, 2004).

Axial Volcanic Zone

Researchers have identified a northeast trending volcanic highland within the ESRP known as the axial volcanic zone (AVZ). The AVZ is a topographic high that runs parallel to the long axis of the ESRP (Figure 3.3-5, Regional Shaded-Relief Topographic Map of Eastern Snake River Plain (ESRP) and Local Geology). This zone of higher elevation is the locus of numerous volcanic features including lava flows, spatter cones, shield volcanoes, and rhyolitic domes. Volcanic activity within the AVZ has occurred in the last two million years. Additionally, a series of volcanic rifts and fissures are located perpendicular to the AVZ (Figure 3.3-6, Volcanic Rift Zones, Volcanic Vents, and Dike-Induced Fissures and Faults). The AVZ also acts as a drainage divide separating the Snake River and Big Lost River watersheds (Wetmore, 1999). The EREF site is located within the AVZ (Figure 3.3-5, Regional Shaded-Relief Topographic Map of Eastern Snake River Plain (ESRP) and Local Geology).

Rhyolite Domes

Pleistocene rhyolite domes are found scattered along the Axial Volcanic Zone of the ESRP. Big Southern Butte, Middle Butte, and East Butte are prominent examples. They range in age from approximately 300 ka (Big Southern Butte) to 1.4 Ma (a thyolite dome near East Butte) (Kuntz, 1979). The Big Southern Butte is believed to have formed in close relation to the chemically evolved lavas at the Cedar Butte eruptive center (Hughes, 1999) dated around 400 ka (Kuntz, 1994). Volcanism at these volcanic buttes is believed to reflect the extensional structural deformation that affects near surface and deeper crustal rocks at the intersection of the Arco and Rock Coral volcanic rift zones. Both these domes were formed as non-explosive extrusive plugs of compositionally evolved magmas (Kuntz, 1979). East Butte and Middle Butte will be discussed later.

Hydromagmatic Eruptions

The Menan Buttes volcanic deposits, located about 45 km (28 mi) northeast of the proposed EREF site (Figure 3.3-5, Regional Shaded-Relief Topographic Map of Eastern Snake River Plain (ESRP) and Local Geology), is one of several hydromagmatic (also known as phreatomagmatic) eruptive centers found in the ESRP. As basaltic magma encountered shallow ground water associated with the Snake River, moderately explosive eruptions occurred. These eruptions produced unconsolidated ash mixed with pebbles and sand sized fragments from the near surface alluvial deposits. The Menan Buttes are the largest hydromagmatic eruptive centers found in the ESRP (Hughes, 1999).

Basaltic Plains Volcanism

The distinctive low relief produced by coalesced shield and lava flows of the ESRP prompted Greeley (Greeley, 1982) to name the features of the area “basaltic plains volcanism,” to distinguish them from the more voluminous flood-basalt volcanism of regions such as the Columbia Plateaus. Flood-basalt volcanism involves a small number of voluminous eruptions having high effusion rates (high magnitude, low frequency volcanism). In contrast, basaltic plains volcanism of the ESRP involves a large number of small eruptive centers with comparatively low effusion rates (high frequency, low magnitude volcanism). Hundreds of lava flow units are produced during each eruption, extending up to tens of kilometers (miles) from the vent, possibly during a period of months to years; certainly no longer than a few decades (Kuntz, 1992a; Champion, 2002).

It is estimated that approximately 3.3 km^3 (0.8 mi^3) per 1,000 years of basaltic volcanic deposits erupted throughout the region during the past 15,000 years (Kuntz, 1992a). Basaltic volcanism in the region occurred as lava and scoria was erupted from dikes beneath volcanic rift zones. The regional northwest trend of these zones and their associated vents suggest they were oriented perpendicular to the least-compressive regional stress. Tube fed pahoehoe lava flows were erupted from fissures at shield volcanoes and extended up to 48 km (30 mi) away from their vents (Kuntz, 1992a). Lava flows follow subtle creases in the terrain and are capable of moving great distances by endogenous flow. As a result, nearly planar surfaces are produced by ponding of successive effusions and the widespread overlapping of lava fields. Isolated Strombolian (mild pyroclastic) events also occurred in the ESRP, and this style of volcanism is marked by cinder and spatter cones situated on eruptive fissures and at the summits of small shield volcanoes. The thickness of each lava flow ranges from 5 to 25 m (16 to 82 ft).

Smaller flow thicknesses can be observed in outcrops or core samples that are near the flow margins. Volcanic features typically associated with the basaltic plains volcanism include:

- Low Profile Basaltic Shields (e.g., Kettle Butte) comprised of interlaced basaltic lava flows that are generally aligned along rifts or fissures (Hughes, 1999): Basaltic plains volcanism produces low shield volcanoes of modest volume (5 +/- 3 km^3 (1.2 +/- 0.7 mi^3)), composed of fluid, vesicular lavas. Low shields are generally characterized by gentle slopes and small size of usually less than 16 km (10 mi) in diameter. The individual lava flows making up Low Shields show various volcanic features, such as collapse depressions, flow and pressure ridges, lava toes with extensive vertical and horizontal jointing, but generally lack lava tubes.
- Fissures, vents and flows associated with rift zones: Fissures and vents, such as spatter cones, pyroclastic cones, and cinder cones, are indicative of point source eruptions along rift zones. Eruptions commonly begin from a fissure system, and long-lived eruptions eventually

consolidate to one or several vents along the fissure system. Evidence of lava lakes is also associated with many vents (Hughes, 1999). Fissure flows are complexes of numerous basaltic lava flows of generally less than 1.5 m (5.0 ft) thickness. The Craters of the Moon and Hells Half Acre are examples of large areas of young, intermingled fissure vents and flows.

- Lava tubes and channels that originate from both fissures in rift zones and less commonly in low shields: Lava tubes were a common mode of lava flow movement across the ESRP landscape. During emplacement of ESRP basalt lava flows, molten rock is continuously supplied to the advancing flow front through lava tubes. The solidified crust on the top, bottom, and ends of the lava flows is kept inflated by the pressure of the molten material in the interior of the flow. As the flow front advances, the crust at the end of the flow is laid down and overridden by the new lava, and the upper crust is stretched, broken, and fissured by movements of magma beneath. Lava tubes can occur in large networks. An example is the Shoshone lava tube system located approximately 160 km (100 mi) southwest of the proposed site which covers about 207 km^2 (80 mi^2). The open topped nature of lava channels makes them difficult to discern once they are covered by younger flows. Lava tubes tend to collapse and fill with sediment and rubble during burial.

Over the last 13,000 years, volcanism has occurred at the following seven monogenetic basaltic lava fields within the region. Locations of these lava fields near the site are shown on Figure 3.3-5, Regional Shaded-Relief Topographic Map of Eastern Snake River Plain (ESRP) and Local Geology.

- Shoshone
- Wapi
- Kings Bowl
- North Robbers
- South Robbers
- Cerro Grande
- Hells Half Acre

Craters of the Moon volcanic field is compositionally and temporally different from the other lava fields listed above. It is a polygenetic volcanic field that evolved during several cycles of volcanism, consisting of numerous eruptive centers of balsaltic through andesitic composition. Eruption ages at Craters of the Moon vents range from 1.5 to 15 ka (Kuntz, 1988).

Unlike the earlier silicic volcanism, no systematic, eastward migration of basaltic volcanism is apparent on the ESRP; and Holocene lavas (younger than 15,000 years) occur across the ESRP. No eruptions have occurred on the ESRP during recorded history, but the basaltic lava flows of the Hell's Half Acre lava field erupted near the southern boundary of the proposed site as recently as 5,400 years ago (Kuntz, 1986).

Volcanic Rift Zones

Volcanic rift zones are found throughout the ESRP (Figure 3.3-5, Regional Shaded-Relief Topographic Map of Eastern Snake River Plain (ESRP) and Local Geology). Kuntz et al. (Kuntz, 1992a) suggest that as many as nine volcanic rift zones cross the ESRP. The majority of the rift zones reflect a northwest-southeast trending lineation similar to what is observed in the Basin and Range province to the north and south of the ESRP. The following volcanic rift zones (from northeast to southwest) are found in the ESRP (Kuntz, 1992a):

- Spencer-High Point volcanic rift zone
- Menan volcanic rift zone
- Circular Butte-Kettle Butte volcanic rift zone
- Lava Ridge-Hells Half Acre volcanic rift zone
- Howe-East Butte volcanic rift zone
- Arco-Big Southern Butte volcanic rift zone
- The Great Rift volcanic rift zone
- Borkum volcanic rift zone
- Richfield-Burley Butte volcanic rift zone

The Rock Corral Butte volcanic rift zone is a southwest-northeast trending rift zone that is perpendicular to all other rift zones found in the ESRP. This rift zone is believed to be related to a Pre-tertiary zone of crustal weakness (Kuntz, 1979).

The northwest trending volcanic rift zones in the ESRP are believed to have formed within the same, extensional, regional-stress field of the adjacent Basin and Range mountains. However, in contrast to the range front faults, there is evidence that the volcanic rift zones are underlain by basaltic dikes. The emplacement of magma as vertical dikes within the rift zones is believed to be the mechanism of crustal extension and low-magnitude seismicity within the ESRP volcanic province (Parsons, 1991). In contrast, crustal extension in the surrounding Basin and Range occurs by normal faulting with accompanying earthquakes of varying magnitudes.

3.3.1.1 Eastern Snake River Plain Stratigraphy

ESRP stratigraphy is composed of igneous and sedimentary rocks over 3,048 m (10,000 ft) thick (Doherty, 1979). The products of rhyolitic, andesitic, and basaltic volcanism are interspersed with sedimentary fluvial, lacustrine, and eolian (wind) deposits. The thickness and lateral extent of the volcanic deposits varies greatly in response to the composition, volume, and location of the erupted material. Most of the ESRP is covered with basaltic materials. Deep boreholes on the adjacent INL have intersected nearly 1 km (0.6 mi) of late Tertiary and Quaternary basalt lava flows and interbedded sedimentary deposits overlying older silicic tuffs (Hackett, 1992). Because they host the vadose zone and the underlying ESRP aquifier, the Quaternary basalts of the INL area have been studied in greater detail than the underlying units.

Subsurface investigations to date at the EREF site included drilling six groundwater monitoring wells with a maximum depth of 223.0 m (730.5 ft). Continuous core samples were collected from one of the monitoring well borings and basalt was the primary rock type encountered from the ground surface to the total depth of the well. Further details regarding the site-specific geology are provided in Section 3.3.2, Geology at the Proposed Site.

Stratigraphic Units

The Snake River Group is the main geologic unit beneath the EREF site in the ESRP (Figures 3.3-2, Age–Distance Plot of Late Cenozoic, Bimodal Volcanism in Snake River Plane-Yellowstone Province, and 3.3-4, General ESRP Geology and Stratigraphy). The Heise volcanics are mostly silicic lava flows and ash tuffs and are estimated to be greater than 1,000 m (3,280 ft) thick in some areas.

Most basaltic eruptions were effusive rather than explosive, and typical landforms of Quaternary mafic volcanism on the ESRP are small shield volcanoes with summit pit crates, fissure fed lava flows associated with zones of tensional fracturing and relatively uncommon tephra cones of magmatic or phreatomagmatic origin (Greeley, 1982). The surface distribution, ages and lithologies of surface basalts and sediments in the INL area have been mapped by Kuntz et al. (Kuntz, 1994), and the surficial deposits of the ESRP have been mapped by Scott (Scott, 1982).

Groundwater investigations at the INL site have led to creation of a working stratigraphic system to describe the complex assemblage of eruptive and sedimentary materials (Anderson, 1996b; Anderson, 1996c). An example of the INL stratigraphic system is presented in Table 3.3-1, INL Stratigraphic Units. The EREF site is located near the southeastern corner of the INL.

Silicic Rocks

Rhyolite deposits presumed to be associated with the rhyolite domes in the region are found in some of the wells in the area. Older rhyolitic and andesitic tuffs are also found at few outcrops within the ESRP (Anderson, 1996c). These older rhyolite deposits are believed to be associated with the buried calderas from past Yellowstone hotspot eruptions, 6 to 10 Ma. The deep Geothermal test well INEL-1 was drilled in 1979 to a depth of 3,160 m (10,367 ft). Samples from the well included rhyolitic ash-flow tuffs with interbeds of tuffaceous sands and air fall ash between depths of 658 and 2,460 m (2,159 and 8,071 ft). Altered rhyodacite porphyry was encountered below a depth of 2,460 m (8,071) ft. The rhyodacite porphyry may have been responsible for altering the overlying welded tuffs and basalt flows (Doherty, 1979).

Basalts

Basalts are the most abundant rock types found at the surface of the ESRP. Thousands of separate lava flows associated with shield volcanoes and cinder cones are found across the ESRP and into the subsurface. Anderson et al (Anderson, 1996c) have separated the basalt flows into stratigraphic units and have attempted to associate these stratigraphic units with surface and subsurface units. The basalts found throughout the region are dense to vesicular with zones of fracturing being the most intense near the top and bottom of flows. The mineralogical compositions are dominated by labradorite plagioclase, augite, and olivine with minor amounts of ilmenite, magnetite, hematite, and apatite (Nimmo, 2004). Flows may be up to 34 m (110 ft) thick and are dispersed with cinders and sediment (Smith, 2004). While small in individual volume, the basalt lava flows were extremely numerous and have produced a total thickness in combination with sediment interbeds ranging from 305 m (1,000 ft) to 914 m (3,000 ft). The total thickness of the Quaternary basalt flows is greatest in the central axis of the ESRP and decreases to the west into the WSRP (Figure 3.3-4, General ESRP Geology and Stratigraphy) (Nimmo, 2004).

Sedimentary Deposits

Sedimentary deposits are interspersed throughout the basalt flows and were deposited during times of volcanic quiescence and continued subsidence of the ESRP. Unconsolidated surface deposits in the ESRP range in thickness from ≤ 3 m (10 ft) in the central portions of the ESRP, where basalt lava flows are thickest, to 305 m (1,000 ft) near the boundaries. The thickness of the surficial unconsolidated deposits is controlled by the proximity to source erosional areas in the upland areas and thinning of the Quaternary basalt lava flows toward the edges of the SRP. Eolian, well sorted fine-grained (clays, silts, and sands), and fluvial and lake deposits, poorly to well sorted deposits with clays, silts, sands, and gravels, are most common in the ESRP (Anderson, 1996b). The sediment interbeds are characterized as having the texture of silt-loam with a particle-size distribution of approximately 10% clay, 55% to 80% silt, and 10 to 25% sand (Nimmo, 2004). Minerals in the sediments include quartz, plagioclase, potassium feldspar, pyroxenes, olivine, calcite, dolomite, and clays (mostly illite with lesser amounts of smectite, chlorite, and kaolinite) (Nimmo, 2004).

Fourteen composite stratigraphic units have been identified during hydrogeologic investigation the INL. These units were assigned using similar rock types and ages and are made up of 5 to 90 separate units (Table 3.3-1, INL Stratigraphic Units). Each volcanic deposit in a composite unit was erupted from a different vent source (Anderson, 1996c). The reductions of volcanic deposits in the oldest units are attributed to large and infrequent volcanic eruptions. The location of these units throughout the region depends on the local subsidence and uplift during their respective eruption times (Anderson, 1996c). The characteristics of each rock type are discussed below. The oldest unit, undifferentiated (U), is composed of multiple basalts and sedimentary interbeds (Anderson, 1996c).

Anderson and Liszewski (Anderson, 1997) indicated that the stratigraphic correlations were for the rock units that comprise the unsaturated zone and the Snake River Plain aquifer beneath the INL site. Additionally, the interrelationships of basalt lava flows can be complex and additional data (since 1996) may affect the correlations. Sample and borehole geophysical data below the base of the Snake River Plain aquifer is very limited because few boreholes or wells extend beyond a thick and widespread layer of clay, silt, and altered basalt.

3.3.1.2 Potential Mineral and Energy Resources

Idaho is home to two major mining districts, including the Coeur d'Alene District in northern Idaho and the Western Phosphate Reserve in southeastern Idaho. Underground mines in the Coeur d'Alene District produce silver, lead, and zinc. Associated metals produced from these mines include molybdenum, copper, and gold (Gillerman, 2008b; IGS, 2004). Open-pit mines in southeastern Idaho, near Soda Springs, produce phosphate for conversion to fertilizers and elemental phosphorus. Idaho also produces a number of industrial minerals, including garnets, sand and gravel, cement, crushed stone, limestone, pumice, dimension stone, zeolites, gemstones, feldspar, and perlite.

The major mining districts of Idaho are distant from the proposed site location. The thick sequences of basaltic lava flows in the area of the proposed site are not known to host economically valuable metallic mineral or hydrocarbon resources. The Mineral Industry Yearbook for 2004 (IGS, 2004) shows no occurrences of metal mining activities in the vicinity of the proposed site (Figure 3.3-7, Mineral Producing Areas of Idaho). The basaltic lava flows are mined for pumice in some areas, but no current mining operations exist at the proposed site location. The closest quarrying operations for pumice, sand and gravel, and crushed stone are those at INL where these materials are used for road construction and maintenance, waste burial activities, and new facility construction (DOE, 2005).

Idaho has limited fossil fuel resources, although there is potential for undiscovered oil and gas in some areas of the state, such as the overthrust belt in southeastern Idaho and the Tertiary sediments in far western Idaho (Gillerman, 2008b). The ESRP is not in an area where oil and gas are expected to be found due to the very thick sequence of young volcanic strata beneath the ESRP, which are not known to generate or store economic amounts of hydrocarbons as either petroleum or natural gas.

The ESRP does have potential for geothermal energy sources because crustal heat flow beneath the ESRP remains high due to the recent movement of the plate across the mantle hot spot (Smith, 2002; Smith, 2004; Wood, 1988). The effect of the high heat flow is a small increase in groundwater temperatures from east to west across the ESRP. For example, recharge water temperatures range from 5 to 7°C (41 to 45°F) compared to 11 to 12°C (52 to

54°F) for the water table in the area of INL and locally up to 18°C (64°F) at the water table in some anomalously hotter zones (Smith, 2002; Smith, 2004). Groundwater temperatures have been related to the rate of water movement with higher temperatures occurring in low permeability zones where water moves slowly and has greater time to heat and lower temperatures occurring in higher permeability zones were water moves more rapidly and mixes with greater amounts of cooler recharge water.

However, geothermal resources in Idaho have been generally defined as groundwater temperatures greater than 29°C (84°F) for direct use or greater than 100°ºC (212°F) for power generation (Fleischmann, 2006). Measured groundwater temperatures in the ESRP are less than 29°C (84°F), and at the current time, there are no facilities that directly utilize geothermal energy at the proposed site or in its vicinity. A study of geothermal resources conducted in 1979 (DOE, 2005) indicated that no economic geothermal resources exist in the area of INL.

3.3.2 Geology at the Proposed Site

The specific geologic characteristics of the proposed site are described in this section. Additional hydrologic and hydrogeologic information is presented in Section 3.4, Water Resources.

3.3.2.1 Natural Drainage Patterns

The Snake River and its tributaries are located near the southern and eastern margins of the ESRP. Near Twin Falls, the Snake River has carved a vertical-walled canyon in the Quaternary basalts and interbedded sedimentary deposits. Elsewhere on the ESRP stream drainage is poorly developed and chaotic because of continual resurfacing by highly permeable basalt lava flows.

The area of the proposed site is comprised mostly of relatively flat and gently sloping surfaces with small ridges and areas of rock outcrop. Most of the site is semi-arid steppe covered by eolian soils of variable thickness that incompletely cover broad areas of volcanic lava flows. Elevations at the site range from 1,556 m (5,106 ft) to 1,600 m (5,250 ft). Many of the areas with thickest soils and gentle slopes with a minimum of rock outcrop are currently used for crops as shown by the irrigation circles outlined by dirt roads in Figure 3.3-8, Topography, Roads, and Drainage.

The U.S. Geological Survey Kettle Lake topographic map shows a few small intermittent stream drainages in the northeastern corner, southeastern and southwestern areas of the proposed site (Figure 3.3-8, Topography, Roads, and Drainage). However, the drainages in the northeastern corner are no longer evident in the field because they are within irrigated crop circles where the natural topography has been smoothed to accommodate crop production. The southeastern and southwestern drainage features likely originated from natural erosional processes during spring snowmelt or heavy rains but now primarily conduct minor amounts of water from irrigated agriculture areas. The southeastern drainages terminate as seepage loss into the ground or by evapotranspiration. In the southwestern area, a single natural drainage was identified during field reconnaissance and this ephemeral drainage can convey water offsite during episodic melt water and precipitation events or agricultural flooding. The drainage is located in the southwestern corner of the proposed site and runs from the south-central area of the proposed site southward toward Highway 20. The source of the water within the site boundary is likely the westernmost center pivot agricultural irrigation system. The drainage also potentially conveys surface water during large rainfall events. Just to the north of Highway 20, a series of small ponds were used historically to collect and store water from this drainage for agricultural uses, but these ponds are no longer in use and are dry. Highway 20 has a culvert to convey water from this drainage to the south away from the roadway. Based on field observations, this drainage has an incised channel into the soil exposing bedrock in some areas.

Only one distinct natural stream drainage was found within the proposed site boundaries by field reconnaissance. It is located in the southwestern corner of the proposed site and runs from the south-central area of the proposed site southward toward U.S. Highway 20 (Figure 3.3-8, Topography, Roads, and Drainage). Just to the north of U.S. Highway 20, a series of small ponds were used in the past to collect and store water from this drainage for agricultural uses; but these ponds are no longer in use. U.S. Highway 20 has a culvert to convey water from this drainage to the south away from the roadway.

3.3.2.2 Surface Geology

Most lava flows at the surface in the vicinity of the proposed site are Pleistocene in age and are blanketed with unconsolidated sedimentary deposits. Areas of rock outcrop within the boundaries of the proposed site are shown in Figure 3.3-9, Areas of Exposed Basaltic Lava Flows. Rock outcrops cover about 14% of the total area of the proposed site and exist in the form of low irregular ridges, small areas of thin soils mixed with blocky rubble, and erosional surfaces in the intermittent stream drainage on the southwest side of the proposed site. The outcrops are typically surrounded by soils of variable depths, producing an irregular pattern of rock exposure in map view (Figure 3.3-9, Areas of Exposed Basaltic Lava Flows). The outcrops are sparsely to moderately vegetated where plants have become established in cracks and joints in the rock.

The northwestern corner, southeastern corner, and southwestern portions of the proposed site contain the highest relative areas of outcrop (Figure 3.3-9, Areas of Exposed Basaltic Lava Flows). These portions of the proposed site are vegetated with sagebrush and grasses of variable density surrounding the outcrops. The northeastern and central portions of the proposed site have relatively smaller areas of outcrop and appear to have thicker soils. Crop circles used for ongoing and past crop production cover the majority of the central and northeastern portions of the proposed site.

The outcrops at the proposed site are comprised of 100% basaltic lava flows of the Quaternary Snake River Group. The basalts are typically strongly vesicular and show a range of oxidation of iron minerals and formation of secondary minerals in vesicles and exposed surfaces (Figure 3.3-10, Photos of Typical Basalt Outcrops 1). In some areas, the surfaces of the vesicular basalts are partially covered with white calcium carbonate. The lava flows show a range of morphologies indicative of eruption, flow, and cooling. These morphologies include jointing in approximate columnar patterns (Figure 3.3-10, Photos of Typical Basalt Outcrops 1), extensive vertical, less extensive horizontal jointing, and open cavities and rubble at the ends of flows (Figure 3.3-11, Photos of Typical Basalt Outcrops 2). The lava flows as a whole show no particular directional orientation. Geologic mapping (Kuntz, 1994) and the close proximity of these lava flows to the volcanic vent at Kettle Butte, which is located near the northeastern corner of the proposed site (Figure 3.3-9, Areas of Exposed Basaltic Lava Flows), indicate that the flows are associated with eruptions originating from that location.

3.3.2.3 Notable Geological Features Within and Adjacent to the EREF

There are few notable geologic features within the proposed site boundaries. The most significant features are the following:

- All flows have the same general appearance of being highly vesicular, extensively jointed, and filled with cavities (Figure 3.3-11, Photos of Typical Basalt Outcrops 2);
- Several basalt flow outcrops exhibit a narrow linear morphology, suggestive of pressure ridges. Figure 3.3-12, Photos of Significant Geological Features, shows a photo of a pressure ridge.

The site lies within a shallow topographic depression about 230 km^2 (89 mi^2) in area. This depression is bounded by surrounding topographically higher elevations ranging from 1,554 to 1588 m (5,100 to 5,210 ft). The summits of seven small basalt shield volcanoes rise above the surrounding terrain. Together, the gently sloping lava fields from these shield volcanoes (erupted mainly 200 to 400 ka) form a shallow topographic depression enclosing the proposed site. The local geology of the adjacent area surrounding the EREF site consists primarily of basaltic volcanic rocks that erupted during the last 500,000 years. Rhyolitic domes and alluvial fan deposits occur to a lesser extent within the adjacent region (Hughes, 1999). The site is located between two volcanic rift zones, the Lava Ridge-Hells Half Acre and the Circular Butte-Kettle Butte rift zones. Volcanism and tectonic activity from these two zones produced shield volcanoes, spatter cones, small calderas, and fissure eruptions (Hughes, 1999).

The western edge of the proposed site near the INL boundary is underlain by basalt lava flows from various shield volcanoes located 5 to10 km (3 to 6 mi) to the west and northwest of the site. Relative stratigraphy along the lava-flow contacts shows that these lava flows are older than the Kettle Butte lavas, but a similar age is indicated by the normal magnetization of the flows and by the correlation of one of the flows with a dated subsurface lava flow from a nearby borehole: the correlated subsurface lava flow has a K-Ar age of 325 +/- 45 ka, the same apparent age as Kettle Butte.

Weakly developed, intermittent drainage channels occur on the lava surfaces and along the contacts of lava flows, particularly near the eastern boundary of the proposed site. Overland flow and the development of strong drainage networks is not facilitated by the thin, discontinuous cover of permeable, unconsolidated surficial sediment and the underlying, highly fractured-permeable lava flows.

Outside of the proposed site boundaries, the most significant geologic features include the following (Figure 3.3-5, Regional Shaded-Relief Topographic Map of Eastern Snake River Plain (ESRP) and Local Geology):

- Axial Volcanic Zone:

  The Axial Volcanic Zone is a northeast-trending, constructional volcanic highland that occupies the central topographic axis of the ESRP. It is underlain by many basalt lava flows erupted from many fissure eruptions and small shield volcanoes during the past 4 Ma. The proposed EREF site is situated within the Axial Volcanic Zone.

- East, unnamed and Middle Buttes:

  East, unnamed, and Middle Buttes are located about 20 to 30 km (12 to 18 mi) from the western boundary and stand well above the elevation of the ESRP. The age of these deposits range from 1.9 to 0.5 Ma (Kuntz, 1979). East Butte is composed of parallel layers of rhyolitic lava (Kuntz, 1979). The unnamed butte studied through well borings and outcrops is a rhyolitic dome (Kuntz, 1979). Middle Butte has been less studied than East Butte thus less is known about its internal structure. The upper surface of Middle Butte is composed of approximately 75 m (246 ft) of basaltic lava flows, but an endogenous rhyolite dome is believed to underlie the butte at depth and account for the uplift of the basalt lava flows (Kuntz, 1979).

- Lava Ridge – Hells Half Acre Rift Zone

  The Lava Ridge – Hells Half Acre rift zone (Kuntz, 1992a) extends 50 km (31 mi) southeast across the ESRP from the southern end of the Lemhi Range. The southeast end of the rift zone is defined by the dike-induced fissures and vent complex of the Hells Half Acre lava field. The central part of the rift zone is defined by several small- to medium-sized shield volcanoes with vents elongated north-south. The northwest end of the zone is ill defined by poorly exposed lava flows of reversed magnetic polarity, mantled by fluvial, lacustrine and eolian sediment. The earliest volcanism (> 730 ka) occurred at the northwestern end, volcanism of the central part is of intermediate age (200 to 500 ka), and the youngest volcanism occurred about 5 ka at the Hells Half Acre lava field at the southeastern end of the zone.

- Hells Half Acre Lava Field

  The EREF site is located approximately 0.5 km (1.1 mi) north of the northernmost outcrops of Hells Half Acre lava field (Figure 3.3-13, Geologic and Physiographic Features Near the Proposed Site). The volcanic features associated with this lava field consist of a basaltic shield volcano and its vents (Kuntz, 2002). The main basalt shield volcano and its eruptive-fissure system, is about 5 km (3 mi) south of the proposed site. Basaltic lavas at Hells Half Acre lava field were erupted along a fissure system and consist of basaltic pahoehoe lavas. The vents of the shield volcano occur within an elongated area 800 m (2,625 ft) long by 100 to 200 m (328 to 656 ft) wide (Kuntz, 2002). Lavas traveled more than 20.0 km (12.4 mi) southeast from their vents, forming a lava field composed of many individual fields up to 100 m (328 ft) wide and over 10 m (33 ft) thick. Hells Half Acre lava flows cover approximately 400 km^2 (154 mi^2) and form one of the largest lava fields on the ESRP. Besides lava flows, spatter and cinder deposits are also found within the lava field and reflect the explosive nature the volcano at different times in its eruptive history. A northwest-trending tension crack is considered to be the feeder system for the fissure eruptions that controlled the lava field (Hughes, 1999).

- Circular Butte – Kettle Butte Rift Zone

  The Circular Butte – Kettle Butte volcanic rift zone (Kuntz, 1992a) is to the east of the EREF site. This rift zone is not well defined or described in the literature as other zones that have experienced more recent activity. Kettle Butte is a large basalt shield which is close to the proposed EREF site and is likely the source of most of the lava flows that are exposed in outcrops at the proposed site.

- Kettle Butte

  Kettle Butte is located about 1.6 km (1.0 mi) off the northeastern corner of the site (Figures 3.3-12, Photos of Significant Geological Features, and 3.3-13, Geologic and Physiographic Features Near the Proposed Site) and is one of the largest ESRP basalt shields. Its prominent summit is occupied by several small collapse craters and pyroclastic cones. Eruptions of Kettle Butte produced an extensive lava field covering at least 320 km^2 (124 mi^2) and about 6 km^3 (1.4 mi^3) in volume (Kuntz, 1979) (Figure 3.3-13, Geologic and Physiographic Features Near the Proposed Site). Although the lava flowed mainly to the northeast, Kettle Butte is the source for most of the lava-flow outcrops within the boundaries of the proposed site. The normal magnetic polarity of Kettle Butte lava indicates an age of volcanism < 730 ka and the lava has a K-Ar age of 316 +/- 75 ka (sample 84ILe-1; Kuntz, 1994). The lava flows and near-vent pyroclastic deposits of Kettle Butte and most other basalt shield volcanoes near the proposed site are included as part of unit Qbc on the geologic map of the INL area, a widespread lithostratigraphic unit composed of middle

Pleistocene basalt lava flows and minor pyroclastic deposits estimated to have erupted about 200 to 400 ka (Kuntz, 1994).

3.3.2.4 Local Stratigraphy

3.3.2.4.1 Soils at the Proposed Site

Thicknesses of unconsolidated surficial sediment and soil cover in the ESRP are variable, ranging from zero in areas of recent volcanism to tens of meters (tens of feet) in areas of wind-blown loess derived from exposed lava flows, lacustrine deposits, and alluvial fill (Hughes, 1999; Scott, 1982; Whitehead, 1994a). Thin soils and basalt outcrops are typical of ridge lines and wind-swept areas, of the axial volcanic zone, the broad constructional volcanic highland on which the proposed site is located.

During the fall of 2007 and the spring of 2008, thirty boreholes were drilled to determine depth to bedrock and collect samples for geotechnical and geochemical testing. Geotechnical testing was conducted at 14 locations, and geochemical testing was conducted at 10 surface locations (Figures 3.3-14A, Borehole and Soil Sample Locations, and 3.3-14B, Cross Section A-A' and B-B' on the Proposed EREF Footprint) and latitude and longitude for soil sampling locations are provided in Table 3.3-2, Site Soil Sample Locations. As shown in Figure 3.3-14B, Cross Section A-A' and B-B' on the Proposed EREF Footprint, the depth of bedrock at the proposed EREF ranges between bedrock outcrop and a soil depth of up to 6.6 m (21.5 ft).

Soil Deposits

Unconsolidated surficial deposits at the proposed site are primarily transported sedimentary materials of eolian origin rather than soils developed in situ as a result of regolith weathering. Scott (Scott, 1982) mapped the surficial deposits in the area of the proposed site as Pleistocene loess deposits, which form a thin discontinuous cover overlying Pleistocene basalt lava flows. The loess is composed of silt and sandy silt containing sparse angular to subrounded basalt gravel derived from nearby lava outcrops, is massive or faintly bedded, and overall is moderately to well sorted.

The U. S. Department of Agriculture soil survey for Bonneville County, Idaho (NRCS, 2008c) categorizes most of the soils at the proposed site as Pancheri silt loams with slopes ranging from 0 to 8 percent (50 to 75% of the area) (Figure 3.3-15, Soil Map of the Proposed Site; Table 3.3-3, Summary of Soils by Map Unit). The Pancheri series consists of deep and very deep, well-drained soils that formed in loess covered lava plains (NRCS, 2008c). The taxonomic class for the Pancheri series is coarse-silty, mixed, superactive, frigid Xeric Haplocalcids. This description is consistent with detailed studies of soils at the nearby INL where they are described as falling mostly in the silt-loam textural class with 0 to 27% clay, 55 to 80% silt, and 10 to 35% sand (Nimmo, 2004). The drainage and permeability of the Pancheri series are described as well-drained, medium or slow runoff, moderate permeability (NRCS, 2008c). The remainder of the proposed site is characterized as Polatis-rock outcrop complex, Pancheri-rock outcrop complex, and lava flows.

3.3.2.4.2 Lithology of GW-1 Rock Cores

Core hole GW-1 was drilled near the geographic center of the proposed site and a continuous rock core was collected from land surface to a total depth of 223.0 m (730.5 ft) below land surface (Figure 3.3-16, Existing Agricultural and Newly Installed Monitoring Wells). A rock boring log was compiled during the drilling process to describe the general features of the core materials. Geophysical logs were also obtained, including a subsurface photographic record of the inner borehole walls, a caliper log of borehole diameter, and a natural-gamma log. Core recovery was excellent, with very little lost material, with relatively few intervals of drilling-induced fracturing, and with the borehole depths indicated on the geophysical logs being minus-0.3 m (1.0 ft) to plus-0.6 m (2.0 ft), relative to the depth markers contained in the core boxes. The lithologic information reported here is based on visual examination of the core materials and selected geophysical logs. The purpose of this report section is to generally describe the subsurface lithologies, to identify individual basalt lava flows and sedimentary interbeds, to describe the overall stratigraphy of the borehole, and to suggest possible correlations of the GW-1 rock cores with other subsurface cores and outcrops near the drill site.

Summary of Lithologic Features Observed in GW-1

Figure 3.3-17, GW-1 Lithologic Log – Summary, summarizes the subsurface lithologies of rock cores from GW-1. Two types of materials were intersected: basalt lava flows and sedimentary interbeds.

Sediment

Sediment composes only 2.4 percent of the core materials from GW-1. Three interbeds of silty loess, each less than 3 m (10 ft) thick, occur in the upper 125 m (410 ft) of the core. The small percentage of eolian and colluvial sediment in the GW-1 core is consistent with its location within the axial volcanic zone, a northeast-trending constructional volcanic highland that forms the topographic axis of the ESRP. Subsurface data from the southern INL area show that the axial volcanic zone has received relatively little sediment during the past several million years, mostly of eolian origin. This is in contrast to the subsided sedimentary basins of the INL to the north and northwest of the axial volcanic zone, which have received thick accumulations of alluvial, lacustrine and eolian sediment, averaging 15% of borehole materials (Anderson, 1997; Champion, 2002). All of the sedimentary deposits in the GW-1 core are moderately to well sorted, calcareous loess of eolian origin, lithologically similar to surficial sediment near the drill site and consisting mainly of silt with minor clay and sand. The loess commonly contains angular blocks of vesicular basalt, a colluvial component derived from the tops of underlying lava flows (e.g., 18 to 20 m (60 to 66 ft) interval). Beneath the loess interbeds, fine calcareous sediment commonly occupies the apertures of open fractures (e.g., 20 to 21.6 m (66 to 71.0 ft) interval). Solution and re-deposition of calcium carbonate from the loess has produced white caliche, commonly deposited on basalt fracture surfaces and vesicles of surface outcrops, and in fractured lava flows beneath the subsurface sedimentary interbeds.

Basalt

Basalt lava flows comprise 97.6% of the GW-1 core. No pyroclastic deposits were identified. About 59 individual lava flows were identified, ranging from < 0.6 to 15 m (2 to 50 ft) in thickness. Intervals of numerous thin, vesicular pahoehoe lava flows occur at depths of 95, 131, 152, 157 and 209 m (310, 430, 500, 515 and 685 ft). Thin pahoehoe flows occur near volcanic vents and at the margins of advancing lava flows. They form through a type of budding process at the leading edge of an advancing flow, and a stack of pahoehoe crusts can form at a given location during the effusion of a single parental lava flow. If the stacks of multiple, thin pahoehoe flows at the depths indicated above are each assumed to be the products of a single parental lava flow, then a total of about 40 basalt lava flows is observed in GW-1.

The tops of pahoehoe flows are marked by the presence of black, fine-grained to glassy, chilled lava crusts a few centimeters (inches) thick, with stretched vesicles, pervasive oxidation of matrix and olivine phenocrysts, and commonly occurring in the GW-1 core as a jumble of vesicular, angular clasts having these lithologic features. Beneath the pahoehoe rubble and within a few meters (feet) of the lava-flow tops is a highly vesicular zone with closely spaced (about 0.3-m (1.0-ft) spacing in outcrops), vertically oriented cooling fractures. In thicker lava flows, the highly vesicular, pervasively fractured lava grades downward into finely vesicular to nonvesicular (massive) lava of the flow interior. Flow interiors formed during slower cooling, yielding greater crystallinity of the intergranular rock matrix, a lighter gray color. Within the massive flow interiors, widely spaced, subhorizontal fractures and thin subhorizontal vesicular zones were formed as a result of simple shear during endogenous flow. Within a few meters (feet) of the bases of the lava flows, vesicularity increases and within 0.3 m (1.8 ft) of the basal contacts the lava matrix becomes black and fine-grained, evidence of chilling against the underlying substrate. The lithologic features of ESRP basaltic lava flows and their modes of formation are further described in greater detail by Kattenhorn and Schaefer (Kattenhorn, 2007) and Welhan et al. (Welhan, 2002).

Most lava flows show little or no petrographic contrast across individual flow boundaries, such as changes in phenocryst sizes, or differences in the absolute or relative abundances of plagioclase and olivine phenocrysts. This suggests that groups of adjacent lava flows were the products of single magma batches, producing cogenetic lava-flow groups, composed of several individual lava flows, and formed in a single volcanic event of geologically brief duration. The best criterion for distinction of lava-flow groups is the presence of a sediment interbed, indicating a hiatus between the emplacement of two lava flows or lava-flow groups. Lava-flow groups can also be distinguished in rock cores, based on visible petrographic changes across flow contacts. Such petrographic contrasts suggest separate magma batches, each with a different history of generation, storage and ascent. In the GW-1 rock core, such petrographic differences include the sizes and relative abundances of plagioclase and olivine phenocrysts, and the presence or absence of glomerophenocrysts in basalt lava flows. Based on their separation by sedimentary interbeds and gross petrographic changes across lava-flow contacts, about ten lava-flow groups are identified in the GW-1 core.

Response of the Natural-Gamma Signal to Basalt and Sediment

Downhole natural-gamma geophysical logs show greater intensities within the more potassium-rich sedimentary interbeds, relative to the potassium-poor basalt lava flows. In GW-1, the natural-gamma signal begins to increase within 0.3 m (1.0 ft) of sedimentary interbeds, relative to lower-intensity natural-gamma signals within the basalt lava flows. For intervals where basalt clasts are a significant proportion of the sediment, the gamma signal increases by about a factor of two, relative to the surrounding basalt lava flows (e.g., the 18-20 m (60-66 ft) interval; 17.9-19.5 m (59.0-64.0 ft) on natural-gamma log). In the core where silty loess composes nearly 100 percent of a sedimentary interbed (e.g., the 59.9-60.8 m (196.5-199.5 ft) interval; 59.4-60.4 m (195.0-198.0 ft) on gamma log), the gamma signal increases three to five-fold, relative to the surrounding basalt. Beneath sedimentary interbeds, fine sediment commonly has percolated downward into the fractures and vesicles of underlying lava flows, but such intervals generally do not display elevated natural-gamma signals.

Potassium in basalts of the INL area varies from about 0.2 to 1.3 wt % K_2O (Anderson, 1997) is lower than the abundance of potassium in sedimentary interbeds, and the intensity of the natural-gamma signal across lava-flow contacts therefore varies much less than across basalt-sediment contacts. Nonetheless, natural-gamma logs are potentially useful for identifying lava-flow contacts and for distinguishing subsurface lava-flow groups, particularly when used together with petrographic, geochemical, paleomagnetic and other information (Anderson, 1995). Lava-flow contacts that are marked by strong petrographic differences are indicated on the GW-1 lithologic summary (Figure 3.3-17, GW-1 Lithologic Log - Summary). Several of these lava-flow contacts are also marked by changes in the intensity of the natural-gamma signal across the contacts, suggesting a significant compositional difference between basalts. The lava flows above the contact at a depth of 74 m (243 ft) have a relatively constant natural-gamma signal of 10-15 units; below this contact, the gamma signal is more elevated and more variable, 20-45 units. Beneath the sedimentary interbed at about 125 m (411 ft) depth, the underlying lavas have a natural-gamma signal of 35-40 units, in contrast to the 20-30 unit signal of lavas above the sedimentary interbed. For the lava-flow contact at 128 m (421 ft) depth, the natural-gamma signal of the overlying lava-flow group decreases abruptly from 35-40 units, to 15-20 units in the underlying group.

Correlation of GW-1 Rock Cores with Outcrops and other Boreholes

No detailed sampling or analysis of lava outcrops erupted from vents near the proposed site has been accomplished, but reconnaissance observations at six roadside localities along a 12.8-km (8-mi) length of U.S. Highway 20 to the south of the proposed site suggest the following tentative correlations between surface and subsurface lava flows. The three basalt lava flows in the uppermost 18 m (60 ft) of GW-1, above the first sedimentary interbed, were erupted from Kettle Butte, a large shield volcano several kilometers (miles) east of the proposed site. Surface lava flows at the location of GW-1 are mapped as having erupted from Kettle Butte (Kuntz, 1994), and subsurface basalt flows from the 1.2-18.0 m (4.0-60.0 ft) interval of GW-1 are petrographically similar to surface outcrops of Kettle Butte lava flows on much of the proposed site. For the 20-109 m (66-357 ft) interval of GW-1, the lava flows are nonporphyritic to weakly porphyritic in plagioclase and olivine, and the location(s) of their source vent(s) are unknown. From 109.0-155.5 m (357.0-510.0 ft) the lavas are strongly porphyritic and contain glomerophenocrysts of plagioclase and olivine up to 1.0 cm (0.4 in); such textures are similar to those observed in outcrops of lavas erupted from a vent to the west of the GW-1 drill site (Qbc map unit of Kuntz, 1994; vent 32 of Anderson, 1997), and are also similar to the porphyritic textures of lava outcrops from Butterfly Butte and nearby vents to the southeast of the GW-1 drill site (Qbd map unit of Kuntz, 1994; vents 28 through 31 of Anderson, 1997).

Anderson and Liszewski (Anderson, 1997) describe the stratigraphy of the unsaturated zone in the INL area, based on more than 300 wells. Most wells are located near INL facilities more than 15.0 km (9.3 mi) to the west and northwest of GW-1. As a result, subsurface correlations are highly uncertain for the southeastern part of the INL and in the area near the GW-1 drill site, but some speculative conclusions can be reached about the GW-1 rock core, its stratigraphic relationships to other subsurface units from the INL region to the west of the proposed site, and possible correlations with nearby volcanic vents that may have been sources for the lava flows in the GW-1 rock core. Table 3.3-4, Characteristics of Volcanism in the INL Area, summarizes information about possible source vents and subsurface stratigraphic units near the proposed site, based on data from Anderson and Liszewski (Anderson, 1997) and Kuntz et al. (Kuntz, 1994).

About 4.8 km (3.0 mi) southwest of GW-1, the well Highway #2 (USGS 214) was drilled to a depth greater than the 223.0 km (730.5 ft) total depth of GW-1; this well has produced stratigraphic data and it anchors the eastern end of a northwest-southeast geologic section across the INL area (Anderson, 1997). Although stratigraphic correlations are uncertain between USGS 214 and other INL wells to the west and northwest, Anderson and Liszewski (Anderson, 1997) suggest the following stratigraphy for USGS 214: the corehole intersects Composite Stratigraphic Units (CSU) 1, 2 and 3, and the upper part of CSU4. These CSUs are composed of basalt lava flows and sediment, with approximate thicknesses as follows: CSU1, 61 m (200 ft); CSU2, 55 m (180 ft); CSU3, 91 m (300 ft); and CSU4, 46 m (150 ft). Very general stratigraphic descriptions of the CSUs are given by Anderson and Liszewski (Anderson, 1997). These general descriptions conform with the GW-1 core observations, with the exception of the very low sediment content of GW-1.

Based on general observations, an uncertain correlation with a nearby well (Highway #2 (USGS 214)), and other data from Anderson and Liszewski (Anderson, 1997), it is likely that most or all of the GW-1 rock core was emplaced between about 200 to 450 ka, has normal magnetic polarity, and consists of CSUs 1 through 3 (and perhaps the upper part of CSU4) as defined by Anderson and Liszewski (Anderson, 1997) for the unsaturated zone and the upper Snake River Plain aquifer in the INL area. All of these CSUs are part of the Snake River Group, a regional stratigraphic unit composed of basalt and sediment that underlies most of the eastern Snake River Plain.

3.3.3 Site-Specific Volcanic Hazard Analysis

The details of the site-specific volcanic hazard analysis are included in Appendix D. A summary of the approach and results of the analysis is presented in the following paragraphs.

For this analysis, the probabilistic approach of Hackett et al. (Hackett, 2002) is adopted, using surficial and subsurface geologic data from the INL area, together with observations of active volcanism from the analog regions of Iceland and Hawaii. Critical references providing much of the supporting data for this analysis include Champion, 2002; Hackett, 1992; Hackett, 2002; Hughes, 1999; Hughes, 2002; Kuntz, 1992a; Kuntz, 1992b; Kuntz, 1994; Kuntz, 2002; and the Volcanism Working Group, 1990. The interpretation of late-Quaternary volcanism in the INL area is the basis for analyzing the characteristics, frequency and magnitude of any future volcanic events, following the paradigm that "the recent geologic past is the key to understanding the future."

Site volcanic hazards are divided into two categories (silicic and basaltic), which have characteristically different chemistry and associated eruption styles. Five silicic volcanic centers formed 1.4 to 0.3 Ma along the axial volcanic zone. This yields a recurrence interval for silicic volcanism within the axial volcanic zone of 220,000 years (5 events per 1.1 Ma = 4.5×10^{-6} per year). This is more than an order of magnitude less frequent than the estimated recurrence of basaltic volcanism within the axial volcanic zone. Additionally, the spatial distribution of Quaternary silicic volcanism in the INL area, and the areas inferred to have been impacted by individual eruptions, are far smaller than for basaltic volcanism. Therefore, the hazards associated with near-field silicic volcanism are considered to be far less important than those of basaltic volcanism and no further analysis was performed.

Inundation by basalt lava flows is the most significant volcanic hazard at the proposed site. During the past 4.3 Ma, the ESRP has been repeatedly inundated by basaltic lava flows, which today are exposed over about 58 percent of the INL area and are found in subsurface wells and boreholes across most of the ESRP.

Combining the similar results of the two analyses detailed in Appendix D, the estimated mean annual probability (preferred value) of lava inundation at the proposed site is 5×10^{-6}. The estimated upper and lower bounds of the annual probability distribution span two orders of magnitude, from 10^{-5} to $x\ 10^{-7}$ respectively.

Comparison with Other Results

Hackett et al. (Hackett, 2002) calculated the annual probability of lava inundation at the Central Facilities Area (CFA), a cluster of facilities on the southwestern INL about 12.0 km (7.5 mi) from vents in the volcanic zones to the west and south, and within a topographic basin about 100 m (328 ft) lower than the surrounding volcanic highlands. The estimated annual probability of lava inundation for the CFA is 5×10^{-6}, without attempted mitigation. This result is identical to the results calculated here for the proposed site. Unlike the proposed site, the CFA is not situated within a volcanic source zone. The agreement of results is understandable because the CFA is nearby and downslope from two volcanic source zones with high recurrence intervals, including the axial volcanic zone.

The New Production Reactor (NPR) site was a proposed facility in the south-central INL, about 10.0 km (6.2 mi) from the nearest vents of the axial volcanic zone to the south. The Volcanism Working Group (Volcanism Working Group, 1990) considered basalt lava-flow inundation to be the most significant volcanic hazard at the NPR site. The annual probability of future lava inundation at the NPR site was qualitatively estimated by the Volcanism Working Group (Volcanism Working Group, 1990) to be "less than 10^{-5}.

These results for the proposed EREF site agree with the results of two other probabilistic volcanic-hazard analyses for sites on the southern INL, suggesting that 5 x 10^{-6} per year is a robust probability estimate for future lava-flow inundation across the southern INL and adjacent areas within about 10 km of the axial volcanic zone.

3.3.4 Site Soil Chemical Characteristics

Geotechnical tests included moisture content, natural dry density, specific gravity, grain size analysis, Atterberg limits, modified Proctor, R value, pH and resistivity, sulfate content and consolidation tests. The laboratory testing was conducted in accordance with ASTM standards. The specific ASTM standards used were ASTM C136 (ASTM, 1992), ASTM D1140 (ASTM, 2000a), ASTM D1557 (ASTM, 2002a), ASTM D422-63 (ASTM, 2002b), ASTM D2216 (ASTM, 1998), ASTM D2435 (ASTM, 2002c), ASTM D2487 (ASTM, 2000b), ASTM D2844 (ASTM, 2001), and ASTM D4318 (ASTM, 2000c). Geotechnical test results are presented in Section 3.3.5, Geotechnical Investigation, and the radiological results of soil samples are discussed in Section 3.11, Public and Occupational Health.

Non-radiological chemical analyses include the eight Resource Conservation and Recovery Act (RCRA) metals, moisture content, organochlorine pesticides, organophosphorous compounds, chlorinated herbicides, fluoride, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). The non-radiological analyses were conducted by certified laboratories. The laboratories used EPA approved methods and all detection limits met or exceeded EPA methods.

The results of the metals, fluoride and moisture content in soils analyses are provided in Table 3.3-5, Concentrations of Metals, Fluoride, and Moisture Content in Soils. The results for VOCs and SVOCs are provided in Table 3.3-6, Concentrations of VOCs and SVOCs in Soils. The results for pesticides and herbicides are provided in Table 3.3-7, Concentrations of Pesticides and Herbicides in Soils. Analysis results were compiled to evaluate background concentrations and compared to soil background concentrations at the nearby INL. The data are presented to establish the natural range of background concentrations against which soil samples collected in the future at the time of decommissioning can be compared against to evaluate site contamination.

The metals arsenic, barium, cadmium, chromium and lead were detected in all soil samples. Arsenic concentrations ranged from 5.5 to 7.7 mg/kg (Table 3.3-5, Concentrations of Metals, Fluoride, and Moisture Content in Soils). The range of arsenic concentrations is similar to soils at the INL (5.8 - 7.4 mg/kg), to the average arsenic concentration in soils in the U.S. of 7.2 mg/kg (Shacklette, 1971) and range for southern Idaho (3.8 to 8.3 mg/kg) (Gustavsson, 2001). The barium concentrations ranged from 160 to 200 mg/kg for barium. These concentrations are less than the range for background used at the INL of 300 to 440 mg/kg. Cadmium concentrations ranged from less than detection limit of 0.50 to 0.71 mg/kg. These concentrations are less than the range for background used at the INL of 2.2 to 3.7 mg/kg. Chromium concentrations ranged from 20 to 25 mg/kg. These concentrations are less than the range for background used at the INL of 33 to 50 mg/kg. Lead concentrations ranged from 14 to 18 mg/kg. These concentrations are similar to the range for background used at the INL of 17 to 23 mg/kg.

Two soil samples had detectable silver at 0.70 mg/kg, but this concentration is close to the detection limit and all other samples had concentrations less than detection levels (Table 3.3-5, Concentrations of Metals, Fluoride, and Moisture Content in Soils). The silver background at the INL is non-detect with detection levels similar to those for this study.

Selenium concentrations ranged from 0.13 mg/kg to 0.42 mg/kg (Table 3.3-5, Concentrations of Metals, Fluoride, and Moisture Content in Soils). The range of selenium concentrations is within the range of selenium concentrations in soils in Bonneville County, Idaho (0.10 to 1.312 mg/kg) (USGS, 2008a).

The concentrations of mercury are less than the analytical detection limits (Table 3.3-5, Concentrations of Metals, Fluoride, and Moisture Content in Soils). Background levels for mercury at the INL are 0.05 to 0.075 mg/kg or similar to the detection limits for the soil samples collected for this study.

Fluoride concentrations ranged from less than the detection limit of 5 mg/kg to 12 mg/kg (Table 3.3-5, Concentrations of Metals, Fluoride, and Moisture Content in Soils). A background comparison for fluoride from the INL was not available.

Moisture content varied from 9.1 to 16.5 percent (Table 3.3-5, Concentrations of Metals, Fluoride, and Moisture Content in Soils). Moisture content in surface soils can be expected to vary seasonally and with the frequency of precipitation events.

The only VOCs detected in surface soil samples were 1,3,5-trimethylbenzene, 1,3-dichlorobenzene, and tetrachloroethene (Table 3.3-6, Concentrations of VOCs and SVOCs in Soils). All detections were close to the detection limits for these VOCs and all occurred at the same location, SS1. The occurrence of 1,3-dichlorobenzene may be related to herbicide use. The presence of tetrachloroethene may be due to its presence in numerous consumer products or its use as a solvent at the site; however, the exact source of this compound is uncertain. The presence of 1,3,5-trimethylbenzene could be related to vehicle exhaust, but it is also used as a solvent.

SVOCs detected in surface samples include benzo(a)pyrene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene (Table 3.3-6, Concentrations of VOCs and SVOCs in Soils). All the concentrations of SVOCs that were detected were close to the detection limits. Benzo(a)pyrene was detected in the soil samples from locations SS2, SS4, SS9, and SS10. Indeno (1,2,3-cd) pyrene was detected in the soil samples from locations SS2, SS4, SS9, and SS10. Dibenzo(a,h)anthracene was detected at locations SS2, SS4, SS9, and SS10. These compounds are Polyaromatic Hydrocarbons (PAHs). These compounds can occur as a result of road runoff (found in fuels or exhaust and road tar) or incomplete combustion of wood as a result of (natural) fire residue. Given the low concentrations for all these compounds, either source is possible. Because these PAH compounds are probably due to vehicle exhaust/road runoff or natural wildfires, these PAH occurrences are considered to represent background concentrations.

No detection of pesticide or herbicide compounds occurred in the surface samples, except for chlorpropham (Table 3.3-7, Concentrations of Pesticides and Herbicides in Soils). Chloropropham was detected in three of the 10 surface soil samples at concentrations ranging from 0.0055 to 0.0110 mg/kg. This compound is used to inhibit sprouting of potatoes to be stored and its detection is consistent with the agricultural history of this site.

The soil samples were also analyzed for radiological chemical components. These analyses were performed by gamma isotopic and uranium specific analyses. Soil samples were analyzed for naturally-occurring primordial radionuclides, the thorium decay series, and the uranium decay series. The 10 soil samples were also analyzed for cesium, potassium, and actinium. Refer to Section 3.11, Public and Occupational Health, for a discussion of the radiological analyses results for these soil samples.

3.3.5 Geological Investigation

Site geotechnical investigations were conducted in November 2007 and in May 2008. The results of these investigations are provided in Appendix E. The investigation in November 2007 consisted of 20 test borings. The subsequent investigation in May 2008 consisted of 10 test borings. The boreholes were drilled using a hollow-stem auger, split-spoon sampling and a Dames and Moore sampler. Split spoon sampling was performed in accordance with ASTM D1586-99 (ASTM, 1999). The data from the subsurface investigation was generally consistent with the published regional information obtained during the review of available geologic and soil information. The site investigations included the installation and monitoring of groundwater wells, geophysical investigations in boreholes, and surface geology mapping. The borings and sample locations are shown in Figure 3.3-14A, Borehole and Soil Sample Locations and were located to provide coverage of the site.

The soil is generally 0 to 4.3 m (0 to 14.0-ft) thick and overlies fractured basalt lava flows. At one of the test-hole locations the soil was approximately 6.6 m (21.5 ft) thick. Soils are of eolian origin and are classified primarily as low-plasticity clays. Colors of the soil include light tan, tan, light brown, grayish brown and dark brown. Rock outcrops cover 14% of the total area of the proposed site. Geologic mapping of the bedrock exposures indicates that the basalt is strongly vesicular and contains discontinuities such as strongly developed columnar jointing and cavities. Several collapsed lava tubes filled with rubble were reported in the northern portion of the site area.

The Standard Penetration Test (SPT) N-values ranged from 1 to 53. N-values ranged from 1 to 43 for a depth of 1.5 m (5.0 feet) below ground surface and between 11 and 53 for depths 3 m (10 feet) or more below ground surface. The N-values suggest a consistency that ranges from very soft to hard. Rock Quality Designations (RQD) for one deep cored boring indicate that the bedrock ranges from fair to excellent quality (64% to 100%) within the top 30 m (100 ft) of the boring. Several localized zones of broken rock and soil were observed at considerably greater depths. A fractured interval between 69 m (225 ft) and 70 m (230 ft) yielded an RQD of 0 and a 2.5 m (8.0 ft) layer of soil was encountered between 123 m (403 ft) and 125 m (410 ft). Thin layers of soil were encountered between 18.6 m (61.0 ft) and 19.5 m (64.0 ft) and 59.1m (194.0 ft) and 60.8 m (199.5 ft). The depths of these zones greatly exceed the anticipated depth of influence of foundations and will not negatively impact the capacity of the rock to provide adequate bearing.

Laboratory tests on soil samples included moisture content, natural dry density, specific gravity, grain size analysis, Atterberg limits, modified Proctor, Hveems's resistance value (R value), pH, resistivity, sulfate content, and consolidation tests. The laboratory testing was conducted in accordance with ASTM standards. The specific ASTM standards used were ASTM C136 (ASTM, 1992), ASTM D1140 (ASTM, 2000a), ASTM D1557 (ASTM, 2002a), ASTM D422-63 (ASTM, 2002b), ASTM D2216 (ASTM, 1998), ASTM D2435 (ASTM, 2002c), ASTM D2487 (ASTM, 2000b), ASTM D2844 (ASTM, 2001), and ASTM D4318 (ASTM, 2000c). The natural dry density of finer soil samples tested, were 1.30, 1.41, 1.45, 1.67, and 1.79 g/cm^3 (81.2, 88.0, 90.4, 104.4, and 112.0 lbs/ft^3). The natural moisture content of the materials tested ranged from

9.6 to 19.0%. The liquid limit and plasticity index ranged from 27 to 42% and 10 to 24%, respectively. Percent passing the No. 200 sieve ranged from 84 to 98%. The samples of the site soils are classified as CL, low plasticity clays, according to the Unified Soil Classification System. Modified Proctor tests performed in accordance with ASTM D1557 (ASTM, 2002a) resulted in maximum dry densities of 1.8 g/cm^3 (111.0 lbs/ft^3) at an optimum moisture content of 14.5% and 1.8 g/cm^3 (112.5 lbs/ft^3) at an optimum moisture content of 14.0%.

Two resistance R-value tests were performed on samples taken from depths of 0.3 m (1.0 ft) and 1.5 m (5.0 ft). The R-values for these samples were 17 and 16 respectively. These values are at the upper limit of the typical range (5-15) of R-values for clays.

The pH for the soils was 8.36 and the water soluble sulfate values from two tests were 100 and 1,700 ppm. Tests on two samples yielded resistivities of 1,229 Ohm-cm and 245 Ohm-cm. The resistivity values are low and suggest an environment with corrosion potential.

The compression index, C_c, from consolidation tests ranged from 0.114 to 0.260 indicating soil of low compressibility.

Groundwater was not encountered during the subsurface investigations that were limited to the surface soils. Groundwater was encountered in the monitoring wells at depths of more than 150 m (500 ft).

Basalt of the nature found at the site typically provides adequate support for footings, mats, and deep foundations for the anticipated loads. The Naval Facilities Engineering Command Design Manual (NAVFAC) (NAVFAC, 1986a) presents presumptive allowable bearing pressures for spread footings that range from 960 kpa to 7,660 kpa (10 to 80 tons per sq ft) for rock with consistency varying from soft to hard. Peck, Hanson and Thornburn (Peck, 1974) present allowable contact pressures on jointed rock as a function of RQD. An allowable contact pressure of 10 tons/ft^2 is recommended for an RQD of zero. Peck, Hanson and Thornburn (Peck, 1974) note that the allowable contact pressure beneath foundations is governed exclusively by the settlement associated with the defects in the rock, and not by strength. The expected loading for the proposed structures will therefore be far less than that required by bearing capacity (strength) considerations.

Other support alternatives to be considered in detail at the final design and discussed in Appendix E will be removal of unsuitable surface soils and backfilling with structural or engineered fill to the founding elevation of the foundation. The site soil is generally classified as low plasticity clay and is unlikely to be suitable for use as structural fill. The structural fill requirements will be detailed at the final design stage but suitable materials will include crushed rock, well graded gravel and sand mixtures.

Additional soil borings and rock coring will be performed at the site. Laboratory testing of soil and rock samples and additional in-situ tests will be performed as necessary to determine static and dynamic soil and rock properties. This information will be used to evaluate foundation bearing capacity, estimated settlement and provide geotechnical input for soil/rock structure interaction analysis.

It is expected that the final design subsurface information will confirm there is no need to perform a liquefaction analysis. Liquefaction potential is greatest where the groundwater level is shallow and saturated loose fine sands occur within a depth of about 15 m (50 ft). Groundwater was encountered in the monitoring wells at depths of more than 150 m (500 ft). The surface soils at the site are dry and partially saturated. Therefore, potential for liquefaction of the surface soils with groundwater at these depths appears highly unlikely. If required, the assessment of soil liquefaction potential will be performed using the applicable guidance of

Regulatory Guide 1.198, Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites, dated November 2003 (NRC, 2003c).

Allowable bearing pressures will be determined for the proposed foundations and anticipated loading. Allowable bearing pressure for the stability of structures will be based on the strength of the underlying soil and rock. For structures founded on rock the allowable bearing capacity is expected to be much higher than the loads that will be applied. The methods used to determine allowable bearing pressure will follow applicable methods in one or more of the following publications: NAVFAC DM7.02, Foundations and Earth Structures (NAVFAC, 1986a); Foundation Engineering Handbook (Winterkorn and Fang, 1975); Foundation Analysis and Design (Bowles, 1996); Foundation Engineering (Peck, 1974); and Rock Foundations (ASCE, 1996).

Settlement evaluation will consider the manufacturers and or other specified allowable total and differential settlement of equipment and buildings. The methods used will follow applicable methods in one or more of the following publications: NAVFAC DM7.01, Soil Mechanics (NAVFAC, 1986b); Foundation Engineering Handbook (Winterkorn and Fang, 1975); Foundation Analysis and Design (Bowles, 1996); and Foundation Engineering (Peck, 1974).

3.3.6 Regional and Local Tectonics

3.3.6.1 Basin and Range Tectonics

Extensional tectonics within the Basin and Range province, north and south of the ESRP, play an important role in dike emplacement and local ESRP tectonics. Although it is believed that the shallow and mid-crustal magma chambers related to the Yellowstone hotspot have solidified and cooled, relatively high temperatures within the upper mantle beneath the ESRP continued to produce basaltic magmas that form dikes or have erupted onto the surface. Continued stretching of the ESRP in the northeast southwest direction is evident by the northwest trending tension crack and fissure systems (Smith, 2004). Outside of the ESRP, the extension is accommodated by north to northwest-trending normal faulting (Parsons, 1998).

Three distinct structural features are common within the northern portion of the Basin and Range province:

- Reactivated thrust faults – extension resulted in renewed movement along low angle, pre-Basin and Range structures;
- Older Folds – deformation of originally flat lying rocks and;
- Normal faults – extensional stresses result in typically listric faults creating ranges within the Basin and Range province.

Thrust faults are associated with tectonic activity from the Mesozoic Cordilleran orogenic belt (Link, 1999) and pre-Basin and Range extensional. However active normal fault grabens are believed to be linked to these older thrust fault and their preferential zones of weakness. The Putnam thrust is an example of extensional normal faulting associated with a reactivated thrust fault located southeast of the ESRP (Kellogg, 1999). Extensional tectonics of the basin and range in the ESRP was initiated ~17 to 5 Ma (Rodgers, 1990; Janecke, 1992; Janecke, 1993; Janecke, 1994; Fritz, 1993; Anders, 1993; Sears, 1998). To the north of the ESRP, the Lost River, Lemhi, and Beaverhead ranges show that the Basin and Range extension was accommodated by north to northwest trending normal faults.

Seismic activity in the Basin and Range province is associated with rupture events, producing earthquakes, as faulting occurs. The 7.3 magnitude Borah Peak earthquake was a rupture event of the Lost River normal fault in 1983 (Link, 1999). The Borah Peak earthquake produced an approximate 1.8 m (6.0 ft) dip slip. The Borah Peak earthquake was centered approximately 137 km (85 mi) from the EREF site. In contrast, emplacement and inflation of dikes has allowed the crust of the nearby ESRP to expand nearly aseismically by allowing release of accumulated elastic strain with only small magnitude earthquakes (Parsons, 1998).

3.3.6.2 Subsidence

Subsidence and volcanism have continued into recent times (Holocene). The ESRP has subsided approximately 1.0 km (0.6 mi) since the passage of the Yellowstone mantle plume beneath the area. The subsidence began approximately 4 Ma and continues today in response to isostatic adjustments to the mid-crustal intrusions of gabbro and crustal contraction as the area cools (Smith, 2004). The subsidence has not been uniform and regions with a faster subsidence have accumulated sediments at faster rates. Smith (Smith, 2004) infers that a feature known as the Big Lost Trough, located along the north and northeastern boundary of the INL is an area of relatively higher subsidence, where up to 50% of the stratigraphic column is comprised of sedimentary interbeds within the basalt flow sequence.

3.3.6.3 Tension Cracks, Fissures, and Faults

A tension crack is an extensional feature within the ESRP that forms as lava migrates beneath the surface in dikes. Tension cracks are commonly found together, up to five, with multiple crack sets found within a small area (Kuntz, 2002). These cracks are propagated as lava ascends to the surface at different rates and volumes. Tension cracks in the ESRP represent pressure cracks formed on the edges of fissures due to dike emplacement. Fissures represent the dikes that were able to breach the surface (Kuntz, 2002). Local tension cracks, faults, fissures, and grabens are found at Kings Bowl and Craters of the Moon lava fields, the Spencer-High Point and Arco-Big Southern Butte volcanic rift zones, and adjacent to the site in the Lava-Ridge – Hell's Half Acre volcanic rift zone (Kuntz, 2002) (Figure 3.3-5, Regional Shaded-Relief Topographic Map of Eastern Snake River Plain (ESRP) and Local Geology).

Kings Bowl and Craters of the Moon

Kings Bowl lava field erupted approximately 2,200 years ago (Kuntz, 2002). Eighteen eruptive fissure segments make up a 0.600 km (0.375 mi) fissure system that produced the volcanic materials and structures found in this location. Tension cracks at Kings Bowl extend to 11.3 km (7.0 mi) northwest-southeast. The Open Crack rift set at Craters of the Moon lava field are two tension cracks sets (Kuntz, 2002). At Minidoka, the northern tension crack set consists of two pairs of cracks that extend 8 km (5 mi) and 6.5 km (4.0 mi). The cracks are separated by 1.9 km (1.2 mi) and are 4,500 years old, the same age as the Craters of the Moon lava field. The New Butte crack system is a composite of two crack set segments. The northern and southern tension crack segments extend 5 and 10 km (3.1 and 6.2 mi), respectively (Kuntz, 2002).

Spencer-High Point and Arco-Big Southern Butte

The Spencer – High Point rift zone is a west-northwest to east-southeast trending volcanic rift zone that extends ~70.0 km (43.5 mi). Vertical off-sets are observable associated with two grabens within the rift zone. The northern graben has steep walls up to 10 m (33 ft) high and is 700 m (2,297 ft) wide by 1.4 km (0.9 mi) long. This graben is believed to be related to dike emplacement beneath the area (Kuntz, 2002) as evidenced by the eruptive fissures along the graben and volcanic vents. Similar to the northern graben the western graben has steep walls, up to 12 m (39 ft) high, is 2.5 km (1.6 mi) long and up to 250 m (820 ft) wide. Unlike the northern graben, the southern graben is believed to be related to faulting in bedrock beneath the lava flows. This is based on a 14º difference in the trend direction for southern graben (Kuntz, 2002).

The Arco-Big Southern Butte volcanic rift zone trends from the northwest to the southeast for ~45 km (28 mi). Extensional faults are abundant throughout Box Canyon, located at the north end of the Arco-Big Southern Butte rift zone. These faults have offsets ranging from 1.0 to 8.0 m (3.3 to 26.2 ft) and extend up to 4.0 km (2.5 mi) in length. The extensional faults mark a large graben ~10.0 km (6.2 mi) long and up to 3.5 km (2.2 mi) wide. Volcanic activity is absent within the northern portions of the graben but abundant on its flanks and in the southern region. This trend is due to faulting in the northwestern portion and dike emplacement within the central and southeastern portions (Kuntz, 2002).

Lava-Ridge – Hell's Half Acre

Tension cracks are evident within the Lava-Ridge - Hells Half Acre rift zone and lava field. Local tension cracks extend greater than 2.0 m (6.6 ft) in width. One individual tension crack found at Hells Half Acre lava field is approximately 1.0 km (0.6 mi) long (Kuntz, 2002). The total length of the measured tension cracks at Hell's Half Acre lava field is 4.3 km (2.7 mi). The total length of the fissure system at Hell's Half Acre is 5.5 km (3.4 mi).

3.3.6.4 Dike Emplacement

Dike emplacement and inflation are important controls on extensional features in the ESRP (Parsons, 1998). Dikes within the ESRP are believed to vertically ascend to the surface from depth. The vertical ascent of the dikes reduced the amount of faulting in the region. Instead an abundant amount of tension cracks and fissures are found (Kuntz, 2002). Parsons and Thompson (Parsons, 1991) found that in extensional basaltic systems normal faulting can be suppressed when magmatic pressures are greater than the least principle stress. These magmatic pressures push dikes against their walls effectively opposing tectonic stresses. Thus, earthquakes and faulting are limited in areas with vertical dike emplacement, like the ESRP (Parsons, 1991). As dikes migrate to the surface only small to moderate earthquakes (maximum magnitudes of less than 5.5) are associated with their movement (Parsons, 1998; Hackett, 1994; Hackett, 1996). Parsons et al. (Parsons, 1998) estimated the rate of dike emplacement at 10 m (33 ft) (width) per 1,000 years at the estimated strain rate in the ESRP.

3.3.7 Seismic Hazard Assessment

A site-specific probabilistic seismic hazard assessment (PSHA) was performed for the planned EREF to be sited in Bonneville County, Idaho (Appendix F). Seismic ground motion amplitudes in bedrock were determined for annual frequencies of exceedance ranging from of 10^{-2} to 10^{-5}. Uniform hazard response spectra (UHRS) were determined for top of bedrock for annual frequencies of exceedance of 10^{-3}, 10^{-4}, and 10^{-5}.

The site is situated in a less seismically active region of the ESRP. Introduction and solidification of molten volcanic materials in ESRP fracture zones as they developed in the past are believed to be a possible mechanism responsible for the present low level of seismic activity (Parsons, 1991). Most of the areas to the north, east, and south of the ESRP experience earthquake activity along faults related to regional Basin and Range crustal extension; the ESRP, however, is an area of low present-day seismicity. The PSHA models the site region to be composed of a less seismically active ESRP surrounded by more seismically active Basin and Range provinces and faulted terrain.

Uniform hazard response spectra were determined for the top of basalt bedrock. The uppermost 30.5 m (100.0 ft) of bedrock material is estimated to have a shear wave velocity of approximately 1,400 m/sec (4,700 ft/sec) based on regional geophysical measurements in ESRP bedrock. The EREF site most likely has a bedrock shear wave velocity that is equal to but more likely greater than the National Earthquake Hazards Reduction Program (NEHRP) site condition B-C characterized by a shear wave velocity of 760 m/sec (2,493 ft/sec) in the uppermost 30 m (98 ft) of geologic material. It is noted that USGS 2008 seismic hazard maps are developed for the NEHRP B-C Boundary site condition (Petersen, 2008). Ground motion prediction equations by Spudich et al. (Spudich, 1999) and by Boore and Atkinson (Boore, 2008) were used in this site-specific PSHA to estimate seismic ground motion response spectra in bedrock ranging from the B-C boundary condition to hard bedrock conditions. The selected attenuation models predict seismic ground motion amplitude scaling for earthquakes caused by normal slip on regional faults that is a tectonic characteristic of the intermountain west Basin and Range geologic province within which the site is situated.

The PSHA was performed using a logic-tree format in which a total of 4 seismic source models were convolved with three ground motion prediction models. This method produced 12 combinations of seismic source and ground motion models. The weighed PSHA results for these 12 examined cases are listed below:

Annual Probability of Exceedance	Peak Horizontal Ground Acceleration	Spectral Acceleration (5% damping ratio)	Peak Pseudo-Relative Velocity (5% damping)
10^{-3}	61.37 cm/sec^2 0.063 g	161.15 cm/sec^2 (5 Hz) 0.164 g	6.96 cm/sec (2.5 Hz)
10^{-4}	147.09 cm/sec^2 0.150 g	373.09 cm/sec^2 (5 Hz) 0.381 g	15.97 cm/sec (2.5 Hz)
10^{-5}	293.61 cm/sec^2 0.299 g	743.50 cm/sec^2 (5 Hz) 0.758 g	33.53 cm/sec (1.0 Hz)

The site-specific PSHA results are below those determined for the 2008 update of the USGS national hazard maps. USGS PGA estimates are 30% higher at 10^{-3} per year and 40% higher at 10^{-5} per year than values shown above determined in the site-specific PSHA. The difference in seismic hazard estimates can result from the following possible causes.

- The site-specific PSHA used ground motion models for normal slip fault mechanisms; the USGS possibly used various fault mechanisms, or unspecified fault mechanisms, which predict higher amplitude seismic ground motions.
- The weighted result for the site-specific PSHA includes hazard results for hard rock attenuation models, which leads to lower amplitude seismic ground motions. The USGS 2008 results are for the NEHRP B-C Boundary site condition that is a firm rock condition that results in higher amplitude seismic ground motions relative to hard rock site conditions.

- The site-specific PSHA used a local earthquake frequency model determined for the ESRP; the USGS possibly used a larger background seismicity model for the Basin and Range province and a local cell earthquake activity rate that could exceed the historical earthquake rate (Petersen, 2008).

TABLES

Table 3.3-1 INL Stratigraphic Units
(Page 1 of 1)

Eastern Snake River Plain Stratigraphic Units	Composite Unit Number (Anderson, 1996b; Anderson, 1997)	Thickness of Deposits (m / ft) (variable by well location)	Number of Basalt Deposits	Number of Sedimentary Deposits	Number of Andesite Deposits	Number of Rhyolite Deposits	Age of Deposits (ka)
Snake River Group	1	0-86.5 / 0-284	78	12	0	0	5-250
	2	0-97.8 / 0-321	18	13	0	1	250-350
	3	0-93.0 / 0-305	17	17	1	0	350-440
	4	0-146.9 / 0-482	9	11	4	0	440-515
	5	0-100.3 / 0-329	3	6	0	0	515-580
	6	0-105.8 / 0-347	5	8	0	1	580-650
	7	0-124.7 / 0-409	7	10	0	0	650-800
Upper part of Idaho Group	8	0-490.4 / 0-1609	11	9	0	0	800-1800
	9		10	4	0	0	
	10		6	4	0	1	
	11		2	3	0	0	
	12		5	2	1	1	
	13		3	3	0	0	
	14		4	1	0	0	
	U	Varies	Multi	Multi	Multi	Multi	1800-4000

Sources: Anderson, 1996b; Anderson, 1997

Table 3.3-2 Site Soil Sample Locations
(Page 1 of 1)

Soil Sample No.	Location Description	Latitude	Longitude
SS1	Northeast corner of site	43° 35' 39.7"	112° 24' 59"
SS2	Full Tails Cylinder Storage Pad	43° 35' 31.7"	112° 25' 54"
SS3	Northwest portion of site	43° 35' 25.3"	112° 26' 48.3"
SS4	West of Cascade Halls	43° 35' 17.1"	112° 25' 54"
SS5	Cascade Hall	43° 35' 10.6"	112° 25' 35"
SS6	Between access road, stormwater detention basin and perimeter drainage swale	43° 34' 50.7"	112° 25' 54"
SS7	South portion of footprint	43° 34' 50.5"	112° 25' 23"
SS8	West of facility	43° 34' 47.6"	112° 26' 44.2"
SS9	Down gradient of facility along drainage	43° 34' 29.6"	112° 25' 35"
SS10	South east portion of site	43° 33' 40.7"	112° 25' 10.9"

Table 3.3-3 Summary of Soils by Map Unit
(Page 1 of 2)

Map Unit Name	Soil Description	Unified Soil Classification Designation(s)
Pancheri silt loam, 0 to 2 percent slopes	The Pancheri component makes up 85 % of the map unit. Slopes are 0 to 2 %. The parent material consists of loess. Depth to a root restrictive layer is greater than 152 cm (60 in). The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 152 cm (60 in) is moderate. Shrink-swell potential is low. This soil is not flooded and is not ponded. There is no zone of water saturation within a depth of 183 cm (72 in). Organic matter content in the surface horizon is about 2 %.	CL – ML
Pancheri silt loam, 2 to 4 percent slopes	The Pancheri component makes up 85 % of the map unit. Slopes are 2 to 4 %. The parent material consists of loess. Depth to a root restrictive layer is greater than 152 cm (60 in). The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 152 cm (60 in) is moderate. Shrink-swell potential is low. This soil is not flooded and is not ponded. There is no zone of water saturation within a depth of 183 cm (72 in). Organic matter content in the surface horizon is about 2 %.	CL – ML
Pancheri silt loam, 4 to 8 percent slopes	The Pancheri component makes up 85 % of the map unit. Slopes are 4 to 8 %. The parent material consists of loess. Depth to a root restrictive layer is greater than 152 cm (60 in). The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 152 cm (60 in) is moderate. Shrink-swell potential is low. This soil is not flooded and is not ponded. There is no zone of water saturation within a depth of 183 cm (72 in). Organic matter content in the surface horizon is about 2 %.	CL – ML
Pancheri-Rock outcrop complex, 2 to 25 percent slopes	The Pancheri component makes up 70 % of the map unit. Slopes are 2 to 25 %. The parent material consists of loess. Depth to a root restrictive layer is greater than 152 cm (60 in). The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 152 cm (60 in) is moderate. Shrink-swell potential is low. This soil is not flooded and is not ponded. There is no zone of water saturation within a depth of 183 cm (72 in). Organic matter content in the surface horizon is about 2 %.	CL – ML

Table 3.3-3 Summary of Soils by Map Unit
(Page 2 of 2)

Map Unit Name	Soil Description	Unified Soil Classification Designation(s)
Polatis-Rock outcrop complex, 2 to 25 percent slopes	The Polatis component makes up 65 % of the map unit. Slopes are 2 to 25 %. The parent material consists of loess over bedrock derived from basalt. Depth to a root restrictive layer, bedrock, lithic, is 51 to 102 cm (20 to 40 in). The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 152 cm (60 in) is moderate. Shrink-swell potential is low. This soil is not flooded and is not ponded. There is no zone of water saturation within a depth of 183 cm (72 in). Organic matter content in the surface horizon is about 2 %.	CL – ML

Table 3.3-4 Characteristics of Volcanism in the INL Area
(Page 1 of 1)

	CALDERA FORMATION	RIFT-ZONE VOLCANISM	AXIAL-ZONE VOLCANISM	AREAS BETWEEN VOLCANIC ZONES
MAGMA TYPES	rhyolite (viscous and gas-rich)	basalt (fluid and gas-poor)	basalt and subordinate rhyolite	basalt (and minor rhyolite)
VOLCANIC STYLE AND PRODUCTS	highly explosive; voluminous pumice and fine ash blankets entire regions	mild & effusive; erupt mainly lava flows from fissures, low shield volcanoes and small tephra cones	as per rift zones, but also local rhyolite domes & intrusions (Big Southern, Middle, East Buttes) with local explosive phenomena	as per volcanic rift zones (VRZs) and axial volcanic zone
STRATIGRAPHY	calderas filled with up to several km (several mi) of welded, silicic ash-flow tuffs, lava flows and volcaniclastic sediment [Heise Volcanics]	piles of 1 to 30m (3.3 to 99 feet) thick basalt lava flows &minor interbedded sediment; total lava thickness up to 1 km (0.6 mile) in INL area [Snake River Group]	basaltic lava flows and dispersed small tephra cones; isolated rhyolite domes and intrusions [Snake River Group]	fine clastic sediment of fluvial, lacustrine and eolian origin; fewer lava flows than near VRZs [Snake River Group]
TECTONICS AND PHYSICAL CONFIGURATION	collapse: broad, oval depressions, 10s to 100 km (10s to 62 miles) wide and 1 to 2 km (0.6 to 1.2 mi) deep, ringed by inward- dipping fractures	extensional: NW- trending belts of open fissures, monoclines small normal faults and basaltic vents	extensional, but magma-induced fissures or, faults are rare; a diffuse, NE-trending, volcanic highland along the ESRP axis	subsidence: broad, low topographic basins between extensional and constructional volcanic highlands; seldom disturbed by magma intrusion
GEOLOGIC AGE	6.5 to 4.3 million yrs in site area, now covered by younger basaltic lava. [2.1 to 0.6 million yrs on Yellowstone Plateau]	Surficial INL basalts: 1.2 to 0.05 million yrs; most are 0.7 to 0.1 million yrs. Inception of major basaltic volcanism was ca. 4 million yrs ago.	Basalt: >1 million yrs (Middle Butte), to 5,400 yrs (Hells Half Acre). Rhyolite: >1 million yrs (near East Butte) to 300,000 yrs (Big Southern Butte)	As per rift zones
QUATERNARY ERUPTION FREQUENCY	zero in Site area; Quaternary calderas closest to INL occur on Yellowstone Plateau	low; one eruption per 35,000 to 125,000 yrs	low: one basaltic eruption per 35,000 yrs one rhyolitic intrusion or dome every 200,000 yrs or longer	very low; by definition less frequent than within rift zones; one eruption per 125,000 yrs or longer

Source: Hackett, 2002.
Note: Refer to Figure 3.3-6 for Map Description of Volcanic Zones and Related Features

Table 3.3-5 Concentrations of Metals, Fluoride, and Moisture Content in Soils
(Page 1 of 2)

Analyte	Soil Sample Concentrations (mg/kg)					Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	
Arsenic	5.5	7.7	5.5	7.1	6.6	1.3 - 1.8
Barium	160	180	180	200	170	0.50
Cadmium	0.56	0.61	ND	0.69	0.59	0.50
Chromium (III)	21	20	20	25	23	0.50
Lead	15	16	14	18	16	0.60 - 0.81
Selenium	0.26	0.19	0.15	0.17	0.42	0.05
Silver	ND (<0.8)	ND (<0.5)	ND (<0.6)	0.7	ND (<0.7)	0.5 - 0.8
Total Mercury	ND (<0.05)	ND (<0.05)	ND (<0.05)	ND (<0.05)	ND (<0.05)	0.05
Soluble Fluoride	12	ND (<5)	ND (<5)	ND (<5)	10	5
Percent Moisture (%)	15.9	12.2	9.1	12.2	15.7	0.1

ND (<0.8) = Not Detected (parenthetical numbers denote the sample specific detection limit for which the result was less)

Table 3.3-5 Concentrations of Metals, Fluoride, and Moisture Content in Soils (Page 2 of 2)

Analyte	Soil Sample Concentrations (mg/kg)					Detection Limits (mg/kg)
	SS6	SS7	SS8	SS9	SS10	
Arsenic	7.3	6.7	7.1	6.9	6.5	1.3 - 1.8
Barium	170	200	170	170	190	0.50
Cadmium	0.58	0.74	0.57	0.6	0.55	0.50
Chromium (III)	21	23	21	22	25	0.50
Lead	16	17	16	16	18	0.60 - 0.81
Selenium	0.2	0.15	0.16	0.16	0.13	0.05
Silver	ND (<0.6)	ND (<0.6)	0.7	ND (<0.6)	ND (<0.5)	0.5 - 0.8
Total Mercury	ND (<0.05)	ND (<0.05)	ND (<0.05)	ND (<0.05)	ND (<0.05)	0.05
Soluble Fluoride	ND (<5)	10	ND (<5)	ND (<5)	ND (<5)	5
Percent Moisture (%)	11.1	15.7	11.8	16.5	10.5	0.1

ND (<0.8) = Not Detected (parenthetical numbers denote the sample specific detection limit for which the result was less)

Table 3.3-6 Concentrations of VOCs and SVOCs in Soils
(Page 1 of 8)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
VOCs											
1,1,1,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.002
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,1-Dichloropropene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,2,3-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,2,3-Trichloropropane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,2,4-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,2,4-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,2-Dibromo-3-chloropropane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,2-Dibromoethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,2-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,3,5-Trimethylbenzene	0.0067	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.002

ND = Not Detected (less than laboratory detection limits)

Table 3.3-6 Concentrations of VOCs and SVOCs in Soils
(Page 2 of 8)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
VOCs											
1,3-Dichlorobenzene	0.0082	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.002
1,3-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
1,4-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
2,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
2-Chlorotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
4-Chlorotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Bromobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Bromochloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Bromodichloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Bromoform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Bromomethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Carbon tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Chlorodibromomethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Chloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2

ND = Not Detected (less than laboratory detection limits)

Table 3.3-6 Concentrations of VOCs and SVOCs in Soils
(Page 3 of 8)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
VOCs											
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
cis-1,3-Dichloropropene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Dibromomethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Dichlorodifluoromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Hexachlorobutadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Isopropylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
m+p-Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Methyl ethyl ketone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2
Methylene chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
n-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
n-Propylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
o-Xylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
p-Isopropyltoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
sec-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2

ND = Not Detected (less than laboratory detection limits)

Table 3.3-6 Concentrations of VOCs and SVOCs in Soils
(Page 4 of 8)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
VOCs											
Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
tert-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Tertrachloroethene	0.0086	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.002
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
trans-1,3-Dichloropropene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Trichlorofluoromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
Vinyl chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
SVOCs											
1,2,4-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
1,2-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
1,3-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
1,4-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
1-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
2,4,5-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
2,4,6-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
2,4-Dichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33

ND = Not Detected (less than laboratory detection limits)

Table 3.3-6 Concentrations of VOCs and SVOCs in Soils
(Page 5 of 8)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
SVOCs											
2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
2,4-Dinitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.7
2,4-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
2,6-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
2-Chloronaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
2-Chlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
2-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
2-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
3,3-Dichlorobenzidine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.67
4,6-Dinitro-2-methylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.7
4-Bromophenylphenylether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
4-Chloro-3-methylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
4-Chlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
4-Chlorophenylphenylether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
4-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.7
Acenaphthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33

ND = Not Detected (less than laboratory detection limits)

Table 3.3-6 Concentrations of VOCs and SVOCs in Soils (Page 6 of 8)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
SVOCs											
Azobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Benzidine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.67
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Benzo(a)pyrene	ND	0.014	ND	0.035	ND	ND	ND	ND	0.059	0.014	0.0033
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
bis(-2-chloroethoxy)Methane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
bis(-2-chloroethyl)Ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
bis(2-chloroisopropyl)Ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
bis(2-ethylhexyl)Phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Butylbenzylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Dibenzo(a,h)anthracene	ND	0.012	ND	0.024	ND	ND	ND	ND	0.038	0.0099	0.0033
Diethyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Dimethyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Di-n-butyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33

ND = Not Detected (less than laboratory detection limits)

Table 3.3-6 Concentrations of VOCs and SVOCs in Soils
(Page 7 of 8)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
SVOCs											
Di-n-octyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Hexachlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Hexachlorobutadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Hexacholorocyclopentadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.67
Hexachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Indeno(1,2,3-cd)pyrene	ND	0.025	ND	0.081	ND	ND	ND	ND	0.146	0.024	0.0033
Isophorone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
m+p-Cresols	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Nitrobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
n-Nitrosodimethylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
n-Nirtoso-di-n-propylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
n-Nitrosodiphenylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
o-Cresol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.7
Phenanthrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33

ND = Not Detected (less than laboratory detection limits)

Table 3.3-6 Concentrations of VOCs and SVOCs in Soils
(Page 8 of 8)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	**SS2**	**SS3**	**SS4**	**SS5**	**SS6**	**SS7**	**SS8**	**SS9**	**SS10**	
SVOCs											
Phenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
Pyridine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.67

ND = Not Detected (less than laboratory detection limits)

Table 3.3-7 Concentrations of Pesticides and Herbicides in Soils
(Page 1 of 7)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
Pesticides											
Alachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Ametrym	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Atraton	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Atrazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Benefin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Bromacil	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Butachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Butylate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Carboxin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Chlorpropham	ND	ND	ND	0.0074	ND	0.0055	ND	0.0110	ND	ND	0.0033
Chlorpyrifos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Cyanazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Cycloate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Diazion	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Dichlorvos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Diphenamid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033

ND = Not Detected (less than laboratory detection limits)

Table 3.3-7 Concentrations of Pesticides and Herbicides in Soils
(Page 2 of 7)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
Pesticides											
Disulfoton	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
EPTC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Ethalfluralin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Ethoprop	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Fenamiphos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Fenarimol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Fluridone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Fonofos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Hexazinone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Isopropalin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Kelthane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Malathion	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Merphos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Methyl paraoxon	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Metolachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Metribuzin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033

ND = Not Detected (less than laboratory detection limits)

Table 3.3-7 Concentrations of Pesticides and Herbicides in Soils
(Page 3 of 7)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	**SS2**	**SS3**	**SS4**	**SS5**	**SS6**	**SS7**	**SS8**	**SS9**	**SS10**	
Pesticides											
Mevinphos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
MGK-264	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Molinate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Napropamide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Norflurazon	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Oxadiazon	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Oxyfluorfen	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Pebulate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Pendimethalin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Phorate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Profluralin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Prometon	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Prometryn	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Pronamide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Propachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Propazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033

ND = Not Detected (less than laboratory detection limits)

Table 3.3-7 Concentrations of Pesticides and Herbicides in Soils (Page 4 of 7)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
Pesticides											
Simazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Simetryn	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Stirofos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Terbacil	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Terbufos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Terbutryn	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Triadimefon	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Triadimefon	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Triallate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Tricyclazole	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Trifluralin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Vernolate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0033
Organochlorine Pesticides											
4,4'-DDD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
4,4'-DDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017

ND = Not Detected (less than laboratory detection limits)

Table 3.3-7 Concentrations of Pesticides and Herbicides in Soils (Page 5 of 7)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
Organochlorine Pesticides											
4,4'-DDT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
Aldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
alpha-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
alpha-Chlordane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
beta-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
Chlordane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.017
delta-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
Dieldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
Endosulfan I	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
Endosulfan II	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
Endosulfan sulfate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
Endrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
Endrin aldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
Endrin ketone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
gamma-BHC (Lindane)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
gamma-Chlordane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017

ND = Not Detected (less than laboratory detection limits)

Table 3.3-7 Concentrations of Pesticides and Herbicides in Soils
(Page 6 of 7)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
Organochlorine Pesticides											
Heptachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
Heptachlor epoxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
Methoxychlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0017
Toxaphene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.167
Chlorinated Herbicides											
2.4.5-T	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.004
2.4.5-TP (Silvex)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.004
2.4-D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.02
2.4-DB	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05
3.5-Dichlorobenzoic Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01
4-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01
Acifluorfen	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01
Bentazon	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05
Chloramben	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01
Dacthal	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.02
Dalapon	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05

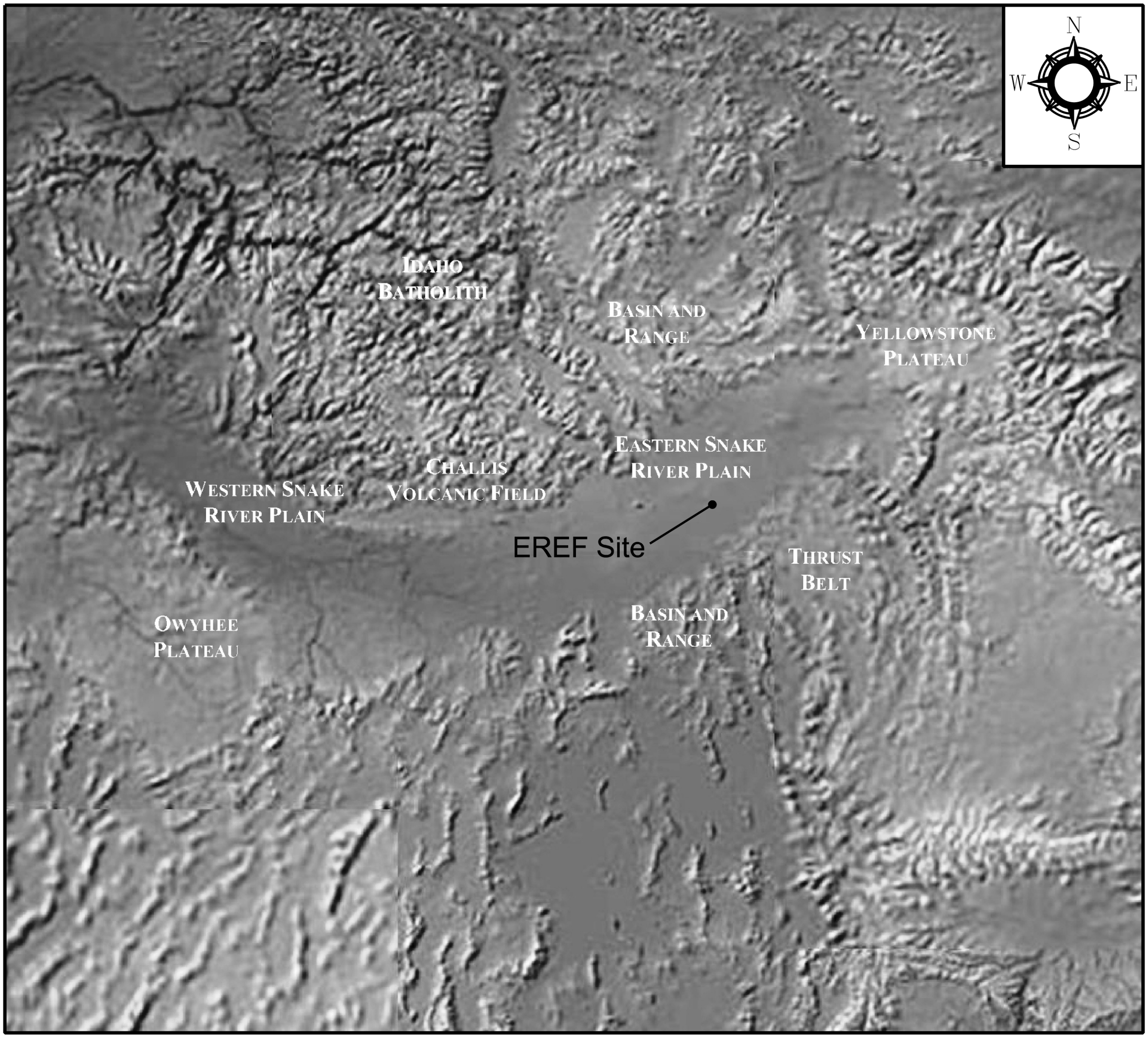
ND = Not Detected (less than laboratory detection limits)

Table 3.3-7 Concentrations of Pesticides and Herbicides in Soils
(Page 7 of 7)

	Soil Sample Concentrations (mg/kg)										Detection Limits (mg/kg)
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	
Chlorinated Herbicides											
Dicamba	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.005
Dichlorprop	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.02
Dinoseb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.02
MCPA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4
MCPP	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4
Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.002
Picloram	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01

ND = Not Detected (less than laboratory detection limits)

FIGURES



SCALE

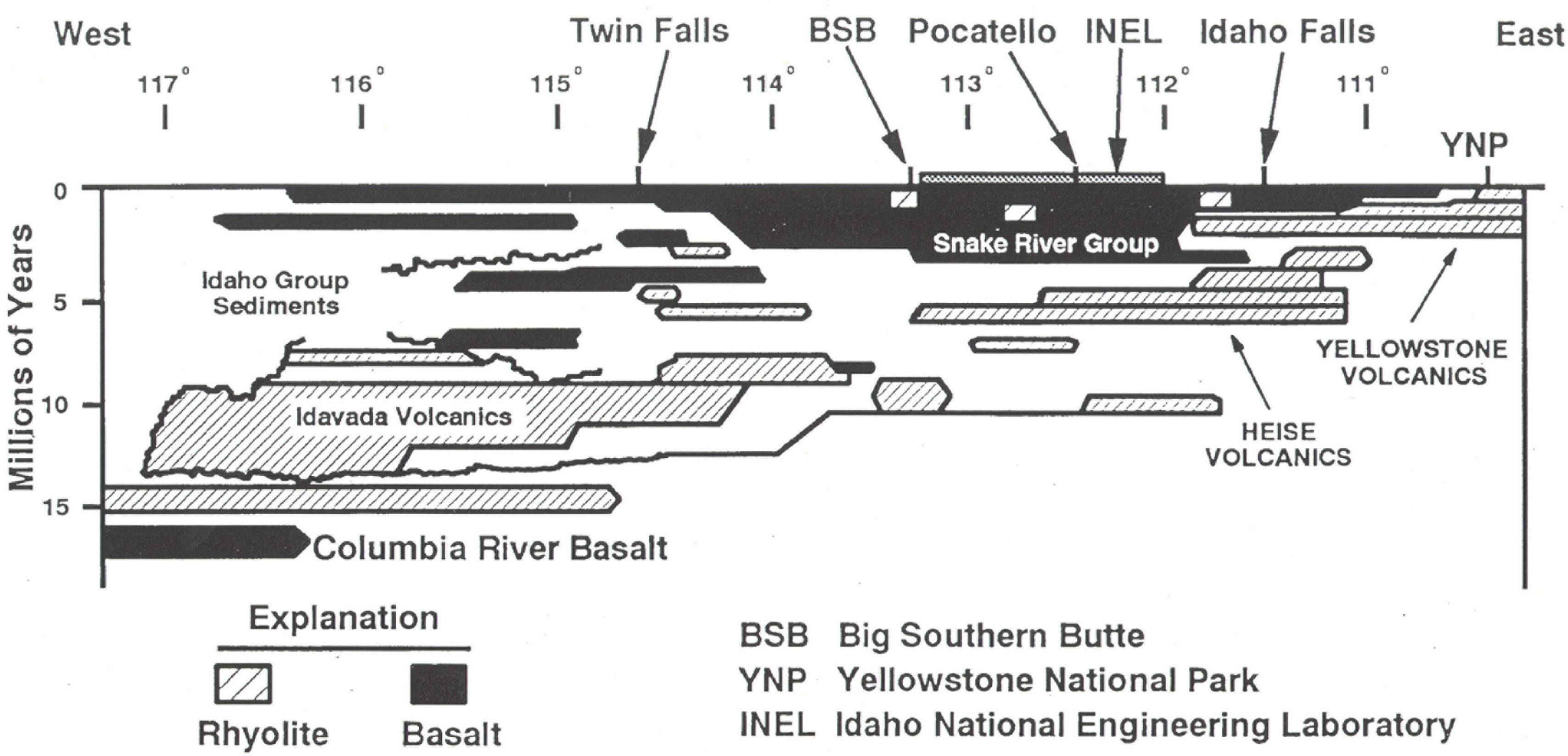
0 100 (km)

0 60 (mi)

Figure 3.3-1 Rev. 0

Regional Shaded-Relief Topographic Map of Snake River Plain and Surrounding Physiographic Regions

EAGLE ROCK ENRICHMENT FACILITY ENVIRONMENTAL REPORT



Source: Hackett, 2002.

Figure 3.3-2 **Rev. 0**

Age-Distance Plot of Lake Cenozoic, Bimodal Volcanism in Snake River Plain-Yellowstone Province

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