Chapter IV: Affected Environment

A. Physical Resources

1. Air Quality

Air quality is important for health, visitor enjoyment, scenic vistas and the preservation of natural systems and cultural resources. Air quality is generally very good in the parks because of their surrounding low population density (except for Golden Spike) and lack of major industrial development.

There are two types of air quality designations for the 10 parks under the Clean Air Act (CAA) (1977). Class I areas are afforded the highest degree of protection under the CAA. This designation allows very little additional deterioration of air quality. Class II areas have limits on increases of particulate matter and sulfur dioxide above baseline conditions. A limited amount of air quality degradation is permitted as long as National Ambient Air Quality Standards (NAAQS) are not exceeded.

The CAA requires the EPA to, among other things, identify and publish a list of common air pollutants that could endanger public health or welfare. These are referred to as "criteria pollutants," and the EPA has established for each of them a maximum concentration above which adverse effects on human health may occur. These threshold concentrations are called NAAQS. Areas that have violated the NAAQS are federally designated as "nonattainment" areas. Sections 118 and 176 of the Act require federal facilities to comply with and conform to State Implementation Plan (SIP) requirements where an action could adversely affect air quality.

Areas classified as in attainment are those which meet the NAAQS under the CAA. These standards are health-based for PM_{10} (particulate matter less than 10 microns in diameter) or fine dust. There are also attainment standards for ozone, and nitrogen and sulfur dioxides.

For example non-attainment areas for the NAAQS in Idaho include northern Ada County (carbon monoxide) and portions of Bannock and Power counties (particulates) (State of Idaho, Department of Environmental Quality, Air Quality). These areas are located more than 100 miles from City of Rocks, Hagerman Fossil Beds and Minidoka. A portion of Craters of the Moon is located in Power County and the nearest boundary of the park is 12 miles from American Falls and approximately 30 miles from Pocatello.

Non-attainment areas for the NAAQS in Montana include Missoula (nitrates and particulates) and Butte (particulates). Butte is 65 miles from Big Hole and 35 miles from Grant-Kohrs. Missoula is more than 100 miles from the Nez Perce – Bear Paw and Little Bighorn and 85 miles from Grant-Kohrs and approximately 100 miles from Big Hole.

Non-attainment areas in Utah include the Northern Wasatch Front, Cache Valley and Utah Valley. For particulates (<2.5 microns), these are Box Elder County (where Golden Spike is located). Salt Lake County is also in non-attainment status for PM 10 particulates, particulates < 2.5 microns, and sulfur dioxide and maintenance status for carbon monoxide and ozone. Salt Lake County is adjacent to and south of Box Elder County. Golden Spike is more than 35 miles from the Salt Lake County nonattainment areas.

A Wyoming NAAQS ozone nonattainment area was designated in 2009 for the Upper Green River Basin. The western edge of this area is 20 miles northeast of Fossil Butte National Monument. Prevailing winds are from the west.

a. City of Rocks Air Quality

City of Rocks is designated a class II area under the CAA. Although protecting and maintaining scenic quality was among the reasons for the designation of the reserve, minimal quality monitoring has been conducted. Slight increases in pollutants could cause major decreases in visibility. Known sources of poor air quality include the release of particulates from routine high winds (including dust emissions from nearby agricultural fields during dry conditions).

The Comprehensive Management Plan (NPS CIRO 1994:109) notes that the west-central U.S., including southern Idaho, has the best visual air quality in the country (Sisler *et al.* 1991 in NPS CIRO 1994:109). The plan also states that air quality at City of Rocks is likely similar to Craters of the Moon because of its similar setting and conditions and that the same probable deterioration as has been experienced at Craters of the Moon (see below) has also likely occurred at City of Rocks.

City of Rocks is currently conducting a two-year project for nitrogen deposition monitoring facilitated by the University of California, Riverside to determine whether this dry deposition contributes to the spread of noninvasive plants. The park is also conducting air quality monitoring for ozone in support of the GMP process. There are currently no results from either of these monitoring efforts.

b. Craters of the Moon Air Quality

A portion of Craters of the Moon (Wilderness Area) is in a mandatory class I airshed. The rest of the monument and the preserve is in a class II area. There are few nearby pollutant sources. Among those identified include suburban and urban areas near the southern part of the monument and preserve and the Idaho National Engineering Laboratory. The primary sources of air pollution in the vicinity are related to motor vehicles, unpaved roads and agriculture along with some long distance transport of urban pollutants from the Salt Lake City area. Onsite monitoring of fine particulates (which affect visibility), ozone and wet deposition of nitrates, ammonia and sulfates have been ongoing since at least 1992.

c. Fossil Butte Air Quality

Fossil Butte is in a class II area. There are several fossil fuel uses near Fossil Butte. The Pacificorp Viva Naughton Power plant and the Pittsburgh and Midway open pit coal mine are within 10 miles of the monument. Williams Field Service has a natural gas processing facility approximately 25 miles downwind of Fossil Butte NM. British Petroleum and Chevron/Texaco operate sulfur load out terminals approximately nine miles south of Kemmerer, Wyoming, on U.S. Highway 189. Exxon operates a large gas processing plant approximately 35 miles east of the monument. Other energy development is more distant from the monument. Mobile sources of pollution in the area include railroads, motor vehicles and ranch equipment (NPS FOBU 2005:13).

Although some air quality monitoring was conducted prior to the GMP (NPS FOBU 1980:18), no air quality monitoring is currently being conducted at Fossil Butte (NPS FOBU 2005:13). Wet deposition monitoring stations are located at Murphy Ridge, Utah (60 km southwest), and Pinedale, Wyoming (130 km northeast). Dry deposition is also collected at Pinedale. Ozone monitoring stations are located near Logan, Utah. Based on available information, there is no indication that class II air quality standards are violated at Fossil Butte (NPS FOBU 2005:13). According to the GMP, NPS managers would cooperate with regional air authorities, state authorities, and agencies having jurisdiction over adjacent lands (NPS FOBU 1980:18).

d. Golden Spike Air Quality

Golden Spike air quality is affected locally by automobile and industrial pollution from the Salt Lake City / Ogden / Provo metropolitan area, where copper and oil refineries are among the major pollution sources. In addition, a chemical plant (Thiokol) is located in Box Elder County. Thiokol affects local air quality when two to three times a week, excess fuel is burned off, resulting in a large emissions cloud that can be seen by visitors to the park (NPS GOSP 1976: SFM-7, Benson pers. comm. 2010). Other industrial uses in the area include extraction of petroleum and development of geothermal power.

At the park, an auto tour encourages some additional driving, however because the park does not have overnight use, there are no impacts from campfires or other than vehicle exhaust emissions.

e. Grant-Kohrs Air Quality

Grant-Kohrs Ranch is within a class II airshed. According to the FMP (2004), current monitoring indicates standards for this class are now being met (NPS GRKO 2004). Unlike many mountain valleys, the Deer Lodge Valley is wide enough that inversions are not a major problem, and overall conditions are good (NPS 1993 in NPS GRKO 2004). Winds are most common from the west to south-southwest. Average seasonal wind speeds range between 10 and 15 mph, being higher in the winter and spring. Average wind speeds tend to be highest late afternoon and lowest in early to mid-morning (MDEQ 2002 in NPS GRKO 2004).

There are no nearby industrial sources of pollution. Minor pollution occurs in the fall from timber slash burning and agricultural burning and from occasional burning at a sawmill south of Deer Lodge. Spring pollution sources include road dust and agricultural burning and occasional burning at a sawmill. During winter months, the major pollutant is residential firewood burning (NPS GRKO 2004).

f. Hagerman Fossil Beds Air Quality

Hagerman Fossil Beds is a class II area. Monument air quality is generally very good. Notable exceptions are from blowing dust in spring when fields are planted on farmland to the west, and during agricultural burning. Air pollution from industrial sources and vehicles is likely minimal due to the rural environment which surrounds the monument. Ambient air quality is monitored in Twin Falls (NPS HAFO 1995:73).

g. Little Bighorn Air Quality

Little Bighorn is a class II area. Baseline air quality data is available for the monument at a wet deposition monitoring station supported by the USGS. The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) monitors contaminants in the rain and snow. This monitoring began in 1984. Smoke particulates are monitored through Interagency Real Time Smoke Monitoring supported by the Montana/Idaho Airshed Group.

The WASO Air Resources Division (ARD) completed the report “Air Quality and Air Quality Related Values Monitoring Considerations for the Rocky Mountain Network” in March 2005. Park air quality related values (AQRVs) include: visibility, vegetation, fish and wildlife. Ozone-sensitive plants that occur in the monument include spreading dogbane (*Apocynum androsaemifolium*), white sagebrush (*Artemisia ludoviciana*), common milkweed (*Asclepias syriaca*), green ash (*Fraxinus pennsylvanica*), chokecherry (*Prunus virginiana*), and skunkbush (*Rhus trilobata*). There is not enough park-specific information available to determine if the surface waters and soils within the monument are sensitive to changes in air quality.

Little Bighorn trends (1994-2003) show sulfate concentrations decreasing, nitrate concentrations with no trend, and ammonium concentrations increasing. Overall, ozone concentrations are increasing in the ROMN (NPS LIBI 2007:22-23).

Air pollutant emissions come from a variety of sources, including mobile sources (e.g., cars, trucks, off-road vehicles), stationary sources (e.g., power plants and industry), and area sources (e.g., agriculture, fires, and road dust) (NPS LIBI 2005a:1). Little Bighorn is located within Big Horn County at the junction of Interstate 90 and Montana Highway 212. Visitation averages 305,000 visitors annually, many by bus and recreational vehicle. There are several power plants and industry pollution sources, like oil, coal, sulphur and sugar, approximately 70 miles from Little Bighorn. Agriculture and ranching are the primary uses of lands in the area of Little Bighorn. Prescribed burning of crop lands in Big Horn County is a common practice which adds to smoke produced by wildfires in Montana.

h. Minidoka Air Quality

Minidoka is a class II area. Local sources of air pollutants include automobile exhaust and wind-blown dust. Regional sources of air pollutants include wind-blown dust, generated by agricultural activities, smoke from seasonal agricultural burning and periodic wildland fires, and scattered point sources principally associated with the food processing industry, including Confined Animal Feeding Operations (CAFOs).

Because another CAFO is planned nearby that would house 8,000 – 13,000 cows, an air quality modeling study was conducted to determine the potential effect of the CAFO on Minidoka. Agricultural livestock facilities produce odorous compounds, including ammonia (NH_3), methane (CH_4), nitrous oxide (N_2O), volatile organic compounds, and particulates. Estimated ambient pollutant concentrations for ammonia, hydrogen sulfide (H_2S) and particulates greater than 10 microns (PM_{10}) were identified.

i. Nez Perce: Bear Paw Air Quality

Nez Perce National Historical Park is a class II area. Bear Paw Battlefield is under the jurisdiction of Blaine County and Air Quality Control Region 141 which is in an attainment area for NAAQS. There are currently no major point sources of air pollution in the vicinity of the site. As a result, air quality and visibility are generally considered excellent. Occasional periods of degradation may occur due to regional haze, wind, or range fire smoke. The primary sources of air pollution in the vicinity are related to motor vehicles, unpaved roads and agriculture.

j. Nez Perce: Big Hole Air Quality

Big Hole is a class II area. Air quality in the Big Hole Valley is typical of non-industrialized, low population density areas in Montana and is considered to be good. Winter temperature inversions may degrade air quality as atmospheric pollutants become trapped in the lower atmosphere stagnant air masses. This valley is considered to be in attainment with NAAQS. The nearest nonattainment area to Big Hole is Butte, located approximately 65 miles to the northeast. Butte is in nonattainment status for particulate matter. Missoula, located approximately 100 miles due north of Big Hole, is in non-attainment for both particulate matter and carbon monoxide (MDEQ 2003 *in* NPS BIHO 2005).

From September of 1984 to June of 1986, continuous monitoring of total suspended particulates (TSP) was performed in Dillon (approximately 60 miles southeast of Big Hole) to address local concerns related to industrial particulate emissions (MDEQ 2003 *in* NPS BIHO 2005). The monitoring data showed low readings and was discontinued. As noted in the July 2003 *Montana Air Monitoring Network Review*, the MDEQ does not record any other air monitoring data for Beaverhead County, nor did the monitoring plan for 2004 indicate air quality concerns or proposed monitoring in Beaverhead County (MDEQ 2003 *in* NPS BIHO 2005). Barretts Mill, located approximately six miles south of Dillon, is the only industrialized major source of air emissions reported for Beaverhead County (MDEQ 2003 *in* NPS BIHO 2005).

2. Geology

a. City of Rocks Geology

The reserve is located in the far northeastern part of the Basin and Range province in the southern Albion Mountains. The Raft River Valley is on the east and the Snake River Valley is on the north. Monumental granite rock outcrops give the reserve its name. Elevations range from 5,650 feet in the Circle Creek basin to 8,867 feet on Graham Peak.

The reserve contains some of the oldest rocks in the western U.S., dated to about 2.5 billion years ago. These metamorphic rocks border igneous rocks that are much younger (28.6 million years). The rock formations in the reserve developed through a process called exfoliation, where thin rock plates and scales sloughed off along joints from contraction when the rocks cooled or from expansion when overlying materials eroded away. Vertical, horizontal and dome-shaped joints in the rocks are responsible for the north-south orientation of many of the formations and for "bornhardts" – dome shaped towers. On the tops of many rocks are pan-holes, depressions from weathering that often fill with water.

The following description is taken from Kenworthy *et al.* 2005:

> *Green Creek Complex (Precambrian) and Almo Pluton (Oligocene):* There are two main geologic units that form the distinctive rock outcroppings at City of Rocks, the Precambrian Green Creek Complex and the Oligocene Almo Pluton. The oldest of these units is an assemblage of rocks informally known as the Green Creek Complex. The Green Creek Complex is characterized by intrusive igneous granites and metamorphic schists and amphibolites. These rocks, approximately 2.5 billion years old, are some of the oldest rocks in the United States (Miller and Bedford 1999 *in* Kenworthy *et al.* 2005). The lower portion of the "Harrison Series" mapped by Anderson (1931 *in* Kenworthy *et al.* 2005) is equivalent to the Green Creek Complex. The Oligocene-aged Almo Pluton is a granite body that was thrust up into the Green Creek Complex while both units were still underground. The granites of the Almo Pluton have been dated at approximately 28.6 million years old (Miller and Bedford 1999 *in* Kenworthy *et al.* 2005). Rocks of the Green Creek Complex are darker than those of the Almo Pluton, making for the stark contrast of the two rock types at the Twin Sisters (NPS n.d. *in* Kenworthy *et al.* 2005).

City of Rocks National Natural Landmark: The City of Rocks National Natural Landmark (NNL) was designated in 1974 because it is a geologically unique area that exhibits nationally significant features, including the dominance of bornhardt formations, the scarcity of tors, a wide range of elevations over which the landforms are distributed, and evidence that the landforms have been carved from the upper parts of a pluton. City of Rocks demonstrates the exfoliation process on a small scale (shaping of domes), whereas Yosemite National Park demonstrates the process on a large scale (such as at Half-Dome and North Dome).

NNLs are nationally significant natural areas designated by the Secretary of the Interior. To be nationally significant, a site must be one of the best examples of a type of biotic community or geologic feature in its physiographic province.

b. Craters of the Moon Geology

Volcanism has generated an array of features and habitats that make the monument a recognized outdoor laboratory. As a result, the monument draws scientists and visitors from around the world to study and experience the diverse volcanic terrain.

The monument is located in the Snake River Basin-High Desert (Omernik 1986 in NPS CRMO 2005) and is primarily comprised of three geologically young (Late Pleistocene-Holocene) lava fields that lie along the Great Rift. The Great Rift zone is a belt of open cracks, eruptive fissures, shield volcanoes, and cinder cones. The monument protects most of the Great Rift area, which includes the numerous lava flows and other discharges from the Great Rift volcanic rift zone. It compares in significance to other volcanic rift zones such as those found in Hawaii and Iceland. The Great Rift varies between one and five miles wide and extends for more than 50 miles (NPS CRMO 2005:5).

Many features and structures associated with basaltic volcanism are represented in the Great Rift, including various kinds of lava flows, volcanic cones, and lava tubes. There are also lava-cave features such as lava stalactites and curbs, explosion pits, lava lakes, squeeze-ups, basalt mounds, an ash blanket, and low shield volcanoes. Some lava flows within the Great Rift diverged around areas of higher ground and rejoined downstream to form isolated islands of older terrain surrounded by new lava. These areas with remnant vegetation are called "kipukas." In many instances, the expanse of rugged lava surrounding these small pockets of soil has protected the kipukas from people, animals, and even nonnative plants. As a result, these kipukas represent some of the last undisturbed vegetation communities in the Snake River Plain (NPS CRMO 2005:5).

Young lava flows and other features cover about 450,000 acres of the monument. The remaining 300,000 acres in the monument are also volcanic in origin, but are older and covered with a thicker mantle of soil. This older terrain supports a sagebrush steppe ecosystem consisting of diverse communities of grasses, sagebrush, and shrubs, and providing habitat for a variety of wildlife. This area also includes lava tube caves, older volcanic formations, and volcanic edifices locally known as buttes (NPS CRMO 2005:5-6).

The monument contains the youngest and most geologically diverse section of basaltic lava terrain found on the Eastern Snake River Plain, an extensive area of volcanic formations that reaches across southern Idaho east to Yellowstone National Park. It includes three distinct lava fields: Craters of the Moon, Kings Bowl, and Wapi. The Craters of the Moon Lava Field is significant in that it is the largest basaltic lava field of predominantly Holocene age (less than 10,000 years old) in the lower 48 states (Kuntz *et al.* 1992 in NPS CRMO 2005)(NPS CRMO 2005:5).

c. Fossil Butte Geology

Fossil Lake, Lake Gosiute, and Lake Uinta formed an ancient sub-tropical lake ecosystem commonly referred to today as the "Green River Lake System." The lakes were located in what now are the states of Wyoming, Utah, and Colorado. The original Fossil Lake was 40-50 miles long (north/south) and 20 miles wide (east/west). During its approximately two million-year life, its length and width varied considerably.

Today, the national monument protects small portions of the original Fossil Lake and the larger Green River Lake ecosystem. The park consists of 13 square miles (8,198-acres) of the 900-square-mile (595,200 acre) ancient Fossil Lake. One of the park's geological formations is formed from the ancient lake sediments. Scientists refer to these lake sediments, now rocks, as the Green River Formation. These rocks preserve a tremendous variety of fossils. In addition to the Green River Formation, the colorful Wasatch Formation, composed of river and stream sediments, is exposed in the national monument. The Wasatch Formation contains fossilized teeth and bone fragments of many Eocene mammal species, including early primates and horses. These fossils tell us about animals living near Fossil Lake, thereby adding the terrestrial component to Fossil Lake's story (www.nps.gov/fobu).

The major geologic formations of interest at Fossil Butte are the Wasatch and Green River formations. The Wasatch formation displays the red, purple, and yellow badlands. The Green River formation, with buff to white colors, is situated above the Wasatch formation and contains the main fossil fish deposits. The outcrops of these formations are very sparsely vegetated (NPS FOBU 2005:12)

d. Golden Spike Geology

Lying within the summit of the major pass over the Promontory Range, Golden Spike is between the North Promontory and the Promontory Mountains in the northern part of the Great Salt Lake Basin. When ancient Lake Bonneville covered the area between 20,000 and 100,000 years ago, the summit was below 230 feet of water, 1,000 feet above the current Great Salt Lake and 4,200 feet above sea level. Lake Bonneville was almost as large as Lake Michigan. Because the level of the lake fluctuated, the Promontory Mountains were once islands in the lake. As a result, old lake terraces from this glacial period form prominent features in the area. The highest terrace was associated with the highest level of the lake, the Bonneville Level. Below this was the Provo Level which formed the knob on Fremont Island and below this was the Stansbury Level.

Most surface areas are covered with fine-grained lake sediments and alluvial deposits. Subsurface deposits consist primarily of Pennsylvania sandstones, shales, limestones and Tertiary extrusive materials. Numerous fault lines run through the Promontory Range (NPS GOSP 1976: SFM 3). A natural asphalt seep, discovered in the early 1900s, is located at Rozel Point, just outside of the monument.

e. Grant-Kohrs Ranch Geology

The following summary was taken from the Grant-Kohrs Ranch Geologic Resource Evaluation Report by the NPS Geological Resources Division (GRD) (NPS GRKO 2007):

Grant- Kohrs Ranch National Historic Site sits in the broad Deer Lodge Valley of the Clark Fork River in west- central Montana. Local geology varies greatly within the Grant-Kohrs Ranch area. In the eastern mountains, the Cretaceous Boulder Batholith granitic (monzogranite, granodiorite, and aplite) igneous intrusion is the predominant rock type. Several high- angle normal faults cut the area trending north, northwest, and northeast. Along the western side of the valley, the rocks are comprised of folded and faulted sedimentary units intruded by Cretaceous granitic to dioritic igneous dikes and stocks.

Precambrian age rocks underlie the Grant-Kohrs Ranch area almost entirely. These rocks are part of the Belt Supergroup that is Late Proterozoic in age. These were deposited in an ancient marine basin. In the Deer Lodge Valley, these units are exposed on the western side, juxtaposed against Mesozoic and Cenozoic age rocks by a large range- bounding fault. Individual formations recognized among these older rocks include the Snowslip, Shepard, Mt. Shields, Bonner, McNamara, and Garnet Range units (Loan 2001 in NPS GRKO 2007).

The Jurassic Swift Formation and Cretaceous Golden Spike Formation are exposed north of the park. The Carter Creek and Kootenai formations are also present locally. These sedimentary units contain sandstone, mudstone, black shale, chert pebble conglomerate, rare limestone beds, and andesitic lava flows (Berg 2004 in NPS GRKO 2007).

The locally present Cretaceous Blackleaf Formation is a mixed unit of shales, sands, volcanoclastics, and silts deposited during marine transgression (Dyman *et al.* 1993 in NPS GRKO 2007). Many Cretaceous units were deposited during the regressions and transgressions of the Western Interior Seaway.

On the eastern side of Deer Lodge Valley are the Elkhorn Mountain Volcanics and other Cretaceous to Tertiary age basaltic flow units. These volcanic rock units are exposed over large areas of the map coverage.

The late Cretaceous to early Tertiary compressional Sevier–Laramide orogenic events caused huge blocks of buried rock to slide over younger rock in an easterly direction. These episodes caused the dramatic juxtaposition of rock ages found today at Grant-Kohrs Ranch.

Tertiary age sediments cover the central portion of the valley and result from local basins filling with sediments when extension along normal faults followed mountain building. These sediments consist of lacustrine beds, fluvial deposits, and ash beds. Extensive volcanism also accompanied extension and produced rhyolite tuffs interbedded with limestones, some intrusive dikes, and extensive ash beds. These sediments are as thick as 3,064 m (10,052 ft) 11 km (seven miles) south of Grant-Kohrs Ranch National Historic Site (Berg 2004 in NPS GRKO 2007).

Pleistocene glaciation and other geomorphological agents such as streams and landslides have all left recent, Quaternary age deposits on the landscape of the Deer Lodge Valley. Extensive terraces flank both sides of the Clark Fork River. Poorly sorted glacial till and outwash as well as slope deposits (landslides) and alluvial fans are present along the sides of the valley.

Large quantities of flood-deposited tailings are present throughout the Deer Lodge Valley. These deposits were derived from exposed and easily eroded mine and smelter waste and tailings. They are enriched in arsenic, cadmium, copper, iron, manganese, lead, and zinc (Smith *et al.* 1998 in NPS GRKO 2007). All of these contaminated deposits lie within the extensive 100-year floodplain of the upper Clark Fork River.

f. Hagerman Fossil Beds Geology

The topography of south-central Idaho was shaped by two events: volcanic activity in the north, which began 15 million years ago and resulted in the rock formations at City of Rocks, Craters of the Moon and other areas on the Snake River Plain; and the Great Bonneville Flood, which occurred about 15,000 years ago, and which left irregular surfaces of scored basalt, branching river channels, dry falls and rock basins containing melon gravel (NPS HAFO 1995:72).

The Hagerman Valley is in the central Snake River Plain region of the eastern portion of the Columbia Plateau physiographic province. The Snake River flows west, then north through this valley and forms the eastern boundary of the monument. On the monument side of the Snake River, the valley wall rises steeply and abruptly, about 550 feet above the Snake River. Much of this steep terrains forms badlands-type topography characterized by bluffs, landslide scarps and hummocky deposits. The bluffs are composed primarily of poorly consolidated lake, floodplain, and stream deposits, volcanic ash and thin basalt flows that extend farther to the west (NPS HAFO 1996:40).

The Snake River Plain is a major late Cenozoic tectonic/volcanic feature at the north end of the Basin and Range Physiographic Province (Bonnichsen and Breckenridge 1982 in NPS HAFO 2003:7). The plain extends in a crescent shape across southern Idaho for roughly 300 miles and it is divided into two main regions identified as the western and eastern Snake River Plain. The town of Hagerman is located on the eastern plain while the monument lies in the western plain. The western Snake River Plain is about 40 miles wide, bounded by normal faults, and has a northwest-southeast trend. Displacement started about 17 million years ago by rifting and down warping of the plain. The subsequent stretching of the crust produced a basin that began filling with sedimentary and volcanic rocks of considerable thickness during the Miocene, Pliocene and Pleistocene (NPS HAFO 2003:7).

Strata at the monument are typically characterized by a series of sediments named the Idaho and Snake River Groups. Deposition of the Idaho Group began eleven million years ago on the silicic Idavada Volcanics. Cope (1883 in NPS HAFO 2003:7) identified and named these sediments "The Idaho Group" and the body of water where these sediments collected "Lake Idaho". The Idaho Group is composed of seven formations identified by Malde and Powers (1962 in NPS HAFO 2003:7), which include the Glenns Ferry and Tuana Formations. These Cenozoic sediments crop-out on the steep bluffs west of the Snake River and are composed of clastic deposits inter-bedded by occasional basalt flows, silicic volcanic ash, and basaltic pyroclastic deposits. Most of the sediments are poorly consolidated and range in texture from clays to gravel (NPS HAFO 2003:7).

The age of the Glenns Ferry Formation is broadly constrained from Pliocene to early Pleistocene, or five to 1.5 million years ago. (Malde 1991 in NPS HAFO 2003:8). Deltaic, fluvial and flood plain environments are the primary constituents of the Glenns Ferry Formation exposed on the bluffs of the monument. Malde 1972 in NPS HAFO 2003:8) suggests the depositional setting as a highly sinuous meandering stream, its floodplain and delta near the east end of Lake Idaho. The climate was predominately humid but also semi-arid at times. These deposits are commonly characterized by monotonous fine-grained, graded, calcareous, pale-olive silt beds from one to three feet thick and capped with a dark, carbonaceous clay from one to several inches thick (Malde 1965 in NPS HAFO 2003:8).

The Tuana Gravel Formation rests unconformably on the Glenns Ferry Formation. Saddler (1997 in NPS HAFO 2003:8) describes the composition of the Tuana gravels as coarser grained sediments in the silt, sand and gravel fractions. The base of the Tuana Formation exhibits cut and fill stream channels in the underlying silts and clays of the Glenns Ferry Formation. These stream channels are commonly filled with fine sand. A caliche layer has formed several feet below the surface on the bluff tops, although no major deposits exist on the hillsides. The caliche covers most of the plateau and reflects a climatic change from the Tuana environment and is considered to have formed during arid interglacial periods of the Pleistocene (Bjork 1968 in NPS HAFO 2003:8). Outcrop observations indicate the caliche is a very dense layer averaging several feet thick, which thins to less than one foot in thickness in some locations. The caliche is resistant to weathering and forms a cap rock near the top of the bluff in most of the monument and surrounding area (NPS HAFO 2003:8).

g. Little Bighorn Geology

Elevations at Little Bighorn range from 3,200 to 3,400 feet. The low sloping terrain is characteristic of the sedimentary plains of southeastern Montana Soils. The west side of the southern portion of the project area is characterized by a steep shale outcropping. The area adjacent to Medicine Tail Coulee, which cuts through the middle of the project area in an east-west direction, is identified as frequently flooded (USDA 2005 in NPS LIBI 2005a:15).

Little Bighorn geology is primarily Cretaceous, Bearpaw Formation and Judith River Formation. The Custer unit river boundary is Quaternary, Alluvium and Alluvial terrace deposit (NPS LIBI 2006). The Judith River Formation is fine-grained sandstone interbedded with shales and forms an important aquifer in the area. The alluvium, which typically is less than nine meters thick, forms the principal aquifer in the Little Bighorn River Basin (Tuck 2003 in Mast 2007:53).

h. Minidoka Geology

The site is located in south-central Idaho on the Snake River Plain, which is bounded by the Camas Prairie to the west, the Snake River to the south and east, and Craters of the Moon National Monument and Preserve, and the Lost River, Lemhi and Bitterroot Ranges to the north. This region is part of the Columbia Plateau physiographic province, also known as the Columbia Intermontane Province (USFS 1994). Minidoka is located in an area dominated geologically by basaltic lava flows, called the Snake River Basalts. This area is characterized by nearly horizontal sheets of basalt laid down in the Snake River drainage to form a plain. Lava flows range from less than 100 feet thick to several thousand feet thick. Block-faulted mountains are also found in this area. The basalts are primarily from two periods: the older flows are of the Miocene and Pliocene epoch (2 to 25 million years old); the younger lavas are Pliocene (less than 10 million years old) through recent times. The Snake River Basalts are about 60 miles wide and essentially flat; however, the eastern portions are much higher in elevation. The surface is a youthful lava plateau with a thin wind-blown and stream deposited soil layer covering it. In the vicinity of Minidoka, the most prominent surface features of this volcanism are squeezed-up lava ridges (USFS 1994 in NPS MIIN 2006).

i. Nez Perce: Bear Paw Geology

Bear Paw Battlefield lies on a glaciated plain formed during several periods of late Wisconsin glaciation. The landscape of gently rolling hills is bisected from the southwest to the north by Snake Creek, a tributary of the Milk River.

The following summary is taken from Kenworthy *et al.* 2005:

> Schmidt *et al.* (1964) mapped three geologic units within Bear Paw Battlefield, the Late Cretaceous Judith River Formation, Quaternary (Pleistocene) glacial ground moraine, and Quaternary (Recent/Holocene) alluvium.
>
> *Judith River Formation (Late Cretaceous)*
> The Late Cretaceous-aged Judith River Formation, part of the Montana Group, is mapped by Schmidt *et al.* (1964) in isolated exposures in the northern and southern reaches of the site. Bergantino and Porter's (2002) smaller scale 1:100,000 map shows the Judith River Formation throughout the vast majority of the site without the glacial deposits of Schmidt *et al.* (1964). In the Bear Paw Battlefield area, the formation is characterized by a sequence of sandstone, siltstone, and claystone, generally light gray in color (Schmidt *et al.* 1964). These sediments are associated with the terrestrial "coastal plain" deposits, and some marine sandstones, of the Cretaceous Interior Seaway (e.g. Gill and Cobban 1973, Sahni 1972).

j. Nez Perce: Big Hole Geology

The following description of Big Hole geology is taken from Kenworthy *et al.* 2005:

Ruppel *et al.* (1993) mapped two geologic units within the boundaries of Big Hole, the Tertiary Bozeman Group and Quaternary alluvium. Fossils are known from the Bozeman Group outside the boundary of the park.

Bozeman Group (Eocene, Oligocene, Miocene, Pliocene)
The Bozeman Group is mapped within Big Hole on either side of the alluvial deposits of the North Fork Big Hole River. The Bozeman Group is a heterogeneous assemblage of rocks and rock types that have undergone various nomenclatural changes as geologic interpretations have changed over time. Hanneman and Wideman (1991) present a more in-depth summary of these interpretations for valleys east of Big Hole, and include a geologic bibliography of the area. In brief, the Bozeman Group is a collection of strata, found in many basins now contained within present-day valleys of southwestern Montana (Big Hole is within the Big Hole Basin). Sediment deposition occurred by wind, lakes, streams, and rivers (e.g. Kuenzi and Fields 1971). These strata are generally characterized by light gray to yellowish brown sandstone and siltstone. Interbeds of limestone and pebble- and cobble-sized conglomerate are also known from the Bozeman Group (Ruppel *et al.* 1993).

Bozeman Group strata are often thinly veiled by Quaternary sediments. Some authors have attempted to divide the Bozeman Group into formations such as the Renova and Sixmile Creek formations (Kuenzi and Fields 1971). However Hanneman and Wideman (1991) and Ruppel *et al.* (1993) note that it is nearly impossible to distinguish the formations in the field.

3. Soils

Soil development is a function of the geology, landforms, relief, climate and natural vegetation, and each type is associated with a particular element of the landscape.

a. City of Rocks Soils
Surficial deposits including alluvial silt, sand, and gravel can be found in many areas throughout the reserve. These deposits are modern sediments associated with stream deposits and erosion (Kenworthy *et al.* 2005). Basin soils (slopes less than 20 percent) are moderately to very deep (more than 60 inches to bedrock) and composed of sandy or gravelly loam (a mixture of sand, silt and clay). Mountainside soils (slopes greater than 20 percent) are shallow (less than 20 inches to bedrock) and are composed of very gravelly or cobbly loam, or coarse sandy loam with large rock fragments exposed at the surface. The majority of the reserve soils are highly erodible (NPS CIRO 1994:110).

Wind and water erosion are moderate to severe. Soil erosion on steep slopes and intermittent stream channels has formed deep gullies, where vegetation has been disturbed / removed. Elsewhere, in creek bottoms, overlying vegetation protects soils from erosion.

b. Craters of the Moon Soils
The soils of the monument area are variable, reflecting the differences and interactions among parent material, topography, vegetation, climate, and time. The most important differences involve the presence or absence of lava flows and the degree of soil development on volcanic substrates. The lava flows, which occupy two-thirds of the monument, are made up of basalt lava rock. The soils on the younger basalt flows and cinder beds are limited to the initial decomposition of rock and cinders and deposition of windblown loess within crevices, cracks, and fissures (NPS CRMO 2005:110-11).

Sagebrush steppe, mountain areas, and kipukas within the monument have deeper, well-formed soils. The high desert environment results in lighter colored soils with low organic matter content. Most of the soils in the monument area are silt loam to sandy loam in texture and vary in depth. They are moderately drained to well drained, except where clay horizons are present. Soils that are disturbed, not properly vegetated, or located on steep slopes are highly susceptible to water and wind erosion (NPS CRMO 2005:111).

Soil Origins: The soils in the monument and surrounding area developed from rocks deposited during a sequence of geologic events that began almost 600 million years ago. During the latter part of the Tertiary Period, from about 16 million years ago, until recently in the Yellowstone area, explosive volcanic activity across the Snake River Plain deposited layers of pyroclastic tuffs and silica rich lavas. More recent basalt lava flows and windblown loess have subsequently covered these rhyolite rocks. The windblown dust (loess) from sources further west, weathering of rock and basic soil development processes have resulted in varying depths of soils on recent and older basalt flows in the monument (NPS CRMO 2005:11).

Soil Types: Soil types in the project area fall into the following two types (NPS CRMO 2005:111-12): shallow basalt soils and loess soils. *Shallow Basalt Soils* – This is a complex of soils developed on the recent basalt flows. Due to the uneven, broken surface of the basalt, soil depths range from a few inches on exposed ridges to six or eight feet on the lee sides of the ridges and in low-lying areas. The type of vegetation varies depending on soil depth and may include various types of shrubs including fern-bush, syringa, and mountain big sagebrush, with some low and Wyoming big sagebrush. *Loess Soils* – The loess soils are from glacial Snake River silts and lacustrine materials that have been windblown out of the Snake River drainage. Typical shrub vegetation includes mountain big sagebrush, Wyoming big sagebrush, basin big sagebrush, or some three-tip sagebrush.

c. Fossil Butte Soils

The NRCS (formerly SCS) has completed an "Order 3" survey of Fossil Butte (Glenn 1974, cited in Kyte 2001). An Order 3 soil survey identifies soil series (NPS FOBU 2005:11).

The report notes that all of these series are used for rangeland, recreation, and wildlife habitat. The erosion hazard for each soil complex that was mapped is discussed in the soil report. Most soils are considered to have a moderate to severe erosion hazard.

There is concern about erosion, particularly in Chicken Creek. Monitoring of Chicken Creek began in 1986 and in 1994 the park began planting willows along the drainage. Several structures to retard the rate of erosion were constructed at various points along Chicken Creek. Stock pond construction also contributed to the erosion of Chicken Creek. The stock ponds were constructed, and their dams breached prior to establishment of the monument. The dams have all been removed (NPS FOBU 2005:11).

Slumping has occurred in many locations scattered throughout the monument. Slumping occurs when clay soils become saturated or the forces of gravity cause weak strata to fail. The Resource Management Plan describes the slumping as a natural phenomenon and not of management concern. Cliff areas containing fossils are subject to wind and water erosion and freeze/thaw mechanisms; these also are natural processes (NPS FOBU 2005:11).

Soil Types: The following are the major soil series in Fossil Butte (NPS FOBU 2005:72-73):

Cundick Series: Soils are generally well-drained with slow permeability. The surface layer is reddish brown clay ranging from six to 20 inches deep over Wasatch shale. Elevation is 7,000 to 8,000 feet. Typical native vegetation on these soils includes low sagebrush, rabbitbrush, and native grasses.

Fossilon Series: Soils are generally well-drained with moderately slow permeability. The surface layer is a pale brown clay loam ranging from six to 20 inches deep over a marlstone member of the Green River formation. Elevation is 7,200 to 8,000 feet. Typical native vegetation on these soils includes low sagebrush and native grasses.

Gunsone Series: Soils are generally well-drained with slow permeability. The surface layer is a light reddish brown clay ranging from nine to 60 inches deep. Elevation is 6,600 to 7,500 feet. Typical native vegetation on these soils includes big sagebrush, winterfat, and native grasses.

Moyerson Series: Soils are generally well-drained with slow permeability. The surface layer is a pale brown clay ranging from six to 20 inches deep over Wasatch shale. Elevation is 6,600 to 7,400 feet. Typical native vegetation on these soils includes winterfat and native grasses.

Prow Series: Soils are generally well-drained with moderate permeability. The surface layer is a light brownish gray clay loam ranging from six to 20 inches deep over soft marlstone of the Green River formation. Elevation is 7,200 to 8,000 feet. Typical native vegetation on these soils includes big sagebrush, serviceberry, bitterbrush, rabbitbrush, and native grasses.

Redmanson Series: Soils are generally well-drained with moderate permeability. The surface layer is a grayish brown loam ranging from 19 to 60 inches deep. Parent materials from the Wasatch and Green River formations are intermingles. Elevation is 7,000 to 8,000 feet. Typical native vegetation on these soils includes big sagebrush, snowberry, serviceberry, aspen, bitterbrush, and native grasses.

Swift Creek Series: Soils are generally well-drained with moderate permeability. The surface layer is a pale brown loam ranging from 40 to 60 inches deep over marlstone and limestone members of the Green River formation. Elevation is 7,000 to 8,000 feet. Typical native vegetation on these soils includes big sagebrush, serviceberry, rabbitbrush, snowberry, and native grasses.

Tisworth, Fine Variant, Series: Soils are generally well-drained with slow permeability. The surface layer is a light brown clay or clay loam ranging from 20 to 60 inches or more deep. Elevation is 6,600 to 7,500 feet. Typical native vegetation on these soils includes greasewood, rabbitbrush, snakeweed, and native grasses.

d. Golden Spike Soils

The following information is taken from the USDA-NRCS for Golden Spike:

Abela series- consists of very deep, well drained soils that formed in alluvium or lacustrine deposits derived mainly from limestone, sandstone, and quartzite. Abela soils are on fan remnants and lake terraces. Slopes are two to 25 percent. The mean annual precipitation is about 13 inches and the mean annual temperature is about 47 degrees F. This gravelly loam is grayish brown in color. *Uses*: The native vegetation is dominantly Wyoming big sagebrush, yellowbrush, bluebunch wheatgrass, cheatgrass, and annual weeds.

Eccles series - consists of very deep, well drained soils. These soils formed in lacustrine deposits from limestone and sandstone on lake terraces. Slopes range from 0 to 10 percent. Average annual precipitation is about 13 inches and the mean annual temperature is about 48 degrees F. This fine sandy loam is pale brown in color. *Uses*: About 80 percent is used for non-irrigated cropland with the remainder used as rangeland. Non-irrigated crops are small grain and alfalfa. Rangeland vegetation is bluebunch wheatgrass and big sagebrush with some Indian ricegrass, threeawn, and cheatgrass.

Hansel series - consists of very deep, well drained soils that formed in lacustrine deposits derived from a mixed variety of rocks. Hansel soils are on lake terraces and lake plains. Slopes are 0 to 10 percent. The average annual precipitation is about 13 inches and the mean annual air temperature is about 48 degrees F. This silt loam is light brownish gray in color. *Uses*: Used mainly for non-irrigated cropland, growing small grains on a crop-fallow rotation. A small area is irrigated in the Curlew Valley, growing alfalfa and small grains.

Hupp series - consists of very deep, well drained, moderately rapidly permeable soils that formed in alluvium from limestone and quartzite. Hupp soils are on alluvial fans and fan remnants. Slopes are 1 to 10 percent. The average precipitation is about 14 inches and mean annual temperature is about 47 degrees F. This gravelly silt loam is grayish brown in color. *Uses*: These soils are used primarily for rangeland, but some areas are used for non-irrigated cropland to produce small grains, alfalfa and crested wheatgrass. The potential vegetation is mainly big sagebrush, bluebunch wheatgrass and Sandberg bluegrass.

Kearns series - consists of very deep, well drained soils that formed in alluvium and lacustrine deposits derived from sedimentary rocks. Kearns soils are on alluvial fans and lake terraces. Slopes are 0 to 20 percent. The mean annual precipitation is about 16 inches and the mean annual temperature is about 50 degrees F. This silt loam is brown in color. *Uses*: Kearns soils are used for irrigated and non-irrigated cropland. Crops are alfalfa, small grain, corn for silage, sugar beets, tomatoes, and dryland wheat. In Utah this series is correlated with Upland Loam (Basin Big Sagebrush) ecological sites.

Kidman series - consists of very deep, well drained or moderately well drained soils that formed in alluvium or lacustrine deposits derived from quartzite, sandstone, granite, limestone, and gneiss. Kidman soils are on alluvial fans, fan remnants, stream terraces, and lake terraces. Slopes are 0 to 40 percent. The mean annual precipitation is about 15 inches and the mean annual temperature is about 48 degrees F. This fine sandy loam is brown in color. *Uses*: Kidman soils are used mainly for irrigated cropland. The major crops are alfalfa, sugar beets, small grains, tomatoes, asparagus, corn, and irrigated pasture. Potential vegetation in rangeland is mountain big sagebrush, Wyoming big sagebrush, bluebunch wheatgrass, and western wheatgrass.

Palisade series - consists of very deep, well drained soils that formed in lacustrine deposits derived from limestone and sandstone. Palisade soils are on lake terraces. Slopes are 1 to 10 percent. The mean annual precipitation is about 10 inches and the mean annual temperature is about 48 degrees F. This silt loam is pale brown in color. *Uses*: Palisade soils are used for irrigated cropland and rangeland. Common crops are alfalfa, small grains, and corn for silage. The present vegetation on rangeland is mainly Wyoming big sagebrush, Indian ricegrass, and rabbitbrush.

Promo series - consists of shallow, well drained or somewhat excessively drained soils that formed in colluvium and residuum derived dominantly from limestone. Promo soils are on hills and mountains. Slopes are five to 60 percent. The mean annual precipitation is about 12 inches and the mean annual temperature is about 46 degrees F. This silt loam is pale brown in color. *Uses*: Promo soils are used for rangeland. The native vegetation is black sagebrush, bluebunch wheatgrass, basin wildrye, antelope bitterbrush, Utah juniper, and annual weeds and grasses.

Pomat series - consists of very deep, well drained soils that formed in lacustrine deposits derived from mixed sources and alluvium derived from limestone and sandstone. Pomat soils are on lake plains, intermediate-level and high-level lake terraces, and on escarpments of terraces. Slopes are 1 to 40 percent. The mean annual precipitation is about 13 inches and the mean annual temperature is about 47 degrees F. This silt loam is light brownish gray in color. *Uses*: About 75 percent of Pomat soils are used for dry cropland and the other 25 percent is used as rangeland. The native vegetation is dominantly Wyoming big sagebrush, mountain big sagebrush, and bluebunch wheatgrass.

Red Rock series - consists of very deep, well drained soils formed in alluvium on alluvial fans and stream terraces. Red Rock soils have slopes of 0 to six percent. The average annual precipitation is about 14 inches and the mean annual temperature is about 50 degrees F. This silt loam is grayish brown in color. *Uses*: Dry cropland. Native vegetation is big sagebrush, Great Basin wildrye, bluebunch wheatgrass, and cheat grass.

Sandall series - consists of moderately deep, well drained soils that formed in colluvium over residuum derived mainly from limestone. Sandall soils are on mountains, hills, and ridges. Slopes are three to 60 percent. The mean annual precipitation is about 12 inches and the mean annual temperature is about 48 degrees F. This outcrop complex is brown in color. *Uses*: Sandall soils are used for rangeland and wildlife habitat. The potential natural vegetation is mainly Wyoming big sagebrush, bluebunch wheatgrass, Sandberg's bluegrass, antelope bitterbrush, and Utah juniper.

Sanpete series - consists of very deep, well to somewhat excessively drained soils that formed in alluvium derived dominantly from limestone, sandstone, shale, and igneous rock. Sanpete soils are on alluvial fans, ballenas, inset fans, fan remnants and alluvial plains and have slopes of 1 to 60 percent. This gravelly slit loam is pale brown in color. *Uses*: These soils are used mainly for rangeland and for irrigated crops of alfalfa, small grains and pasture. The principal vegetation is Indian ricegrass, needle and thread grass, winterfat, bud sage, black sagebrush, and shadscale. These soils are correlated to Semidesert ecological sites in Utah.

e. Grant-Kohrs Soils

Soil Types: Soils adjacent to the Clark Fork River are mostly deep loams of the Anaconda series. These soils are favorable for irrigation and are subject to seasonal flooding. Lower bench soils east of the river are of the Beaverall series. They are generally deep and well drained with a gravelly loam surface and a clay loam to sandy loam substratum. Most of the bottomland soils and lower elevation lands west of the river are of the Teton View series, and are usually deep and poorly drained. Upland soils are shallow, with capabilities limited to grazing (NPS GRKO 1993).

At Grant-Kohrs, 31B Varney Clay Loam (0-4 percent slopes) and 24B Con Loam (0-4 percent slopes) are considered prime farmland if they are irrigated. These areas are irrigated.

f. Hagerman Fossil Beds Soils

Monument soils are shallow to very shallow, with low water holding capacity. Bluff soils are loosely consolidated and highly erodible. Soils on the Bruneau Plateau are deep to moderately deep and well-drained. Subsoil permeability is moderate, with moderate to high available porosity (NPS HAFO 1995:73).

Soil Types: The monument contains 10 soil series described by the NRCS (NRCS 1996 in NPS 2003:8) (Antelope Springs Loam, Badlands-Kudlac Sandy Loam, Bahem Silt Loam, Dolman Silt Loam, Kudlac Silty Clay, Purdam Silt Loam, Quincy Silt Loam, Quincy Loamy Sand, Rakane-Blacknest Loam, Scoon Fine Sandy Loam, Sluka Silt Loam) (NPS HAFO 2003:8-9).

The permeability of these soils has been divided into seven textural classes. The Purdam and Rakane-Blacknest series is moderately slow with 0.2 to 0.6 inches per hour. The Sluka, Bahem and Dolman series are moderate with 0.6 to 2.0 inches per hour (NPS HAFO 2003:8-9).

All series are well drained and described by the SCS as having intermediate water holding capacity, which retain optimum amounts of moisture, but are not wet close enough to the surface or long enough during the growing season to adversely affect crop yields. All series, except the Bahem, have a hardpan which starts about two feet down and continues to four foot depth. The Bahem had no hardpan down to six feet which is the maximum depth of survey data (NRCS 1996 in NPS HAFO 2003:9). A common name for the 'hardpan' soil classification is caliche (NPS HAFO 2003:9).

g. Little Bighorn Soils

Soils range from deep to very shallow, and from clay to loamy fine sands. Features, such as slope are more decisive in determining land classification and range sites than are the soil characteristics. The lower slopes and shales have deep soils, which are prone to both wind and water erosion. The effect is a soil that is easily eroded by both natural and human factors. NPS GRD and NRCS soils maps are available.

Natural erosion processes are occurring along the Little Bighorn River on the monument boundary. There is concern that potential loss of artifacts during major flooding events may require some type of stabilization to preserve potential collection sites (NPS LIBI 2007:21).

h. Minidoka Soils

Soil Types: Soils within Jerome County have been mapped and classified by the NRCS (1998 in NPS MIIN 2006). As shown in this survey, the vast majority of Minidoka is composed of the Barrymore–Starbuck soils complex on slopes of 1 to 4 percent. These soils, composed of silt loam, are typically shallow to moderate in depth: fractured bedrock may be encountered at about 18 to 25 inches beneath the surface. Within the county, these soils are typically used for rangeland or irrigated cropland, with the primary management considerations being the lack of precipitation and the shallow depth to bedrock. The risk of water erosion on these soils is slight. Small portions of the national monument, especially areas near the periphery of the site, are composed of other soils. The most prevalent of these is Power silt loam, found along the northern boundary of the national monument. This very deep soil with good water holding capacity is well suited to irrigated agriculture, the principal land use on the privately owned properties adjoining the national monument. Minor inclusions of other soils and basalt rock outcrops may also be present on and immediately surrounding the national monument.

i. Nez Perce: Bear Paw Soils

Soils within this portion of Blaine County have been mapped and classified by the NRCS (Hilts 1986 in NPS NEPE 2002). The following soil descriptions are summarized from NPS NEPE 2002:

Soil Origins: Glacial till that consist primarily of loams and clay loams. These soils are deep and subject to severe erosion when vegetative cover is removed.

Soil Types: Twelve soil types are present on this site (Hilts 1986). The first five soil types are various clay loams with slopes ranging from 0 to 8 percent.

> *Bear Paw clay loam* has slow permeability and slow surface runoff. The hazard of wind erosion is moderate, and water erosion hazard is slight. Small enclosed basins with this soil are subject to ponding generally have a high sodium content and limit the plant species that can grow here.
>
> *Bear Paw-Elloam clay loam on slopes of 0 to 4 percent & Bear Paw-Elloam clay loam on slopes of 4 to 8 percent.* Both of these soils are dense clays that are subject to crusting and becoming dry and hard, restricting root and water penetration. These soils have a moderate hazard of wind and water erosion due to the density of the clay. The potential natural grass community is Idaho fescue, green needlegrass, bluebunch wheatgrass, giant wildrye, prairie Junegrass, and sedges.
>
> *Bear Paw-Vida with slope of 0 to 4 percent (16) and Bear Paw-Vida with a slope of 4 to 8 percent.* The *Vida* clay loams are deep and somewhat well-drained soils found on upper slopes. Their permeability can be slow limiting soil drainage in some areas and increasing the available water holding capacity.
>
> *Farnuf loam* with a slope of 2 to 4 percent is a deep and well drained soil on alluvial fans and stream terraces. This soil is moderately permeable making the available water holding capacity high. A slight hazard of wind erosion exists on this soil type without vegetation.
>
> *Korent-Nesda complex* is a deep and well drained soil that is nearly level on stream terraces and flood plains. Permeability is moderate to 11 inches and rapid below this depth in the soil. Gravelly sand at a depth of 20 inches can cause drought like conditions. The runoff is slow, and spring flooding is a hazard.

Straw-Korent loam is nearly level on the flood plains and stream terraces with gravelly *Korent-Nesda* at the stream edges. This soil is moderately permeable with slow run off making the available water capacity high. The *Straw-Korent* is a deep, well drained loam to silt loam with a slight hazard of water erosion and a moderate hazard of wind erosion. This soil is also subject to rare flooding.

Typic Ustifluvents is a deep, moderately to poorly drained loam to clay loam in the bottom lands, narrow valleys, and drainage ways. These soils can be nearly level to gently sloping or even multilevel terraces with short, steep slopes. In the event of high seasonal runoff, flooding could be a hazard. This soil is dissected by stream channels and drainage ways and has a slow to moderate runoff. The hazard of wind and water erosion is moderate.

Vida-Zahill clay loam is located on strongly rolling hills with slopes ranging from eight to 15 percent. The *Vida-Zahill* is a deep, silty clay loam that is well drained on the lower parts of the slopes. Slow permeability and moderate to rapid runoff make water erosion a severe hazard. Wind erosion is a moderate hazard.

Zahill clay loam this soil is similar to *Vida-Zahill* except that the former soil type is located on the ridges and knolls. Wind and water erosion are the main limitations, and calcareous areas can be found in this soil. The upland slopes composed of *Zahill clay loam* are steep with 25 to 45 percent grade changes. This soil is well drained, has a slow permeability and rapid runoff. The hazard of wind erosion is moderate, but water erosion can be a severe hazard due to the steep slopes.

Zahill-Vida clay loam occurs on slopes of 15 to 35 percent. The steep, hilly slopes make runoff rapid and water erosion a severe hazard, but wind erosion is moderate. The *Zahill-Vida* soil is deep and well drained on the slopes below knolls and ridges.

j. Nez Perce: Big Hole Soils

Soil Origins: The underlying geology of Big Hole (and the parent material for soils) is primarily unconsolidated Quaternary alluvium including silt, sand, and gravel (USGS 1955 in NPS BIHO 2005). The northwest and southeast corners of Big Hole consist of undifferentiated Tertiary sedimentary rocks including silt, sand, and gravel (USGS 1955 in NPS BIHO 2005).

Soil Types: The following summary is taken from NPS BIHO 2005:

Preliminary soil mapping results for Big Hole are currently being processed by the NRCS (Berg 2005). There are no digital data available at this time; however, preliminary results indicate there are six main soil units within the Big Hole. From southeast to northwest these are the Mussigbrod-Brod Complex; Hairpin-Libeg, Stony-Monad, Stony Complex; Wisdom-Shewag-Mooseflat Complex; Mooseflat Loam; Monad-Libeg Complex; and MacIver, Phillipsburg, Tiban Family Complex (Berg 2005, Berger 2005).

Canal 1 is located in the Mussigbrod-Brod Complex. This complex is recorded as having slopes of 0–2 percent, no floodplains, and no hydric soils. Canal 2 is in the Hairpin-Libeg, Stony-Monad, Stony Complex. This complex has slopes of 4–15 percent and may contain hydric soils and floodplains within minor components (Berger 2005). Flood frequency is unknown at this time because the floodplains noted in the preliminary report have not yet been assigned criteria by the NRCS (Berger 2005). The Wisdom-Shewag-Mooseflat Complex has 0–4 percent slopes and may contain hydric soils and floodplains within its components. Mooseflat Loam flanks the North Fork and has floodplains and hydric soils. The Monad-Libeg Complex has slopes of eight–35 percent, no floodplains, and no hydric soils. The MacIver, Phillipsburg, Tiban Family Complex is forested with slopes 0–20 percent.

Soil in Big Hole was also analyzed in the summer of 2004 as part of a wastewater treatment project. As reported by Otak in the preliminary engineering report (2004), two test pits were excavated to a depth of 88 inches in the summer of 2004 in areas west of the visitor center and housing complex. A brown loam topsoil layer (up to 20 inches in depth) was present in both pits. The underlying stratum was observed to be well graded, fractured in structure, light brown and tan in color, cobbly, and very gravelly.

Root penetration was observed to depths of up to 48 inches and soils were fairly well-drained. Laboratory analysis of the soil showed a gravel fraction of 33 percent (large cobbles were excluded from sample) and the textural analysis of the portion smaller than 2 millimeters in diameter indicated loamy sand. Using USDA guidelines, the soil was classified as very gravelly, cobbly, and loamy coarse sand.

4. Paleontological Resources

Scientists would expect the number of fossil species to far outnumber the species alive today. The world's fossil record, however, contains only about 250,000 species, whereas scientists estimate that as many as 4,500,000 species may be living in the world today (Raup and Stanley 1978 in NPS 1996:35). Scientists have concluded that very few plants and animals became fossils and that natural processes such as erosion probably destroy most fossils. The access to this limited record is further restricted because few areas of sedimentary rock containing fossils are exposed to view. Despite the obstacles, there a few areas where the odds have been bested and fossils are preserved and exposed in the quantity, quality and variety that allow insights into pieces of the earth's history (NPS 1996:35).

No paleontological resources are known from City of Rocks, Grant-Kohrs Ranch or Minidoka. Based on the information below, such resources could be found at Nez Perce (both at Bear Paw and Big Hole) but none have yet been found.

a. Craters of the Moon Paleontological Resources

Craters of the Moon National Monument and Preserve contains both the oldest (approximately 340 million year old worm burrows) and among the youngest fossils (tree molds in lava up to 16,000 years old) known from the UCBN parks. In addition, the tree molds found in the basalt represent a rare occurrence of fossils associated with volcanic lava (Kenworthy *et al.* 2005). Undisturbed caves may hold a record of the monument's early natural history in the form of fossilized skeletal remains of Pleistocene mammals. Other caves on the Snake River plain have produced fossil remains of mammoth, grizzly bear, bison, musk ox and camel (NPS CRMO 2005:145).

Craters of the Moon contains fossils from tree molds and vertebrate remains found in lava tubes. There are two basic types of tree molds, true molds of trees and "lava trees." Actual tree molds are impressions in solidified lava that are formed as lava surrounds a standing tree. As the tree is surrounded, it begins to burn which releases water vapor from the tree's sap. This sap rapidly cools the enveloping lava which then solidifies and leaves behind a hollow mold or impression of the charred tree. Both vertical tree molds, where the tree remained standing as it burned, and horizontal tree molds, where the tree fell as it burned, are found in the park (Owen 2003 in Kenworthy *et al.* 2005). While tree molds are impressions or hollow molds within the lava, "lava trees" are vertical features rising one to five feet (e.g. Stearns 1928 in Kenworthy *et al.* 2005) from the surface of the lava. Lava trees are usually formed from airborne lava spatter from an eruption. This spatter partially buries the tree, leaving behind a thin conical shell of lava above the main lava flow, with the impression of a tree trunk on the interior surface (J. Apel, personal communication 2005). A number of lava trees are found in the wilderness area of Craters of the Moon, with some only 25-30 yards from an unmaintained park trail (J. Apel, personal communication, 2005).

Lava tubes are formed when the surface of a narrow lava flow solidifies and the molten material underneath flows away. This leaves a cave-like space under the solidified surface which can range in size from a few inches in diameter to over 40 feet high (Indian Tunnel) and over 10 miles long (Bear Trap Cave). Modern and ancient animals have used lava tubes as shelters, producing a collection of paleontological resources within the park and the surrounding areas of the Eastern Snake River Plain. Miller (1974, 1989 in Kenworthy *et al.* 2005) summarizes many of these paleontological resources. Lava tubes on the Snake River Plain have produced bones of extinct *Mammuthus* (mammoth) and *Camelops* (camel) along with modern specimens of *Ursus* (bear), *Canis lupus* (wolf), *Bison* (bison), *Cervus Canadensis* (elk), and pronghorn (Miller 1989 in Kenworthy *et al.* 2005). Remains of smaller animals such as snails, fish, reptiles, amphibians, and birds are primarily known from regurgitated owl pellets found in the lava tubes (Miller 1989 in Kenworthy *et al.* 2005). Within Craters of the Moon, reports include a buffalo horn in Buffalo Cave (Stearns 1928 in Kenworthy *et al.* 2005), the shoulder bone of a cow was discovered in Buffalo Cave, horns and a skull from *Ovis canadensis* (bighorn sheep), a bison skull, various fragmentary limb bones, and an *Ursus arctos* (grizzly bear) skull and femur (Santucci *et al.* 2001 in Kenworthy *et al.* 2005).

Packrat middens are also found in many of the lava tube features of Craters of the Moon and the Eastern Snake River Plain (Miller 1989 in Kenworthy *et al.* 2005). Mammoth bones were discovered at a historic dump site along Goodales Cutoff. Because the bones were charred, one initial interpretation was that they were part of a Paleo-Indian kill/butcher site. It is now thought that the bones were charred during trash fires set in the dump in the early 1920s or 1930s. The bones may have come from a gravel pit elsewhere on the Snake River Plain (Kenworthy *et al.* 2005).

b. Fossil Butte Paleontological Resources

The monument was established in 1972 specifically to preserve outstanding paleontological sites and related geological phenomena. Two geologic formations at Fossil Butte National Monument contain significant fossil remains: the Green River Formation with its buff colored buttes and the Wasatch Formation of bright red-banded badlands. The significance of the two formations is the completeness of the fossil record for this period of geologic time. The greatest concentration of fossils is found in the middle unit of the Green River Formation. The Wasatch Formation contains some of the earliest Eocene mammals in North America (NPS FOBU 2005:15).

A paleontological survey of the Wasatch Formation was conducted in 1979 (Podorsky1981in NPS 1980:17). Knowledge about fossil resources and formation of the monument has been derived from numerous studies (Oriel 1970, Tracey *et al.* 1961, and McGrew 1972 among others in NPS FOBU 1980:18).

Fossil quarrying began about 1881 and continued until establishment of the monument in 1972. Erosion, theft, and vandalism contribute to the continued loss of fossil resources. The fossil-bearing areas are characterized by steep slopes and sparse to no vegetation, with low density often characterized by cushion-type plants (NPS FOBU 2005:15).

Extraction of fossils is restricted to NPS needs (display and interpretation) and by scientific institutions to identify areas with the most potential for discovering significant fossil deposits and to identify which of these can be excavated with minimal disturbance. Fossil deposits not selected for extraction will be allowed to remain undisturbed and to weather naturally (NPS FOBU 2005:18).

The greatest concentration of fossils exposed by historic quarrying is along the south side of Fossil Butte. These exposed fossils are the tailings of early fossil quarrying. The historic quarries should remain undisturbed and protected, yet available for interpretation (NPS FOBU 2005:18).

c. Golden Spike Paleontological Resources

The desert landscape of Golden Spike contains more than a historic record of western expansion; it contains a record of prolific ancient life. Fossils at the park include algae, corals, snails, trilobites, clams, turtles, ammonites, oysters, and plants.

d. Grant-Kohrs Ranch Paleontological Resources

There are no known paleontological resources at the ranch. There has never been a survey of the site, although there is a proposal to complete a survey if funding is acquired. A sand and gravel quarry about three miles south of the site has uncovered a number of mastodon bones. There are no paleontology specimens in the museum collection. Project PMIS 133769 *Conduct Paleontological Survey of Park to Enhance Visitor Services and Project Resources* awaits funding.

e. Hagerman Fossil Beds Paleontological Resources

Hagerman Fossil Beds was specifically set aside for its fossil resources. Hagerman Fossil Beds preserves plant and animal fossils from the Pliocene epoch (3.5 million years ago) such as the oldest member of the *Equus* genus, the "Hagerman Horse." Hagerman Fossil Beds is a rich preserve of scientific information for a portion of geological time called the Blancan – in the late Pliocene epoch, 3.5 million years ago. The sites in Hagerman Fossil Beds are globally significant for their quantity, quality and species diversity. Fossils of vertebrates, invertebrates and plants have been found. This diversity, combined with a stratigraphic record that allows excellent dating and sequencing, provides outstanding opportunities for research on evolutionary changes in plants and animals and the ecological response of species and their environments to climate change (NPS HAFO1996:35).

The fossil beds at Hagerman Fossil Beds are in fluvial and floodplain deposits along the eastern margin of the Glenns Ferry Formation. More than 550 fossil sites have been documented over an area of six square miles in different sediment layers. The Hagerman Horse Quarry is the largest single deposit of an extinct species of horse ever found. More than 100 species of vertebrates, including 16 fish, four amphibians, eight reptiles, 27 birds and 50 mammals have been identified, in addition to freshwater snails, clams, plants and plant pollen (NPS HAFO 1996:35-36).

Nearby John Day Fossil Beds National Monument in Oregon preserves fossils representative of the early Pliocene. The fossils at Hagerman Fossil Beds are a continuation of the story at John Day. The Blancan was a time when the hyena-like dog *Borphagus* became extinct and when many modern species, such as the horse, deer and pocket gopher mad their first appearance. The fossil record also documents the immigration of animals from other continents, including the ancestor to the black bear, *Ursus abstrusus* (NPS HAFO 1996:37).

Monument fossils are from wetland, riparian and grassland savanna habitats. The sediments also preserve evidence of volcanic activity, both local and from the Cascade and Yellowstone regions. The extensive riparian and wetland community contained waterfowl, frogs, turtles, and aquatic mammals such as muskrat, beaver and otter. The rich grassland supported herds of zebra-like horses, camels, llamas, peccaries, and mastodons, similar to east Africa today (NPS HAFO 1996:37).

Paleontological resources must remain underground or be properly stored in a museum collection to ensure preservation. When exposed on the surface, as with archeological resources, they must be systematically collected and removed to preserve them and their scientific value from deterioration by natural forces or damage by people. Most of the monument consists of steep cliffs of highly erodible sandy soils with little vegetation. This makes the fossil resources even more vulnerable to exposure and destruction (NPS HAFO 1996:39).

Fossils are virtually everywhere in the steeper sections of the monument and many are very fragile. Exposed fossils must be properly documented, removed, prepared, identified and stored with their contextual data in a collection. Specimens carelessly moved or removed that do not have documentation of their geological context in the field lose much of their scientific value (NPS HAFO 1996:39).

f. Little Bighorn Paleontological Resources

The park has one paleontological specimen, a portion of a Plesiosaur (marine reptile), which was excavated from the national cemetery in 1977 and transferred as an undocumented loan to Dinosaur National Monument in Vernal, Utah. In 1980, this specimen was transferred to the Smithsonian

Institution in Washington, D.C. The fossil remains include a nine foot section of backbone, containing 50-60 separate vertebrae, a rib, and a portion of the pelvis (NPS LIBI 2007:22).

Nez Perce National Historical Park

Although significant fossil discoveries have been made in Nez Perce National Historical Park (Kenworthy *et al.* 2005), for example, the Tolo Lake mammoth site, wildlife from archeological excavations at Spalding, and well-preserved Miocene plant fossils found near White Bird Battlefield, there are no known paleontological resources associated with Bear Paw or Big Hole, although there are some descriptions of what may be found at the sites based on their location described below.

g. Nez Perce Bear Paw Paleontological Resources

The following description is taken from Kenworthy *et al.* 2005:

> Invertebrate, vertebrate, and plant fossils are known from the Judith River Formation in central Montana. In fact, the Judith River Formation is one of the most well-known fossiliferous formations in the western United States. The Judith River Formation provided some of the first Cretaceous, nonmarine fossils (including dinosaurs) studied by the pioneers of American paleontology, Ferdinand Vandiveer Hayden, Joseph Leidy, Edward Drinker Cope, and Othniel Charles Marsh in the middle-late 1800s. Sahni (1972) and Montenallo (1992) present brief summaries of the early paleontological work performed along the Missouri River between the mouth of Judith River and Armell's Creek.
>
> The invertebrates of the Judith River Formation include approximately 10 species of freshwater pelecypod (clam-like bivalves) mollusks and approximately 15 species of freshwater gastropods (Sahni 1972 referencing Russell 1964). Both Schmidt *et al.* (1964) and Bergantino and Porter (2002) describe oyster coquina (fossil hash) layers which are common within the upper portion of the Judith River Formation.
>
> The vast majority of paleontological material studied from the Judith River Formation in Montana is from vertebrates. Sahni (1972) summarizes the vertebrate fauna known from the formation at that time and numerous articles have been published in the last 30 years describing vertebrate material from the formation. Sahni's (1972) compendium includes freshwater skates and bowfin, gar, bonefish, and an aspidorhynchiformid fish. Amphibians include toads, frogs, and newts.
>
> Softshell turtles, the reptile *Champsosaurus*, a crocodile, an alligatoroid, and a variety of lizards round out the nondinosaurian reptiles. The dinosaurs found within the formation, like most of the vertebrates, are primarily known from teeth and incomplete skeletons. Coelurosaurs (advanced bipedal carnivores), hadrosaurs (duckbilled dinosaurs), pachycephalosaurs (bone-headed dinosaurs), ceratopsians (horned dinosaurs), and nodosaurs (armored dinosaurs) are all known from the formation. The mammalian fauna of north-central Montana, mostly represented by teeth, is summarized by Montenallo (1992) and includes a diverse assemblage of commonly found multituberculates (extinct, rodent-like mammals) and metatherians (marsupials) and less common eutherians (placental mammals) and "tribotheres" (teeth that do not fit the definition of either eutheria or metatheria).
>
> Fossils from the Judith River Formation are not yet known from within Bear Paw Battlefield, although they have been found in areas surrounding the site (R. West, personal communication 2005). The topography of the battlefield is mostly rolling hills and grassland prairie with very limited rock exposures (R. West, personal communication 2005). Generally the extensive paleontological resources of the Judith River Formation are found in highly erosive, "badlands" type topography not found in the battlefield. The Blaine County Museum, which also serves as the interim visitor center for Bear Paw Battlefield, houses a large collection of fossils discovered in the local area.
>
> *Glacial Ground Moraine (Pleistocene):* Schmidt *et al.* (1964) map Quaternary (Pleistocene/Ice Age) glacial ground moraine over most of the battlefield site. The glacial ground moraine is characterized by light gray clay-rich to sandy and pebble till. "Till" is the geological term for material "bulldozed"

and ground up by glacial movement and subsequently deposited. Erratics, literally out-of-place rock material, from the Cleveland quadrangle originated in Canada and was brought to the local area by these glaciers (Schmidt *et al.* 1964).

Alluvial Deposits (Holocene): The Quaternary (Recent) alluvium deposits mapped by Schmidt *et al.* (1964) within the park are found along the major creeks and drainages within Bear Paw Battlefield site.

h. Nez Perce Bear Paw Paleontological Resources

The following description is taken from Kenworthy *et al.* 2005:

Most of the extensive paleontological resources known from the Bozeman Group have been found in basins to the east and southeast of the Big Hole Basin. Fields *et al.* (1985) provides references for paleontological resources, especially vertebrate mammals, found in the Flint Creek, Deer Lodge, Divide, Grasshopper Creek/Horse Prairie/Medicine Lodge, Salmon-Lemhi, Muddy Creek, Sage Creek, upper and lower Ruby River, Beaverhead, Jefferson, Three Forks, and Smith River basins in addition to the Toston area and the Townsend valley. These basins (or valleys) are shown on Hanneman and Wideman's (1991) index map of southwestern Montana. A number of these citations are also listed in the additional references section of this report. Kuenzi and Fields (1971) present a detailed summary of paleontological finds from the Jefferson Basin near Whitehall, MT (about 100 miles east of Big Hole).

Overall, the diverse fossil finds within the Bozeman Group reflect the diverse rock types and depositional environments. Fossils of invertebrates, vertebrates, and plants, have all been found in the Bozeman Group. The invertebrate fossils include a wide variety of gastropods (snails), ostracodes (small aquatic bivalved crustaceans), and pelecypods (clam-like bivalved mollusk) (e.g. Kuenzi and Fields 1971; Roth 1986; VanNieuwenhuise and He 1986). The vertebrates are well represented and have been extensively studied. The mammals in particular are valuable as biostratigraphic indicators and include many taxa such as rodents, rabbits, early horses, artiodactyls, and rhinoceros (e.g. Kuenzi and Fields 1971; Fields *et al.* 1985 for summaries and additional references). Other vertebrate fossils include fish and a rare amphibian (e.g. Cavender 1977; Henrici 1994). Well-preserved plant fossils have also been found in various beds of the Bozeman Group (e.g. Becker 1973, 1961, 1969). The Ruby Flora, for example, has produced a diverse assemblage of fossil plants including: *Abies* (fir), *Picea* (spruce), *Pinus* (pine), *Metasequoia* (dawn redwood), *Acer* (maple), *Betula* (birch), *Celtis* (hackberry), *Fagus* (beech), *Fraxinus* (ash), *Mahonia* (Oregon grape), *Populus* (poplar), *Ribes* (gooseberry/currant), *Rosa* (rose), *Ulmus* (elm), and *Zelkova* (keaki tree) (Tidwell 1998).

Limited paleontological resources are known from the Big Hole Basin, however. Hanneman and Nichols (1981) reported fossils from 11 localities on the eastern side of the Big Hole Basin, about 15 miles east of Big Hole, near Wisdom, MT (Hanneman 1984; D. Hanneman personal communication, 2005). Vertebrate fossils from these localities included turtle, rodent, artiodactyl, *Dromomeryx* sp. (deer-like mammal), *Merychyus* sp. (dog-sized oreodont mammal), small form of *Merychippus* sp. (early horse), large equid, and rhinoceros (Hanneman and Nichols 1981). Hanneman and Nichols also noted abundant fossil wood fragments and vertical animal burrows. This assemblage likely indicates a floodplain-channel depositional environment and an early to late Miocene age (Hanneman and Nichols 1981). The presence of such fossils near Wisdom indicates the potential for similar fossils to be found within Big Hole. However, due to the complex structure of the deposits, it is difficult to ascertain whether the fossil producing layers mentioned above are also the same as those within the park. Fossils are not yet known from the area either within or immediately surrounding Big Hole (D. Hanneman, personal communication, 2005). The Big Hole Chief Ranger also indicates that fossils have not yet been found in the park and that exposures of the Bozeman Group are limited (T. Fisher, personal communication, 2005). Bozeman Group sediments (Renova Formation) are also mapped within Grant-Kohrs Ranch National Historical Site, about 70 miles northeast of Big Hole, near Deer Lodge, Montana (Koch *et al.* 2004).

Alluvium (Holocene/Modern): The alluvial deposits mapped within Big Hole are essentially modern silt, sand, gravels and floodplain deposits associated with the channels of the North Fork of the Big Hole River. Some of the deposits in the Dillon 1 by 2 minute quadrangle may be Pleistocene (Ice Age) in age, however, there are no associated paleontological resources as described by Ruppel *et al.* (1993).

5. Water Resources

This section includes hydrology, water quality, water quantity, wetlands and floodplains, where applicable information is available. In the Northern Rocky Mountains, parks are typically fairly arid. A few include major rivers; others contain few or no surface water resources. Surface water resources include streams, springs and wetlands. Groundwater is important in those parks with few or no surface water resources. Some park water resources are used for domestic, visitor use and/or recreational purposes. The UCBN, ROMN and UCPN have begun monitoring water quality parameters in some parks.

a. City of Rocks Water Resources

Hydrology and Water Quantity: City of Rocks has a number of streams within its boundaries including three forks of the Circle Creek, Trail Canyon Creek, Graham Creek and Emery Creek. Circle Creek flows east toward the Raft River which flows north and eventually empties into the Snake River.

Water Quality: Surface water that flows to the Raft River from the reserve is protected for use as agricultural water supply, cold water habitat, salmonid spawning, and primary and secondary contact recreation under Idaho water quality standards. This surface water is used primarily for agricultural purposes, both by private landowners within the reserve and downstream users outside the reserve.

Wetlands: There are numerous small wetlands, mostly near riparian areas associated with these streams and springs. Wetlands have been identified by the NPS and the National Wetlands Inventory (NWI) (USFWS) from aerial photos. Few jurisdictional wetlands, however, have been studied. Because the area is generally very dry, wetlands are important resources.

Floodplains: There are no river floodplains at the reserve. Flooding associated with small creeks is minimal.

b. Craters of the Moon Water Resources

Hydrology and Water Quantity: There are few streams and other surface water resources in the monument. Entirely within the monument are the Little Cottonwood Creek and Leech Creek watersheds. Portions of the Little Wood River, Big Cottonwood Creek, and Fish Creek are also within the BLM monument. Most streams that drain the Pioneer Mountains quickly become subterranean when they meet the lava flows (NPS CRMO 2005:129).

There are also numerous perennial and ephemeral springs feeding small creeks and wetlands on the slopes of the Pioneer Mountains. Parts of Lava Lake, Huff Lake and Carey Lake Marsh are also within the monument. A number of seasonal playa lakes dot the sagebrush steppe desert. Many have been developed by BLM to increase water holding capacity and longevity. Caves also contain year-round ice deposits, which melt somewhat during the summer (NPS CRMO 2005:129).

Water Quality: Water quality in Little Cottonwood and Leech creeks has been monitored and meets Idaho State standards for temperature, dissolved oxygen and turbidity (Falter and Freitag 1996 in NPS CRMO 2005:130). Conductivity is moderate to low and the water has moderately low alkalinity and carbon dioxide and neutral to basic pH. Nitrate nitrogen concentrations were high and there were low to moderate levels of fecal coliform with high fecal streptococcus that suggests animal influences. Aquatic insects were identified as balanced except in the middle reach of Lower Cottonwood Creek, thought to be as a result of the Martin Mine metals (Falter 1996 in NPS CRMO 2005:130).

Easily accessible ice caves were found to have much higher levels of nutrients than caves located in remote areas and this is likely attributable to human waste (Falter and Freitag 1996 in NPS CRMO 2005:130).

Wetlands: The slopes of the Pioneer Mountains support limited aquatic, wetland and riparian habitat, for several species of water-dependent plants, waterfowl, marsh birds, two frog species and moose. NWI (USFWS) mapped wetlands are located in the northwest corner of the monument. Most wetlands are palustrine (non-tidal, inland wetlands, dominated by terrestrial and emergent vegetation) and are seasonally or temporarily flooded.

Playas hold water long enough to allow some specialized aquatic organisms (fairy shrimp, a fresh water crustacean) to grow and reproduce, but dry up by July or August.

Floodplains: The Little Cottonwood and Leech creek channels are steeply incised, with very narrow floodplains.

c. Fossil Butte Water Resources

Hydrology and Water Quantity: Spring and well development was excluded based on the Assessment of Alternatives that preceded the GMP. According to the GMP, a November 1978 study (Feasibility of Developing Groundwater Supplies in Fossil Butte National Monument by Peter W. Huntoon from the Wyoming Water Research Institute) supports this exclusion. This study noted that small ephemeral supplies were possible from seeps and springs, but that these would not be dependable during dry periods.

The water resources of Fossil Butte consist of seeps and springs, small streams supplied by springs, and ephemeral ponds and streams that carry snowmelt and precipitation runoff. Most of the springs and seeps originate along the base of the Green River formation. Since the recharge area for these springs and seeps is quite small, some may stop flowing during drought periods. Flows in streams dependent on snowmelt or precipitation vary within the year and among years, depending on the amount and timing of precipitation. Beaver ponds, slump ponds, and springs serve as watering areas for wildlife and breeding areas for beaver, amphibians, and a few shorebirds and waterfowl. The RMP indicates that accurate documentation of all spring locations, spring and stream yields and water chemistry does not exist. Kyte (2001) provides considerably more detail on watersheds, streams, and springs (NPS FOBU 2005:13).

Fossil Butte uses water from a spring (#2) for the park water supply. The spring is situated north of the picnic area, where the water is collected and piped to the picnic area, monument headquarters, and other facilities. The monument's enabling legislation provides that water excess to the monument's needs may be made available to users outside the monument. Although water needs of the park have not been quantified, surface water from one spring is piped to a location outside the boundary for livestock use (NPS FOBU 2005:13).

Water Quality: Surface water in Fossil Butte is ephemeral. Spring snow melt and rains create ponds behind slumps and increase flow of springs. During the spring, Chicken Creek flows outside the park. Due to the spring runoff and the clay soils, water in Chicken Creek is generally turbid, similar to other creeks in the area. By midsummer the ponds are dry and the springs reduce flow and Chicken Creek flows just over a few more than a few hundred yards past its headwater springs.

Wetlands: Depressions formed by land slumping are common. Some of these catch runoff water and are wet only intermittently; others are fed by springs and seeps and hold water throughout much of the year. Some of these support wetland-type vegetation such as cattails and sedges. Wetlands range from less than a half acre to perhaps as large as two acres. Most are located north and east of the picnic area. A few other small areas in the vicinity of seeps and springs that arise along the contact between the Green River and

Wasatch formations, collectively comprising two to three acres, may also qualify as wetlands. These areas have sub-irrigated, mottled soils and support obligate wetland species of vegetation (NPS FOBU 2005:13).

Floodplains: There are no floodplains in Fossil Butte.

d. Golden Spike Water Resources

Golden Spike lies at an elevation of between 4,500 and 5,300 feet in a rain shadow, where moisture is diminished by the proximity to the Sierra Nevada's and the Cascades. The presence of these mountains is the main reason the Great Basin is so arid. Most precipitation comes during the winter as snow, with 8-12 inches of rain and 12-14 inches of snow common. Temperatures generally range from about 20-104 degrees Fahrenheit, with the hottest times in the July and August and the coldest between December and February.

Hydrology and Water Quantity: Promontory Summit receives drainage from both the north and south slopes of the Promontory Mountains. Water flows toward the visitor center complex and separates toward the east and west. Blue Creek (located east of the park) is the nearest perennial stream and provides the only surface water at Golden Spike. Engineer Spring, north of the park on the east slope, provides water to a neighboring ranch. During the historic construction period, water was provided by Blue Creek and a spring (now part of the Thiokol Chemical Corporation holdings).

Precipitation soaks quickly through the thin layer of top soil and disappears in the large gravel deposits below. There is a thick hardpan layer about 18-20 inches below the surface near the visitor center. A well tapped into the basin aquifer (430 feet deep) provides potable water.

Water Quality: Water quality in Blue Creek is monitored by the State of Utah and meets state water quality standards. Existing impacts to water quality include formerly poor agricultural and farming practices that have resulted in increased water runoff due to soil compaction and poor range conditions. In the summit area, railroad grades are barriers to normal surface drainage. As a result of poor drainage and the hardpan (see above), once or twice a year, the area surrounding the visitor center is flooded with water several inches deep. Inadequately sized culverts and borrow pits also channelize runoff and contribute to increased erosion (NPS GOSP 1976: RMP-1).

Wetlands: There are no springs or travertine deposits within the monument. Both are found at Rozel Point, approximately 15 miles southwest of Promontory (NPS GOSP 1976: SFM-3)

Floodplains: There are no major floodplains at Golden Spike. Flash floods from occasional severe storms in intermittent drainages have occurred and have eroded historic grades, cuts, fills and trestles (NPS GOSP: SFM-6). According to the GMP, one trestle and one large culvert were lost in the mid-1970s.

e. Grant-Kohrs Ranch Water Resources

Hydrology and Water Quantity: Surrounded by mountains, the broad Deer Lodge Valley is drained by the Clark Fork of the Columbia River. This river traverses the center portion of the park, south to north. There are six small tributary creeks and nine natural springs located on the Ranch that feed into the Clark Fork River. Spring Creek runs through the northern area of the property; Johnson Creek and its Northern Fork flow through the center of the ranch, and Cottonwood Creek flows through the city of Deer Lodge before traversing along the south boundary of the Ranch complex. No Name Creek, originating from a natural spring near the Ranch complex, traverses through the Lower Yard Fields and North Meadow before joining the Clark Fork. Taylor Creek runs along the southern boundary of the Ranch property, paralleling the highway to Montana State Prison.

The Grant-Kohrs ranch supports an elaborate irrigation system that was begun in 1862. Most of the fields and a few portions of the west feedlots contain irrigation ditches that supply water to more than 400 acres. The system is comprised of primary (or "main") ditches that draw water from natural water sources, such as the Clark Fork River, Cottonwood Creek, Taylor Creek, Johnson Creek, and several unnamed springs.

There are several main ditches that flow north through the Ranch. These include the Kohrs-Manning Ditch, Westside Ditch, Kohrs Ditch, which is also known as "The Big Ditch," Hartz Ditch, and Johnson Ditch (NPS GRKO 2004).

Water Quality: Water in the Clark Fork River is a calcium-bicarbonate-sulfate type, and major constituents primarily are derived from weathering of rock fragments in the alluvial fill except sulfate, which is released from oxidation of pyrite present in mine wastes. Arsenic, cadmium, copper, lead, manganese, and zinc, which are trace elements associated with mine wastes from historical mining activities, commonly were measured at detectable levels in the river. Nutrients in the river were mainly human-derived related to wastewater discharge and agriculture. Statistically significant downward trends were detected in dissolved calcium, sulfate, and zinc in the Clark Fork River that were attributed to remediation and restoration efforts during the 1980s and early 1990s. The Clark Fork River in the vicinity of Grant-Kohrs has a beneficial-use classification of C-1 (suitable for bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply) and is listed as severely impaired for aquatic life and cold-water fishery and partially impaired for primary-contact recreational use. The sources of impairment are mine wastes, agriculture, and municipal wastewater discharge.

Groundwater is a calcium-bicarbonate type with moderately high dissolved solids (213 to 536 mg/L). Nutrient concentrations in groundwater were low, indicating minimal effects from agricultural activities in the park. Samples from four of the 21 ground-water wells exceeded the human-health standard for arsenic, although none of the wells are used as a water supply (Mast 2004).

Nutrient input from the sewage irrigation program and trace-element and sediment contamination related to mine tailings and their remediation are the primary water-quality issues for the reach of the Clark Fork River in Grant-Kohrs (Mast 2004).

Wetlands: A small wetland of five to six acres has been created by springs filling in railroad borrow pits. This wetland is just south of the city of Deer Lodge sewage lagoons on the east side of the Clark Fork River.

Floodplains: The 100-year floodplain elevation was identified as 4,500 feet above sea level. Part of the home ranch complex is in the 100-year floodplain, elevations in the home ranch range from 4,498 feet to 4,515 feet. A majority of the Clark Fork River riparian area is within the 100-year floodplain.

f. Hagerman Fossil Beds Water Resources

Hydrology and Water Quantity: The Snake River upstream of the monument drains an area of 35,875 square miles in four states. Since most precipitation falls in winter within the basin, peak flow on the river typically occurs during spring snowmelt runoff. Twenty-five percent of annual peak flows occur in response to late fall or early winter storms (NPS HAFO 2003:11). The entire length of the river adjacent to the monument is part of the Salmon Falls Reservoir created by the Lower Salmon Falls Dam.

On the opposite side of the river from the monument is the Hagerman Bench, which has little natural runoff and is crossed by irrigation ditches. The only major natural drainages into the Snake River near the monument are spring-fed Riley Creek, which enters the river upstream from the monument, Billingsley Creek, which enters the river downstream from the monument, and the Malad River, which is even further downstream (NPS HAFO 1995:70).

Irrigation ditches channelize most of the remaining surface runoff and water from the Thousand Springs area along the basalt cliffs to the east and carry it through canals to the river. The springs area is a result of outflow from a giant aquifer, considered one of the largest hydrologic systems in the world, underlying the Snake River Plain. It is likely that much of the flow of the Snake River is derived from the springs during the dry summer season (NPS HAFO 1995:71).

Drainage from the monument side of the river consists of steep washes on sedimentary bluffs. Before development for irrigation, many small, ephemeral tributaries carried water over the canyon rim into the Snake River. Development resulted in the merging of these into fewer, larger tributaries (NPS 1995:71).

Two washes dominate the bluffs along the Snake River – Fossil Gulch, which cuts through important fossil beds, and Peters Gulch, an intermittent stream in the southeast corner of the monument, which also dissects several fossil beds before entering the Snake River. Natural drainage in the Fossil Gulch area and west of the monument is altered by irrigated croplands which surround the monument. Water from the Fossil Gulch pump station is pumped through pipelines to these agricultural uplands (NPS HAFO 1996:40).

Land use change on the plateau west of the monument, from sagebrush steppe to irrigated farmland, has caused the formation of perched groundwater systems, which discharge along the bluffs within the monument (NPS HAFO 2003:12). Variations in the sediments in the Glenns Ferry Formation indicate that there are several perched aquifers. Buried stream deposits in this formation and local basalt flows function as aquifers, interspersed with the more impermeable floodplain layers. Water movement is facilitated by coarse river sands, which tend to be more permeable. Water is funneled to the sands by the more impermeable overbank deposits of silts and clays. Construction of two irrigation canals supplied with water pumped from the Snake River reach the canyon rim. The canals reach the relatively impermeable caliche layer, allowing seepage from them to recharge the shallow perched aquifer (NPS HAFO 1996:40).

Arroyo and gully erosion of unconsolidated sediments along the steep, poorly vegetated slopes of the monument has proceeded at a rapid pace (NPS HAFO 2003:12). Between 1983 and 1995, five large landslides occurred within the monument. One of these destroyed the pumping station in the Peters Gulch area. In 1995 the entire ridge between the 1983 and 1987 landslides failed. Landslides are a serious threat, not only to paleontological resources but also to human safety and property (NPS HAFO 1996:40-41). Down-cutting by streams whose flow is supplemented by irrigation water has resulted in slope instability problems in upper reaches of these small streams, and in rapid deposition of fine-grained sediment in lower reaches as well as the Lower Salmon Falls Reservoir (NPS HAFO 2003:12).

Water Quality: A two-year baseline surface water quality inventory project started in 1998 with funding from NPS-WRD. Although the project formally ended in FY2000, some aspects continued with equipment purchased from the project and ONPS base funds. The successful data collected occurred from 20 separate field locations, even though the original funding was for seven locations. Overall, baseline water quality parameters are good within the monument. Nitrates approached or very slightly exceeded drinking water standards at several locations (NPS HAFO 2003:13). Two sections of the Snake River within or adjacent to the monument, which include the Lower Salmon Falls Reservoir, are listed on the EPAs impaired water quality (303d) list for sediment and sediment/nutrients.

Wetlands: The draft 1988 NWI map was prepared from 1984 source material. The proposed research center / museum site contains three small depressions (about one acre total) that exhibit wetland characteristics. These depressions may be fed by surface-collected runoff, or by subsurface water from the Bell irrigation ditch that flows through the property. Riparian wetlands are present along the banks of the Snake River along the length of the monument and the proposed research center and museum site. The lower reaches of Fossil Gulch, Peters Gulch and Yahoo Creek, near their confluences with the Snake River may also meet wetland definitions (NPS HAFO 1995:71-72).

Floodplains: A floodplain map prepared for the proposed research center / museum site shows the 100-year flood contour at 2,800 feet elevation and the 500-year flood at 2,850 feet elevation. The spillway elevation for the Lower Salmon Falls Dam downstream is 2,797 feet. No other drainages at Hagerman Fossil Beds meet the definition for regulatory floodplains.

g. Little Bighorn Water Resources

Hydrology and Water Quantity: There are three intermittent tributaries (unnamed stream, Deep Coulee, and Medicine Tail Coulee) which cross the Tour Road right-of-way to the Little Bighorn River. There are no perennial streams flowing through the monument. A portion of the Little Bighorn River forms the southwestern boundary of the Custer unit of Little Bighorn Battlefield. An oxbow pond, formed when an entire channel was abandoned at some time in the recent past, lies near the southwest boundary of the Custer battlefield. NPS Water Resources Division (WRD) and EPA hydrology maps are available.

The following Little Bighorn River summary was taken from the *Assessment of Historical Water Quality Data for National Park units in the Rocky Mountain Network, Colorado and Montana, through 2004* (Mast 2007: 53).

> The streamflow pattern shows that discharge peaks in May and June during snowmelt. Intense rainstorms and saturated or frozen soils are additional factors contributing to increased runoff during the spring. Streamflow decreases rapidly through July and is lowest in August and September because of low precipitation rates and high evapotranspiration rates. During summer months, water also is diverted from the river for irrigation.

Annual water-level measurements were made by USGS at one well in Little Bighorn from 1977 to 1999 as part of a state-wide ground-water monitoring network. The hydrograph for this well shows that ground-water levels were highest in the early part of the record because of above average precipitation during most of the 1970s (Mast 2007:55).

Water Quality: The NPS ROMN has been monitoring the Little Bighorn River since 2007 as part of the Vital Signs Program. The purpose of the Vital Signs Program is to provide scientifically credible, long-term ecological information for natural resource protection and management through natural resource inventories and monitoring of vital signs of ecosystem health (NPS LIBI 2007:18). The monitoring site is a 500 meter long reach of the Little Bighorn River at the western boundary of Custer battlefield. Sampling includes water and sediment chemistry, stream discharge, a detailed characterization of stream and riparian habitat, and composite samples of macroinvertebrates and periphyton. Considering the ecoregion and context it is in, the Little Bighorn River is intact ecologically. As part of the National Rivers and Streams Assessment the site was selected as a reference site for state and regional scale water quality monitoring.

The following was summarized from the *Assessment of Historical Water Quality Data for National Park units in the Rocky Mountain Network, Colorado and Montana, through 2004* (Mast 2007: 55-56).

> The only surface-water stations in Little Bighorn are on the Little Bighorn River adjacent to the west boundary of the monument. There were four water-quality samples collected at one of the sites during 1999 and 2000 that were analyzed for field properties, major constituents, nutrients, trace elements, and suspended sediment.
>
> The Little Bighorn River and tributaries below Grass Creek are classified as B-2, which is surface water suitable for domestic water supply, recreation, aquatic life (salmonid fishes), and agricultural and industrial water supply. The sample collected on May 19, 2000, had constituent concentrations that exceeded trace-element standards for total cadmium, copper, iron, and lead. Concentrations of total trace elements were elevated in this sample likely because it was collected during a period of elevated sediment transport.
>
> Water-quality data are available for six samples collected at three ground-water wells in Little Bighorn that were analyzed for field properties, major constituents, nutrients, trace elements, and pesticides. None of the wells had constituent concentrations that exceeded the human-health standards, although four samples exceeded the secondary manganese standard of 50 µg/L, and three exceeded the secondary iron standard of 300"g/L. Secondary standards are based on aesthetic properties such as taste, odor, and staining. Elevated iron and manganese

concentrations can affect the taste of drinking water and cause staining and scaling of plumbing systems. All of the wells also exceeded the USEPA secondary drinking-water standard for sulfate (250 mg/L) and dissolved solids (500 mg/L).

Wetlands: Under NPS standards, *Director's Order #77-1: Wetland Protection/Wetland Protection Procedural Manual* (NPS 2008), the edges of non-perennial streams in the project area would likely be considered wetlands as well as the Little Bighorn River floodplain and oxbow pond. Salt flats, a type of wetland, are known to occur within the park. No formal comprehensive survey/inventory has been done on wetlands and the salt flats are not monitored as part of the network's Wetland Ecological Integrity protocol for long-term Vital Signs Monitoring Program (NPS LIBI 2007:23). Some salt flats can be seen in historical and modern aerial photos. The salt flats are most likely relic hydric soils, therefore would not likely be considered wetlands under NPS standards (NPS 2008).

Floodplains: There are no Flood Insurance Rate Maps (FIRM) for the Crow Indian Reservation (including land surrounding the monument). According to Big Horn County, the FIRM completed for the remaining portions of Big Horn County (lands other than Crow Indian Reservation land) were based largely in part on the 1978 flood (100 year "plus" flood). Photos taken of the Little Bighorn River during the 1978 flood event show the flood area located several hundred feet in elevation below the monument and several thousand feet horizontally to the south of the monument (BHC 2005 in NPS LIBI 2005a:18). The Tour Road crosses three intermittent tributaries (unnamed stream, Deep Coulee, and Medicine Tail Coulee) to the Little Bighorn River, but has not (in the history of the national monument) been flooded by the Little Bighorn River or its tributaries (NPS LIBI 2005a:18).

Minidoka Water Resources

Hydrology and Water Quantity: There is no naturally occurring surface water on the national monument. In addition, the presidential proclamation establishing the national monument "does not reserve water as a matter of federal law nor relinquish any water rights held by the Federal Government" (NPS MIIN 2006).

The North Side Canal, the primary surface water feature in the area, is immediately outside the national monument, forming its southern boundary. During the growing season, typically from April through October, water is flowing through the canal to provide irrigation to approximately 170,000 acres of south-central Idaho agriculture. The canal is not operated during the late fall and winter. During this time, the canal is dry other than a few shallow pools of water that may linger after the irrigation season or appear briefly following heavy precipitation (NPS MIIN 2006).

Water used by the American Falls Reservoir District No. 2 staff at the BOR visitor services area is supplied by an on-site domestic well. In addition to domestic use, water is used to irrigate the lawn and trees on a portion of the parcel. Waste water is disposed of in a septic tank.

Water Quality: Because there are no surface water resources within the park and the well has not been used since the BOR operations ceased and the land was transferred to the NPS, there is no information about water quality for the site.

Wetlands: One small seasonally flooded area near the North Side Canal appears to have some wetland characteristics, but has not been formally studied.

Floodplains: There are no floodplains at Minidoka.

h. Nez Perce: Bear Paw Water Resources

Hydrology and Water Quantity: The spring fed Snake Creek flows from the southwest to the north along the western edge of the site. Although water is evident at the springs feeding Snake Creek near the northwestern end of the creek, Snake Creek generally appears as a marsh rather than a creek except during spring runoff and following major precipitation events.

Water Quality: Water quality at Bear Paw is currently affected to an unknown degree by adjacent agricultural practices and livestock as well as by natural processes and components, such as erosion, wildlife and fire. In addition, there could be unknown effects relating to surface water runoff of petroleum products from the presence of nearby County Route 240, particularly during spring melt and large storms. The vault toilet located in the lower parking area is not known to be defective, but could contribute a negligible degree of pollutants. There is no potable water provided at the site.

Wetlands: The Snake Creek riparian wetland comprised of willows and other species of low-growing water-dependent riparian species (native species include: willow (*Salix sp.*), roses (*Rosa acicularis, R. Arkansana or R. woodsii*), currant (*Ribes sp.*), snowberry(*Symphoricarpus alba*), buttercup (*Ranunculus sp.*), horsetail (*Equisetum sp.*), stinging nettle (*Urtica dioica*), milkweed (*Asclepias speciosa*), blue-eyed grass (*Sisyrinchium montanum*), cattail (*Typha latifolia*), and cottonwood (*Populus sp.*). Nonnatives include field bindweed, Canada thistle, curly dock, and reed canarygrass.

Floodplains: Due to their locations near Snake Creek it seems possible that portions of the lower parking area, picnic area and vault toilet could be located in a probable 100-year floodplain. There has been no documentation of flooding at the site, however, since the 1877 battle. In the 33 years (1959-1992) the site was managed by the MDFWP and in the nearly 18 years (since 1992) the NPS has been involved with the site, there has been no flooding at the site. In addition, the continued presence of pits excavated into the banks of Snake Creek and in the creek bottom area (downstream of the existing developed areas) as a result of excavations by the Nez Perce or cannonball explosion impacts from the battle remain essentially unaltered, again indicating little or no flooding of the creek vicinity since 1877. Any flooding on Snake Creek would have easily eroded or significantly altered these pits. Therefore it is unlikely that flooding has occurred or would occur at the site.

i. Nez Perce: Big Hole Water Resources

Hydrology and Water Quantity: The only major river within Big Hole is the North Fork, which runs through the park from the southwest to the northeast. Trail Creek and Ruby Creek are located outside and upstream of Big Hole and come together to form the North Fork. The North Fork is designated impaired by the State of Montana due to dewatering and flow alteration. There is a spring and a small seasonal stream located in the northwest portion of Big Hole. The stream runs southeast towards the North Fork. There are no lakes or Wild and Scenic Rivers within Big Hole.

In addition, there are four irrigation canals that cross through the battlefield. Currently two of the canals are still in operation and seasonally transport water from Ruby Creek across the battlefield to downstream users. Nearby ranchers retain water rights to these irrigation canals and to the Big Hole River.

As reported in the *Montana Ground-Water Atlas* (MNRIS 1997 in NPS BIHO 2005), Big Hole lies within the Western Mountain Ranges Region. The most productive and intensively used water source in this region is aquifers within unconsolidated glacial and alluvial sediments. Other sources of groundwater within this region include fractured metamorphic and igneous rocks, fractured consolidated sedimentary rocks, and some permeable glacial deposits.

Within Big Hole, there is one public water supply well. This steel-cased well is 250 feet deep, has a static water level of approximately 76 feet, and yields 10 gallons per minute (Montana Bureau of Mines and Geology [MBMG] 2004). Water from this well is treated at the visitor center by a metered drip chlorination system consisting of a 30-gallon drip tank. There are no sole-source aquifers within Big Hole (EPA 2004b) (NPS BIHO 2005).

Water Quality: Threats to water resources in Big Hole have been listed as flow impairment, mining, agriculture, and stormwater runoff. In addition, the North Fork Big Hole River is listed as impaired on the EPA 303(d) list due to dewatering (Garrett *et al*. 2007). In 2009 the UCBN monitored five core water chemistry parameters in the North Fork Big Hole River including: dissolved oxygen, pH, specific conductance, temperature, and turbidity. Each parameter was evaluated hourly between the months of June and October using a continuous water quality monitor. In addition, aquatic macroinvertebrates were collected using the EPA's Environmental Monitoring and Assessment Program (EMAP) protocol.

Results indicate that most core parameters are within state regulatory thresholds; however, dissolved oxygen levels are slightly below the suggested threshold.

The lack of historical water chemistry data from the North Fork Big Hole River limits comparisons between data collected in 2009 and the state regulatory thresholds. Low dissolved oxygen levels may indicate that water temperatures are elevated relative to "naturally occurring" conditions. Heavy rain on recently burned upstream areas increased turbidity levels in late July and early August.

Wetlands: Detailed wetland mapping for Big Hole has not been completed under the NWI (Bon 2004, USFWS 2004b in NPS BIHO 2005). According to the NPS (2002a in NPS BIHO 2005), wetland and riparian areas exist in the valley bottomland occupied by the North Fork. In addition, approximately 3.5 acres of incidental wetlands have been created by the seasonal leakage from Canals 1 and 2. This accounts for less than five percent of the total estimated wetlands, both natural and incidental, within Big Hole. As reported by ACOE (Steinle 2005 in NPS BIHO 2005), Canals 1 and 2 and their associated wetlands are not jurisdictional waters of the U.S. (NPS BIHO 2005).

Floodplains: There are no FIRM for Beaverhead County, Montana. Much of the lower meadow area surrounding the North Fork of the Big Hole River, however, is prone to seasonal flooding from high run-off events. This includes much of the lower Nez Perce encampment area on the eastern edge of the meadow.

B. Biological Resources

1. Vegetation

a. City of Rocks Vegetation

The reserve contains low rolling grasslands, interspersed with sagebrush and dense sagebrush scrub in lower elevations, while higher elevations contain stands of pinon pine and Rocky Mountain juniper. The northern end of the reserve contains lush grasslands near springs, and occasional aspen groves. Most vegetation within the reserve, except in steep rocky areas, has been dramatically altered from intense grazing, dryland farming, fire suppression, brush control, seeding, development of roads and trails and camping.

An elevation range of 3,147 feet in a variety of exposures, together with protruding granite rock monoliths, has resulted in the identification of eight major plant communities in the reserve. The dominant plant communities and their areal extent include:

- big sagebrush / grasslands (37 percent),
- pinon / juniper woodland / forest (37 percent),
- mixed scrub (8.7 percent), 4) conifer/aspen woodlands (6.8 percent),
- riparian scrub / herbaceous wetlands (2.6 percent),
- mountain mahogany scrub (2.4 percent),
- high elevation meadows (2 percent), and
- unvegetated areas (3.8 percent) (NPS CIRO 1994).

The reserve's vegetation map, produced in 1992, has not been ground-truthed.