Effects of Constructing and Operating the Hells Canyon Complex on Wildlife Habitat

Charles Blair, CH2M HILL
Jeff Braatne, University of Washington
Robert Simons, Simons & Associates
Stewart Rood, University of Lethbridge
and
Brandy Wilson, CH2M HILL

Technical Report
Appendix E.3.2-44

Hells Canyon Complex
FERC No. 1971

April 2001
Revised July 2003 (Minor Typographical Changes)

EFFECTS OF CONSTRUCTING AND OPERATING THE HELLS CANYON COMPLEX ON WILDLIFE HABITAT

Charles Blair, CH2M HILL
Jeff Braatne, University of Washington
Robert Simons, Simons & Associates
Stewart Rood, University of Lethbridge
and
Brandy Wilson, CH2M HILL

Prepared for:

Environmental Affairs Department
Idaho Power Company
P.O. Box 70
Boise, Idaho 83707

April 2001

Table of Contents

Section **Page**

List of Tables

List of Figures

List of Photographs

List of Appendices

This page left blank intentionally.

Executive Summary

Effects of Constructing and Operating the Hells Canyon Complex on Wildlife Habitat

The Terrestrial Resources Work Group discussed three approaches for assessing the effects of constructing and operating the Hells Canyon Complex on wildlife habitat: 1) comparing upstream with downstream reaches, 2) comparing impounded with unimpounded reaches, and 3) comparing historical photographs and descriptions with current photographs and vegetation descriptions. The third approach was pursued for two reasons. First, several problems are associated with the first two approaches (which are spatial in nature), such as comparing upstream and downstream reaches and comparing the Lower Gorge of the Salmon River with the Snake River through Hells Canyon. Second, pre-impoundment photographs, as well as information about wildlife and habitat conditions prior to construction, are available for use in the third, or temporal, comparison.

The main objective of the study was to describe wildlife habitat conditions during two periods: the 1950s (before construction of the Hells Canyon Complex) and the 1990s. The specific objectives of the study were to evaluate 1) influence of anthropogenic disturbances (that is, to qualitatively assess the influence of anthropogenic disturbances on wildlife habitat in the 1950s as compared with such influences in the 1990s); 2) condition of wildlife habitat (that is, to qualitatively assess the general condition of wildlife habitat prior to construction of the Hells Canyon Complex in the 1950s as compared with the 1990s); and 3) effects of constructing the Hells Canyon Complex (that is, to summarize how constructing and operating the Hells Canyon Complex may have altered landscape features and conditions of habitat important to wildlife). Descriptions used to compare habitat conditions during the 1950s and 1990s are based on qualitative indices of habitat conditions and expert knowledge. The study area was divided into four reaches: the Weiser reach, Brownlee reach, Oxbow and Hells Canyon Reservoirs reach, and downstream reach.

Influence of Anthropogenic Disturbances—The physical and biological processes within Hells Canyon have been affected by a wide variety of factors since Euro-American settlement. Settlement patterns in the study area were closely related to topography and water availability. Flatter lands near the Snake River and tributary mouths generally had the highest concentration of people and therefore some of the highest levels of human influence on native plant and wildlife communities.

We used aerial photographs, historical information, and environmental data to describe anthropogenic factors that may have affected wildlife habitat during the 1950s and 1990s. Survey records from the 1870s to early 1900s were obtained for the Idaho side of the study area from the General Land Office (GLO) to provide information about the general types of vegetation at survey locations. We interviewed current and former employees of natural resource and land management agencies who had worked in the study area in the 1950s and early 1960s before and

during construction of the Hells Canyon Complex. Among the wide variety of factors affecting the physical and biological processes were sediment transport, settlement, mining, agriculture and irrigation, ranching and grazing, introduction of exotic plants, and logging. Each of these influences is briefly discussed below.

Sediment—The basic geomorphic and hydraulic processes, which are tied to sediment transport, are affected by disturbances in upstream reaches of the Snake River and in upstream reservoirs and drainages. Well before the 1950s, large-scale agricultural development, mining, logging, and especially livestock grazing occurred along upstream reaches of the Snake River in eastern and southern Idaho, as well as on the floodplains of the major tributaries. These activities generally removed or damaged vegetative cover, increasing the amount of sediment in tributaries to the mainstem of the Snake River. However, significant development of water resources upstream of the study area has countered the effects of increased sediment loads. In the 1950s, the unimpounded drainage area of the Snake River, contributing sediment to the study area from upstream sources, was roughly 9,000 square miles out of the total Snake River drainage area of 69,200 square miles upstream of the study area (USGS 1999). Other upstream projects reduced the sediment-contributing drainage area by about 50,000 square miles. The Hells Canyon Complex reduced the drainage area that contributed sediment upstream of the Imnaha River by about 4,100 square miles. Therefore, the Hells Canyon Complex cut off less than 10 percent of the overall sediment-contributing drainage area, while over 90 percent of the sediment-contributing drainage area was cut off by other upstream water storage projects on the Snake River and its tributaries.

Human Settlement—Humans have inhabited the area for at least 8,000 to 12,000 years (Daubenmire 1970, Chatters and Reid 1999 to 2000). Euro-American settlement of the Hells Canyon area came from three directions: northeast from Missouri, as Oregon Trail emigrants stayed along inviting rivers and valleys instead of continuing to the coast; from the west, as a "backwash" of Oregon Trail travelers returned to less settled lands; and from the south, as California gold seekers followed new strikes in Florence, Pierce, near Baker City, and later in the Boise Basin. Many early settlers ran ferries, operated way stations and hotels, or hauled freight to serve emigrants and miners. Early settlements (1860s) included Brownlee, Olds Ferry, and Pittsburg Landing.

Mining—Mining has played a central role in the development of the Hells Canyon area from Farewell Bend to the confluence of the Snake and Salmon Rivers. During the 1880s and 1890s, the Seven Devils district became an active mining center. Many mines were in operation, including the Blue Jacket, Queen, and Alaska. A railroad was partially built, a smelter was in operation, and three towns—Cuprum, Helena, and Landore—were established. Mining activity also took place across the river in Oregon. In 1899, gold was discovered near the mouth of the Imnaha River. Also that year, more than 50 claims were taken on Squaw Creek, opposite the Seven Devils mining region. The town of Eureka sprang up in the canyon but ceased to exist by 1906 because of transportation difficulties and a lack of major strikes. Two more towns, Homestead and Copperfield, were organized. They experienced a brief boom before the onset of World War I forced many mines to close. GLO records noted three separate mines about 3 miles below the Oxbow Dam site along the Hells Canyon Reservoir subreach and "considerable mining development" apparently along the Deep Creek drainage, which also enters the river right below Hells Canyon Dam. Few GLO records exist for the river below Hells Canyon Dam. However, mining in this reach was noted at Bernard Creek, Eureka Bar, Dug Bar, Salt Creek, Somers Creek, Temperance Creek, and Big Bar. USDA (1980) indicated that 100 mining sites were located along the Snake River within the then-proposed Hells Canyon National Recreation Area. Apparently the Winchester mine near Battle Creek was one of the more prominent mine sites.

Agriculture and Irrigation—Ranching and farming quickly followed on the heels of mining ventures in Hells Canyon. In the Weiser reach, agricultural activities were relatively well established by the 1870s to 1880s (Arrowrock Group 1995). By the early 1900s, most of the flat bottomland and islands on the Snake River floodplain in the Weiser reach had been converted from native wetland, riparian, and shrub-steppe communities to irrigated crops and orchards. Virtually all arable land was farmed by the 1950s (aerial photographs in Series 1 and 2 of Westlake Island and Snake River floodplain in the Weiser reach). The Weiser River had been over-allocated since at least 1909.

In the Brownlee reach, the floodplain narrows substantially. In 1905, homesteaders came to the canyon to establish farms and orchards. But the canyon’s difficult access, limited bottomland, poor access to irrigation, and extreme summer climate made farming exceptionally difficult. Therefore ranching was favored over other agricultural activities. The few flat areas and islands that existed in the upper end of the reach were farmed, but tillable land was limited. Flatter alluvial fans along the river and river bars were farmed by early settlers or used as feedlots for winter livestock (Series 5, 6, and 7 of the Brownlee reach). Later, flatter benches created by the Bonneville Flood were also farmed, and some were irrigated.

In the Oxbow and Hells Canyon reservoirs reach, agricultural development was probably similar to that of the Brownlee reach; settlers generally occupied river bars and benches raising crops and livestock. Irrigation diversions and farming are documented on the Wild Horse River and its tributaries (Arrowrock Group 1995) and probably occurred at the mouths of the few other drainages that had flatter lands that could support a house and garden or orchard. The U.S. Census Office (1896) described extensive agricultural development and irrigation diversion along the Powder River drainage as early as 1889. Apparently, by the 1940s and 1950s, many tributaries of the Powder River were substantially diverted. Irrigation of alluvial fans and terraces along the river was primarily limited to the individual efforts of farmers who diverted water from nearby tributaries to irrigate their crops. Irrigation was limited in the downstream reach (below Hells Canyon Dam) and poorly documented (Arrowrock Group 1995).

Ranching and Grazing—Downstream of Farewell Bend cattle and sheep ranching dominated the area in the 1880s because little cultivated land existed. From 1860 through 1870 and 1892 to 1893, cattle and sheep populations rapidly expanded (Galbraith and Anderson 1971). During the 1920s, cattle grazing mostly replaced sheep grazing (Tisdale 1986*a*). By the 1940s, however, ranchers shifted back to cattle, and numerous feedlots were developed along the Snake River (Asherin and Claar 1976).

The introduction of livestock profoundly affected the native steppe and shrub-steppe vegetation in the Inland Northwest (Daubenmire 1970). Lands not used for crop production were subjected to various degrees of grazing by livestock, and they generally deteriorated (Tisdale 1986*b*). Overgrazing was already considered to be a serious problem by the early 1900s, and unrestricted grazing continued well into the 1940s.

Natural resource agency staff confirmed that range conditions in the study area preceding and during the 1950s were poor (J. Morrison, IDFG retired, *pers. comm.*; P. Grindy, Payette National Forest, *pers. comm.*). Morrison noted that few, if any, trees grew in riparian zones during the 1950s and livestock use of these areas was heavy. Riparian vegetation apparently consisted primarily of shrubby species with very tall sagebrush and mountain mahogany common in many drainages (D. Nadeau, IDFG retired, *pers. comm.*). The U.S. Fish and Wildlife Service (1948) assessment of potential impacts of proposed dams in the Columbia River Basin characterized wildlife habitat quality in Hells Canyon as being in fair to poor condition.

Agency personnel generally believe that range conditions on U.S. Forest Service lands have improved since the 1950s. Plant species diversity has increased, but noxious weeds are more problematic (P. Grindy, Payette National Forest, *pers. comm.*). Current grazing effects on wildlife habitat are probably greatest in the Weiser and Brownlee reaches of the study area because more grazing occurs in these reaches and there is less annual rainfall. Precipitation increases farther north along the river corridor, providing more opportunity for recovery from past abuse. Range conditions have probably recovered more below Hells Canyon Dam because few parts of the Hells Canyon National Recreation Area in the lower portions of the Snake River corridor are still grazed, though no monitoring data are available for the study area to support this premise.

Exotic Plants—Exotic plants, which include invasive and noxious weeds, were recently ranked as the greatest threat to the composition and structure of native plant communities in the Interior Columbia River Basin (Croft et al. 1997). Most of the species identified in the study reach (Table 13) were apparently present in the study corridor before the dam was constructed and flows managed (Invader Database System 2000). The continual spread of exotic plants has steadily degraded wildlife habitat value on both temporal and spatial scales.

Logging—Multiple GLO records from 1870 through 1920 indicate that “no timber” grew along the Weiser or Brownlee reaches (Appendix 1). GLO records from 1902 to 1910 for the Oxbow Reservoir subreach indicate that scattered pines and cottonwoods were present at some sites. Historical photographs in Series 10, 11, and 13 (for the Oxbow Reservoir subreach) show occasional ponderosa pines (*Pinus ponderosa*) near the river. The only deciduous trees visible in these photographs appear to be hackberry (*Celtis reticulata*). GLO records for the Hells Canyon Reservoir subreach indicate no timber at some sites and scattered pine and fir at other locations; cottonwood was mentioned in one record. Several of the photographs from the Hells Canyon Reservoir subreach (Series 16–23) also show conifers present during the 1950s.

A comparison of historical photographs with current photographs indicates that, except for trees inundated by reservoir waters, most of the conifers in the 1950s photographs were also present in 1999. Therefore, for sites not affected by mining, other settlements, or inundation, wildlife habitat quality of these open pine stands probably differed little during the 1950s and the 1990s, although the trees would be more mature in the 1990s, which could cause minor changes in the associated wildlife community.

Condition of Wildlife Habitat—Comparisons of pairs of photographs (called "pair-wise comparisons") were essential for describing and illustrating vegetation and wildlife habitat conditions during the 1950s and the 1990s. We used four photographs for most of the 30 locations—a historical oblique, contemporary oblique, historical aerial, and contemporary aerial—since using both aerial and oblique photograph pairs provided a broader geomorphic and fluvial context. Analyses of vegetation patterns focused on geomorphic types where fluvial regime or flow regulation probably changed vegetation patterns or wildlife habitat. We focused our analysis of vegetation patterns from photographs on qualitative comparisons of the nature and extent of grass, shrub, and forested plant communities, as well as on important habitat features for each study reach.

The overall wildlife habitat quality and quantity of riparian communities in most of the Weiser reach in 1999 appeared to have increased since the 1950s, even though the riparian community was dominated by exotic species. In the Farewell Bend area, slightly more riparian and wetland habitat was associated with backwater areas during the 1950s than during 1997. Agricultural development was similar between the two time periods. However, habitat quality was limited by the long history of unrestricted livestock grazing. Range conditions for unfarmed uplands were probably somewhat better today than in the 1950s. Riparian habitat visible in the historical photographs taken at Weiser and Westlake Island in the Weiser reach between 1899 and 1908 consisted of a fringe of hackberry and some willow along some sections of the riverbanks and virtually no riparian vegetation along most other banks. In contrast, riparian habitat communities appeared to occupy most of the river and island banks in the 1997 aerial photographs. Oblique photographs taken during the 1999 growing season showed relatively mature nonnative riparian trees growing along the river channel.

In the Brownlee reach, the primary difference in vegetation and wildlife habitat quality between the 1950s and 1990s was the heavy grazing of scattered riparian vegetation during the 1950s. Channel-margin sandbars and islands were relatively abundant before the dam was constructed (aerial photographs in Series 4 and 9 of the Brownlee reach). Evidence of riparian vegetation was not discernible in the recent photographs (1999) of the Brownlee reach (Series 4 and 9). Steep slopes of sagebrush-steppe vegetation extend downslope to barren reservoir shorelines. Upland habitats end abruptly at the water's edge when the reservoir is full. The most obvious difference in wildlife habitat quality between the two periods was the presence of scattered riparian vegetation along the river during the 1950s and the lack of such vegetation during the 1990s because of inundation and reservoir fluctuations. However, the habitat quality of the 1950s riparian vegetation was severely degraded by grazing and mining. The islands visible in the 1950s photographs appeared to support little or no riparian vegetation, although other islands not visible in these photographs were also present.

The Oxbow and Hells Canyon reservoirs reach also experienced flow fluctuations because of hydroelectric operations. Most of the increase in woody riparian vegetation appears to be the result of exotic rather than native species. GLO records (from 1901 to 1936) indicate that willow and hackberry were common along the river channel, with upland habitats consisting of overgrazed sagebrush-steppe vegetation. Near the confluence of the Snake River and Pine Creek, some cottonwoods grew along the mainstem. The riparian vegetation visible in historical photographs (1901 to 1950s, Series 10–23 of the Oxbow and Hells Canyon Reservoirs reach) was limited to scattered stands of willow and hackberry along the riverbank. Pines were relatively common on adjacent terraces and slopes. Steep canyon walls were sparsely vegetated by sagebrush-steppe plants. Recent photographs of the Oxbow/Hells Canyon reach revealed scattered patches of woody vegetation along reservoir shorelines (Series 13, 14, and 17). Given minimal water-level fluctuations, deciduous shrubs and trees were relatively common along these reservoir shorelines. Observations in the field and from the aerial photographs suggested that shoreline vegetation might be more widespread along some reaches of Oxbow and Hells Canyon Reservoirs today than in the 1950s. Many islands did not support riparian vegetation during the 1950s because of regular scouring flows. And species diversity appears to be greater in today's shoreline community; however, much of this vegetation is derived from exotic species. Sandbar willow is much less common today, and numerous stands of scattered pines are inundated. Wildlife habitat values of the riparian zones between the two periods are difficult to compare because the dominant plant species have changed and the photographic record is incomplete.

Hydrologic processes in the downstream reach (below Hells Canyon Dam) have been influenced by several factors, such as steeper gradient, increased drainage area, and operation of upstream dams that regulate seasonal peak flows. However, the primary change in vegetation and wildlife habitat quality between the 1950s and 1990s has been the dramatic increase in tributary riparian canopy cover values, canopy height, and woody plant species diversity. Eliminating grazing on most Hells Canyon National Recreation Area allotments that border the river probably caused these changes. GLO records (1901 to 1936) indicated that willow and hackberry were common along the mainstem of the river, with upland habitats having sagebrush-steppe vegetation. Recent photographs of the Hells Canyon reach of the Snake River showed a fragmented riparian fringe of hackberry, with only small, scattered populations of sandbar willow. Steep canyon walls remain sparsely vegetated. The growth and canopy development of hackberry appears to have increased over the last several decades. In several areas, hackberry has expanded downslope toward the channel through the initiation and growth of root suckers (Series 26, 27, and 35 of the downstream reach). The riparian habitats of tributaries also support a much more diverse and continuous cover of trees and shrubs than they did before impoundment when trees were largely absent from tributary riparian communities and emergent plant communities were rare (Series 25 and 27 of the downstream reach). Upland range conditions have improved since the 1950s, especially in those parts of the Hells Canyon National Recreation Area adjacent to the Snake River that are no longer grazed. This trend is likely to continue.

Effects of the Hells Canyon Complex—We used information on the conversion of upland and riparian cover types into aquatic types to determine how landscape features and wildlife habitat changed as the Hells Canyon Complex was constructed and the reservoirs filled. We also developed a general description of the effects of the construction and operation of the Hells Canyon Complex on sediment supply, substrate, and flow characteristics. Available information and descriptions of these characteristics, including Idaho Power Company's current study on sediment transport issues and sandbar morphology, were used to qualitatively assess the long-term influence of construction and operation of the Hells Canyon Complex on wildlife habitat below Hells Canyon Dam.

Constructing three hydroelectric projects in the study area immediately converted terrestrial and riparian vegetation types and farmed and mined lands to permanently or temporarily flooded aquatic habitats. Riparian zones impacted by the Idaho Power dams and flooding were also in poor condition because of overgrazing, mining, timber harvesting, and water diversion. No immediate effects of constructing the dams were identified for wildlife habitat downstream of Hells Canyon Dam.

Operation of Brownlee Reservoir has affected the ability of vegetation to establish. This reservoir is drawn down each year to control floods and facilitate summer hydroelectric generation. Aquatic vegetation cannot grow in the drawdown zone because of the annual exposure. Except for a few exotic annual plants, the annual flooding also prevents upland or shoreline vegetation from establishing. Operation of Oxbow and Hells Canyon Reservoirs causes only minor changes in water level, thereby maintaining a fairly stable wetted perimeter along the shoreline. This mode of operation appears to have positively affected the abundance of shoreline riparian vegetation along portions of these reservoirs. There also appears to be greater species diversity in today’s shoreline community, though much of this diversity is attributed to exotic species. Another landscape-level change in wildlife habitat resulting from higher summer base flows (attributed to project operations) is related to the riparian community downstream of Hells Canyon Dam. Hackberry is much more prominent in riverside riparian zones today than it was before the dam was constructed. Individual plants are larger, and the overall canopy cover is greater today, substantially so in some locations. However, sandbar willow and other native herbaceous riparian vegetation below Hells Canyon Dam appear to be less common today.

This page left blank intentionally.

1. Introduction

1.1. Study Purpose and Goal

The purpose of our assessment is to provide information that will help Idaho Power Company (IPC) relicense the Hells Canyon Complex with the Federal Energy Regulatory Commission (FERC). The main objective of this study is to describe wildlife habitat conditions during two periods: the 1950s (before construction of the Hells Canyon Complex) and the 1990s. These descriptions are based on qualitative indices of habitat conditions and expert knowledge, both of which allow habitat conditions during the 1950s and 1990s to be compared. Since the goal of the study is to assess the effects of constructing and operating the Hells Canyon Complex on wildlife habitat, the results of such comparisons provide a basis for discussing these effects on landscape features and habitat important to wildlife. In our effort to focus on the *effects* of natural and anthropogenic factors on wildlife habitat conditions rather than on the causes of those effects, we describe various factors that have affected or currently affect wildlife habitat only to the extent needed to address habitat conditions during the two periods.

1.2. Study Objectives

The objectives of the study are the following:

1. **Influence of Anthropogenic Disturbances**—To qualitatively assess the influence of anthropogenic disturbances on wildlife habitat in the 1950s as compared with such influences in the 1990s. Human factors that may have influenced wildlife habitat in the Hells Canyon vicinity include farming, ranching, timber harvesting, mining, homesteading, rural community development, and hydroelectric operations.

2. **Condition of Wildlife Habitat**—To qualitatively assess the general condition of wildlife habitat prior to construction of the Hells Canyon Complex in the 1950s as compared to the 1990s. This evaluation of the river corridor is based on representation, distribution, and abundance of general riparian and upland habitat types and other habitat features important to wildlife.

3. **Effects of Hells Canyon Complex**—To summarize how constructing and operating the Hells Canyon Complex may have altered landscape features and conditions of habitat important to wildlife. Relative increases or decreases in habitat types and features are summarized with regard to anthropogenic disturbances.

2. Study Area

Our study area included the Snake River reach of Hells Canyon from the bridge (river mile [RM] 351.2) at Weiser, Idaho, downstream to the confluence of the Snake and Salmon

Rivers (RM 188.2) (Figure 1). In this reach, the Snake River forms the border between Oregon and Idaho. The study area was divided into four reaches:

- **Weiser Reach**—Weiser Bridge in Weiser, Idaho, to the headwaters of Brownlee Reservoir, at Farewell Bend, Oregon
- **Brownlee Reach**—From Farewell Bend, Oregon, through the Brownlee Reservoir including the Powder River Arm, downstream to Brownlee Dam
- **Oxbow and Hells Canyon Reservoirs Reach**—Oxbow and Hells Canyon Reservoirs
- **Downstream Reach**—Hells Canyon Dam to the confluence of the Snake and Salmon Rivers (unimpounded downstream reach)

When the study area was established, Oxbow and Hells Canyon Reservoirs were considered two separate reaches, for a total of five study reaches. However, because Oxbow and Hells Canyon Reservoirs have many similarities and typically function as one unit in terms of system operation, the reaches were combined in this report.

2.1. Climate

Hells Canyon is located in the Upper Great Basin (Snake River Plains west) and Blue Mountain/Idaho Batholith Provinces. It is significantly influenced by the rain shadow of the Cascade Mountain range to the west. The average annual precipitation for Weiser, Richland, Brownlee, and Lewiston ranges from about 380 to 500 millimeters (15 to 20 inches), depending on elevation. Nearly 45 percent of the average annual precipitation at the Brownlee weather station falls between November and January, which contrasts strongly with the 9 percent that falls between July and September.

Mean annual temperatures are similar among the four weather stations. Generally, the climate becomes drier and warmer downstream of Brownlee Reservoir. Climate information from Brownlee Dam (RM 284.6) is probably characteristic of the central section of the study area. The canyon bottom area is dry with seasonal temperatures ranging from about –5 ºC in January to about 35 ºC in July. Mean temperatures below 1,000 meters above mean sea level (3,281 feet msl) range from 0 ºC in January to between 28 ºC and 33 ºC in July (Johnson and Simon 1987). As a general rule, winters in Hells Canyon are relatively mild, while summers are hot.

2.2. Physiography, Geology, and Soils

Hells Canyon is the deepest and one of the most rugged river gorges in the continental United States. It ranges between 2,000 and 3,000 feet deep from Weiser to Oxbow Dam. Below Oxbow Dam, the river enters a narrow, steep-sided chasm up to 5,500 feet deep. From the confluence with the Grande Ronde River, the Snake River then flows onto a basin and through a much shallower canyon to Lewiston, Idaho. The elevation of the Snake River near Weiser, Idaho, is about 2,090 feet msl, descending to about 910 feet msl at the confluence of the Salmon River. Throughout the canyon, topography is generally steep and broken with slopes often dominated by rock outcrops and talus slopes.

Hells Canyon consists of a series of folded and faulted metamorphosed sediments and volcanics overlain uniformly by nearly horizontal flows of Columbia River basalt (Bush and Seward 1992). The canyon itself was formed through a combination of erosion by the Snake River and regional uplift of the Blue Mountains in Oregon and Seven Devils Mountains in Idaho (Vallier 1998). The progressive river scour and gradual uplift of the mountainous region created the steep canyon. The Snake River probably cut to its present level during the Pleistocene. Northeast-trending, high-angle fault patterns characterize the extensive Snake River fault system running throughout the study area (Fitzgerald 1982). In addition to basalt, extensive limestone outcrops are found in some tributary drainage areas, and local granitic outcrops also occur.

The soils throughout Hells Canyon are derived primarily from Columbia River basalt, covered in most areas with a thin mantle of residual soils from weathered native rock. Isolated areas contain deposits of windblown silt. The amount of soil cover declines northward through Hells Canyon near Hells Canyon Dam (RM 247). Most rock faces are nearly vertical, with little soil cover. Most soil complexes are well drained and vary from very shallow to moderately deep. Loams are the dominant textural class and vary from very stony to silty, often with a clay subsoil component.

2.3. Aquatic Habitat

Aquatic habitat varies in quality and complexity from south to north through the study area. Near Melba, Idaho, the Snake River is a low-gradient (0.2 to 0.4 meters per kilometer) river, with numerous island complexes. The first reservoir in the three-reservoir complex is Brownlee Reservoir, which is steep-sided and 55 miles long, with a maximum depth of 300 feet. One of the dominant habitat features of Brownlee Reservoir near Farewell Bend is the transition zone between riverine and lacustrine habitat. Oxbow Reservoir, the next reservoir, is a 12-mile-long reregulating reservoir, with maximum depths approaching 80 to 100 feet. The last reservoir is Hells Canyon Reservoir, which is a 22-mile-long reregulating reservoir with a maximum depth of 200 feet. The design of the powerhouse and dam leaves a 2-mile stretch of the original river channel from Oxbow Dam to the outflow of the powerhouse with a minimum flow of 100 cubic feet per second (cfs). Shorelines along Hells Canyon Reservoir are generally steep. The Snake River below Hells Canyon Dam is a high-gradient river (1.8 meters per kilometer) and has a wide diversity of available habitats, including a diverse substrate, numerous large rapids, shallow riffles, and deep pools.

2.4. Fluvial Processes

The flow of water and sediment from the upstream watershed through the study area is governed by riverine hydraulic characteristics. Such characteristics are dictated by the geomorphology, channel geometry, and resistance to flow that have developed along this reach of the Snake River through time. At the upstream portion of the study area, the Snake River meanders through a relatively broad alluvial plain before entering the confined reach of Hells Canyon. In Hells Canyon, the gradient of the river steepens, and the flow becomes more swift and turbulent. Portions of the study reach, starting in the transition area between the alluvial plain and the canyon, have been inundated by the three reservoirs. In the alluvial valley portion, the river, its bed and banks, and associated riparian habitat can interact dynamically. In the canyon portion, interaction between the river and its bed and banks is limited to areas that can be mobilized by the flow, such as bars, islands, terraces, and fans. These areas consist of finer sediment particles instead of bedrock or coarse colluvial boulder canyon walls and hillsides. Sediment trapping by upstream reservoirs, as well as by the Hells Canyon Complex, has reduced the sediment supplied to and transported through the study reach.

2.5. Plant Operations

Though the three-dam Hells Canyon Complex has always been a multiple-use facility, it was initially constructed primarily for power generation. During the past decade or so, the framework for operations at Hells Canyon Complex has changed significantly due to recreation and anadromous fish spawning and protection efforts (per the 1980 Hells Canyon Settlement Agreement). Operations of the three plants are closely coordinated for efficiency within the bounds of the requisite license and environmental restrictions. Flow releases increase generation during the daytime and decrease generation during the night to meet the daily power demands. Because the hydraulic capacities of the Oxbow and Hells Canyon plants are significantly less than the hydraulic capacity of the Brownlee plant, Oxbow and Hells Canyon Reservoirs are often drafted at night to receive the increased outflows from Brownlee Reservoir during the day.

3. Methods

To address the three primary study objectives (see section 1.2.), we required information on physical processes and on settlement patterns before and after Euro-American inhabitation in the study area. Also, knowledge of the land-use practices of early settlers is important for understanding wildlife habitat conditions during the 1950s. Similarly, knowledge of more recent anthropogenic factors and land management practices are necessary for understanding current conditions. Therefore, we obtained and reviewed the following types of information (see the separate bibliography at the end of this bound report):

- Historical accounts of early settlement and land use
- Historical and current photographs of selected locations

- General Land Office (GLO; predecessor to the Bureau of Land Management [BLM]) accounts and records
- Historical state and federal wildlife agency survey reports
- Interviews with state wildlife agency personnel who worked in the study area during the 1950s
- Historical and current hydrologic data
- Livestock grazing records for federal lands adjacent to the study area reaches
- Historical and current literature on vegetation, wildlife, and wildlife habitat within the study area

Our study was based entirely on existing information. IPC and other interested parties were asked to research their files to help our study team obtain any historical photographs and documents available for the 1950s and 1990s. Much of the required historical information from state and federal land and resource agencies with management authority in the Hells Canyon Complex study area was contained in old records and files that were not readily accessible to the study team, despite our systematic efforts. Because these agencies had neither the time nor the budget to search their files, they allowed us access and, given limited time, we focused on collecting sources thought to be most beneficial for the study. Some agencies had potentially useful data in various stages of analysis that could be facilitated by outside funding; however, such funding was beyond the scope of this investigation. Readily available information, such as BLM and U.S. Forest Service (USFS) land and resource management plans, was generally provided as requested.

3.1. Evaluation of Agency-Proposed Assessment Approaches

Agencies proposed three approaches for assessing the effects of constructing and operating the Hells Canyon Complex on wildlife habitat to the Terrestrial Resources Work Group of the Collaborative Team:

- Comparing upstream with downstream reaches
- Comparing impounded with unimpounded reaches (within the Snake River or comparing the Snake River with the adjacent Salmon River)
- Comparing historical photographs and descriptions with current photographs and vegetation descriptions

We conducted a thorough literature review on each proposed assessment technique and considered the relative validity of applying each to the Hells Canyon Complex study corridor.

3.1.1. Comparison of Upstream with Downstream Reaches

To determine whether upstream and downstream comparisons were valid, we used a qualitative analysis to investigate possible differences in the geomorphology of reaches of the Snake River upstream of Brownlee Reservoir compared with the geomorphology of the Hells Canyon River reach downstream of Hells Canyon Dam. That analysis focused on river slope and channel and floodplain morphology between upstream and downstream reaches. If these comparisons revealed major differences between these key geomorphic variables, then a comparison of upstream and downstream reaches would be inappropriate.

3.1.2. Comparison of Impounded with Unimpounded Reaches

We also investigated the applicability of comparisons of impounded and unimpounded reaches, specifically the lower gorge of the Salmon River (below White Bird) and the Hells Canyon reach of the Snake River. Possible differences between the Snake and Salmon Rivers in channel geomorphology, historical conditions, and land uses in the watershed were considered to determine whether such a comparison would be valid. For example, numerous anthropogenic disturbances—livestock grazing, road construction, timber harvesting, and mining—have probably increased sediment inputs into the Salmon River, confounding a simple comparison of the occurrence of sediment, sandy beaches, and sand-associated riparian vegetation along the Salmon and Snake rivers. Also, no major dams occur on the Salmon River or its tributaries, while much of the Snake River watershed above the Hells Canyon Complex has been dammed.

3.1.3. Comparison of Historical Photographs and Descriptions with Current Photographs and Vegetation Descriptions

We investigated the possibility of comparing pre- and post-impoundment photographs and descriptions. As part of that investigation, we had to determine the availability of pre-impoundment photographs, especially those from photographpoints that could be identified and revisited for comparison with post-impoundment conditions. The greatest number of photographs available were from the 1950s and showed pre-impoundment conditions.

3.2. Influence of Anthropogenic Disturbances

We used aerial photographs, historical information, and environmental data to describe the following anthropogenic factors that may have affected wildlife habitat during the 1950s and 1990s:

- Hydrologic and fluvial processes
- Mining
- Logging
- Livestock grazing
- Agriculture and irrigation
- Residential
- Fire
- Exotic plants

- Subsistence and recreational hunting and other activities

Historical accounts by Madeline Buckendorf, Carol Smolinski, Cort Conley, and other sources were used to identify important environmental and historical data on the influence of anthropogenic factors on vegetation and wildlife habitats within the Hells Canyon study area.

In addition, the effect of such human activities as farming, ranching, homesteading, mining, and hunting were assessed for their resulting changes to local hydrology and geomorphology and the influence of those changes on plant communities and vegetation conditions during the 1950s and 1990s. Other factors—such as mining, timber harvest, ranching, and water-storage or diversion projects upstream of the projects—were also examined, and a qualitative summary description of the influence of these factors on sediment supply, substrate, and flow during the 1950s and 1990s was developed. Then we investigated the expected effect of these factors on wildlife habitat during the two periods.

Human activities may impact plant communities in ways that cannot be readily evaluated by using photographs and historical accounts. Therefore, our assessments were reviewed using current knowledge of the effects of land-use practices on wildlife habitat. The context was based on historical accounts and results of range monitoring in southern Idaho and eastern Oregon. These data we obtained from GLO survey records, the BLM, and USFS. Literature about the effects of livestock grazing on shrub-steppe, grassland, and riparian plant community types was also reviewed. In addition, we reviewed literature about the general habitat value of various agricultural land-use categories to help us assess the influences of anthropogenic factors on wildlife habitat.

GLO survey records from the 1870s to early 1900s were obtained for the Idaho side of the study area to provide information about the general types of vegetation at survey locations. We found that the information in the Idaho GLO records provided only very general descriptions on vegetation presence. Therefore, we decided that the Oregon GLO records would not further our understanding of early anthropogenic influences on wildlife habitat.

To compile local knowledge of pre-impoundment wildlife and habitat conditions, we interviewed current and former employees of natural resource and land management agencies. These employees had worked in the study area in the 1950s and early 1960s before and during construction of the Hells Canyon Complex. In addition, Historic Federal Aid Project study results—funded by Pitman-Robertson monies archived at Idaho Department of Fish and Game (IDFG), Oregon Department of Fish and Wildlife (ODFW), and U.S. Fish and Wildlife Service (USFWS)—contained pertinent wildlife information. Additionally, we reviewed editions of IDFG and ODFW popular magazines dating from the 1950s and early 1990s.

The presence of exotic or noxious plant species degrades wildlife habitat value. Therefore, we sought to document the approximate arrival times of noxious and invasive species into the study corridor. We contacted regional herbaria to determine plant collection dates of exotic or noxious plants. This work was primarily conducted through electronic reviews of key species with managers of regional herbaria (University of Washington, Washington State

University, University of Idaho, Northeast Oregon State, and Boise State University) and in the Invader Database System (2000). The noxious and invasive species corresponded to species selected for Hells Canyon River Environment Model (HCREM) modeling efforts.

We used several books and articles to identify patterns of anthropogenic disturbance of riparian habitats prior to dam construction, including *Saints, Sinners and Snake River Secrets* by L.C. Densley (1987); *Snake River of Hells Canyon* by J. Carrey, C. Conley and A. Barton (1979); *My Home Below Hells Canyon* by Grace Jordan (1954); *White Man Comes to Snake River* by T. J. Green (State Archaeologist, 1988); and *Islands and Rapids* by T. Vallier (1998). We also used the IPC *Hells Canyon Oral History Report* and literature review prepared by Madeline Buckendorf (Arrowrock Group 1995). Progress reports on the archaeological inventory of Hells Canyon by J. C. Chatters and K. C. Reid (1999 to 2000) were used for descriptions of anthropogenic impacts within the study corridor.

3.3. Condition of Wildlife Habitat

The review of aerial and oblique photographs from the 1950s and 1990s, combined with review of other available information previously discussed, allowed us to develop general descriptions of upland and riparian plant communities—including general condition, major species composition, and structural diversity—for the two time periods. The discussion of 1990s conditions was supplemented by plant community data in the study area (Holmstead 2001). This discussion also includes qualitative comparisons of these conditions between the 1950s and 1990s. All historical and contemporary photographs were archived, scanned, and incorporated into a Geographic Information System (GIS) mapping database.

3.3.1. Hydrologic and Fluvial Processes

River flow is the primary link among various natural resources and operations of the Hells Canyon Complex. The hydrologic and geomorphic processes of these river flows affect both substrate and vegetation. Therefore, we qualitatively compared flow regime, sediment supply, and transport to demonstrate the general fluvial and geomorphic factors affecting substrate conditions and mobility. Our data was based on information from other studies and available sources, including the U.S. Geological Survey (USGS). We investigated the relationship between flows and the mobility of sandbars. The seasonal pattern of flow and key components, such as peaks and recession timing, were specifically evaluated, by river reach, for their effects on sediment supply and riparian vegetation that needs fine substrates. In addition, IPC is conducting numerous studies about sediment transport in the study area. In general, these studies were designed to determine the characteristics of sediments transported into and being stored by the Hells Canyon Complex and to evaluate the effects of the sediment transport and storage on beaches and banks below the Hells Canyon Dam.

3.3.2. Historical Photographic Analysis of Riparian Habitats

We reviewed approximately 240 pre-impoundment photographs of the study corridor that were obtained from the following sources:

- Washington State University Archives: Van Aardsell and Pickett Photo Collections (1928 to 1934, Hells Canyon reach of the Snake River)
- Idaho Historical Society (1908 to 1910, Weiser reach)
- Peter Basche, Eugene Antz, Walter Forsea, and Jack Eng (1950s, reservoir reaches)
- Dr. Carol Smolinski (Lewis-Clark State College, Lewiston, Idaho)
- Nez Perce County Historical Society (Lewiston, Idaho)
- Idaho Power Company (1950s, engineering survey and construction photographs of reservoir reaches)

We also contacted other sources: the USFS (Hells Canyon Recreation Office, Wallowa–Whitman National Forest and Payette National Forest) and BLM (Baker City, Oregon). Unfortunately, their collection of historical photographs of Hells Canyon were limited to upland forest and rangeland habitats (Charlie Johnson, USFS Forest Ecologist, Baker City, Oregon; Jane Rohling, USFS Hells Canyon Naturalist, Enterprise, Oregon; and Linda McFadden, USFS Hells Canyon Recreation Office; *pers. comm.*).

Most of the 240 photographs had only limited coverage of riparian habitats and fluvial geomorphic features. From the complete collections, we determined which photographs focused on geomorphic types that were most likely to have been changed by fluvial regime or flow regulation. The 30 photo points (3 to 12 photographs per study reach) selected showed riparian and adjacent upland landscapes prior to dam construction. These photographs were scanned and copied, and their location determined. Once a photo point was located, we took a current photograph (black and white or color) of the area (Table 1), replicating historical photo-angles and dimensions.

Comparisons of these pairs of photographs (called "pair-wise comparisons") were essential for describing and illustrating vegetation and wildlife habitat conditions during the 1950s and the 1990s. We used four photographs for most of the 30 locations—a historical oblique, contemporary oblique, historical aerial, and contemporary aerial—since using both aerial and oblique photograph pairs provided a broader geomorphic and fluvial context. The scale of aerial photographs used in this analysis ranged from 1:6,000 to 1:20,000 (USGS aerial photographic records, Salt Lake City, Utah). We also used pair-wise comparisons to describe changes in vegetation and wildlife habitat conditions between the two periods.

Analyses of vegetation patterns focused on geomorphic types where fluvial regime or flow regulation probably changed vegetation patterns or wildlife habitat. We focused our analysis of vegetation patterns from photographs on qualitative comparisons of the nature and extent of grass, shrub, and forested plant communities, as well as on important habitat features for each study reach. Supplemental information was derived from plant collections and historical records (M. Buckendorf, Arrowrock Group, *pers. comm.*). We derived the following qualitative information from these photographs:

- Presence or absence of riparian and upland plants
- Relative height, structure, and extent of riparian woody vegetation (i.e., diversity of life and growth forms in riparian zones)
- Fluvial geomorphic features—such as sand and gravel bars—and backwater, pool, and riffle habitats
- Anthropogenic disturbances—such as livestock grazing, farming, land clearing, and other activities

Our comparison of historical and contemporary aerial photographs provided a broad perspective of the potential changes in riparian vegetation and fluvial geomorphology within a given reach of the river following dam construction. From these aerial photographs, we qualitatively derived the presence or absence of riparian woody plants, location of the vegetation scour line, and general relationships between riparian woody plants and fluvial geomorphic features, such as islands. Approximate discharge at the time of photography was determined from the unpublished mean daily discharge records of the USGS stream gauges at Hells Canyon Dam and Weiser, Idaho (Table 2).

3.4. Effects of the Hells Canyon Complex

We used information on the conversion of upland and riparian cover types into aquatic types to determine how landscape features and wildlife habitat changed as the Hells Canyon Complex was constructed and the reservoirs filled. The information developed for the 1950s habitat characterization, combined with the location of project facilities and features and the reservoir boundaries, enabled a qualitative discussion of the immediate effects on existing habitat. From our understanding of these immediate effects on habitat, we could assess the nature and likely implications of these changes on wildlife at a landscape level.

However, the effects of other anthropogenic factors had to be separated from project impacts to address the long-term influences of project operation on important wildlife landscape features and the wildlife habitat condition. Between the 1950s and 1990s, seasonal grazing on public lands was reduced; grazing activity within the Hells Canyon National Recreation Area near the river corridor was significantly reduced or eliminated; mining, farming, and ranching activities were greatly reduced; less water was diverted for irrigation; less wood was cut along the tributaries; fire frequency was altered; and exotic or noxious species were more widely distributed. All of these anthropogenic and land-use changes affected wildlife habitat.

Because the long-term effects of project operations were expected to vary considerably by study reach, we reviewed current aerial photographs and IPC cover-type maps, focusing on the immediate reservoir shorelines and riverbank. Both project and non-project factors that would affect plant communities were evaluated during assessment of near-shore areas. The reach below Hells Canyon Dam is affected by project operations as well as by non-project factors, such as the effects of flood control, upstream storage, and flow augmentation. In addition, project and non-project water-management constraints that affect flows, along with project features that restrict sediment transport, probably affect habitat. Therefore, in that reach our efforts remained qualitative and were based on existing information rather than modeling efforts. With a few exceptions, separating the individual effects of flow-management components on wildlife habitat was impossible in a qualitative assessment. However, separating these effects, at least for future water-management scenarios, are addressed by other studies such as the riparian/flow modeling and the wildlife habitat assessment study.

We also developed a general description of the effects of the construction and operation of the Hells Canyon Complex on sediment supply, substrate, and flow characteristics. Available information and descriptions of these characteristics, including a study on sediment transport issues and sandbar morphology (Parkinson et al. 2002), were used to qualitatively assess the long-term influence of construction and operation of the Hells Canyon Complex on wildlife habitat below Hells Canyon Dam.

The Hells Canyon Complex has affected the geomorphology of the river through the study reach by inundating portions of the reach and trapping sediment in the reservoirs. These factors were assessed using geomorphic techniques to compare information about the river from the 1950s with information from the 1990s. Available information from current studies of sediment transport issues was also incorporated and used in this assessment. As we developed the geomorphic context of the Hells Canyon Complex, we considered effects of the dams, hydrology, and sediment transport. Our analysis of the geomorphic effect of reducing sediment load to the river below Hells Canyon Dam compared the sediment-transport capacity with sediment supply (slope comparisons and general relationships governing sediment transport). This analysis also addressed changes in substrate that support riparian vegetation, as did comparisons of aerial photographs of the reach below Hells Canyon Dam. In addition, we reviewed the existing analysis of trends of change to alluvial sand bars by Grams and Schmidt (1991). That information was used to assess changes to geomorphic features and their implications to wildlife habitat.

We conducted the following tasks related to hydrology, geomorphology, and sediment transport as part of the qualitative evaluation:

- Described the basic geomorphic condition of the study area prior to project construction and the direct effects of project construction and operation on the geomorphology of that area.
- Evaluated the effect of project construction and operation on hydrology (flow regime).
- Evaluated the effect of project construction and operation on sediment transport through the study area, as well as the effects on the mobility of substrate and sediment and on the trapping of incoming supply and bed and bank material (for this evaluation, we compared historical photographs, existing reports, and other information).

- Assessed anthropogenic factors on sediment and substrate from available reports and watershed disturbance conditions.
- Assessed pre- and post-construction mobility and status of sandbars on vegetation, based on available information from reports and photographs and from qualitative sediment-transport concepts.

4. Results

4.1. Evaluation of Agency-Proposed Assessment Approaches

We classified studies as either comparative or process based (Table 3). The latter investigations were not further explored. However, comparative studies were further subdivided into spatial and temporal comparisons:

- Spatial comparisons involved one of two methods:
  - Comparisons of upstream reaches with downstream reaches (see Table 4 for a list of studies using this approach)
  - Comparisons of a reach of interest with a reach along a neighboring unimpounded river (see Table 5 for a list of studies using this approach)
- Temporal comparisons evaluated pre-impoundment conditions along a specific river reach relative to post-impoundment conditions (see Table 6 for a list of studies using this approach). One variation sequentially compared a reach after damming (see Table 7 for a list of studies using this approach).

4.1.1. Upstream/Downstream Comparisons and Their Applicability to Hells Canyon

This study approach has been applied in numerous studies of riverine ecosystems (Table 4). The assumption is that, prior to damming, sequential reaches along a river are exposed to relatively similar hydrologic and geomorphic interactions, resulting in similar riparian ecosystems. A dam and reservoir separate the upstream reaches from downstream reaches, which subsequently experience different physical and biological impacts. The riparian zone along the upstream reach, above the influence of the reservoir, is relatively unaltered by the dam and reservoir and continues to function in a more natural, unimpounded manner. In contrast, the downstream reach is affected by the physical and biological changes. Some impacts, particularly the trapping of suspended sediment load, are unavoidable and are a direct result of the presence of a reservoir. Other impacts, especially hydrologic impacts, are indirect, resulting from the pattern of instream flow regulation, which is often altered by reservoir storage-and-release patterns.

In Hells Canyon, a comparison of upstream and downstream reaches is not well suited for analyzing impacts because the reaches upstream and downstream of Hells Canyon Dam differ dramatically in geomorphology. The upstream reach near Weiser, Idaho, is a broad river valley about 3 kilometers wide (Table 8), with an extensive floodplain that is developed for agriculture. The river channel is relatively wide, averaging about 300 meters from right to left bank (Table 8), and has many islands. The longitudinal slope of the river gradient is very shallow, averaging only about 0.4 meters per kilometer (2.0 feet per mile) near Weiser (Table 9). Consequently, current stream velocities are generally low and relatively incapable of transporting large sediment particles. The broad floodplain and streambanks are composed of alluvial deposits with little bedrock confinement. This lack of bedrock confinement causes the channel to be relatively dynamic. Over time (decades or centuries), erosion and deposition of the fine sediments would allow progressive meandering and island alteration in this fluvial landscape (Osterkamp 1997).

In contrast, the Hells Canyon reach is characterized by a very deep and narrow V-shaped valley canyon entrenched in erosion-resistant basalt bedrock. The river channel in this reach is only about 75 meters wide (Table 8), about one-quarter the channel width of the Weiser reach (Table 8 and Figure 2). The floodplain is extremely limited in occurrence and extent. The Snake River has flowed through Hells Canyon for 2 to 6 million years. The canyon was scoured when Lake Idaho drained about 2 million years ago (Vallier 1998). The combined effects of progressive downward scour and gradual geologic uplifting of the mountainous region has created the impressive canyon that exists today. Relative to these ancient major processes, recent processes have been relatively modest. Except for elevated terraces created by the Bonneville Flood 14,500 years ago, the general physical features of Hells Canyon have been altered only slightly during the past 100,000 years (Vallier 1998).

The igneous bedrock in which the river channel is imbedded is unlike the more erosive sedimentary rocks common along many western North American rivers. The shiny surfaces of the bedrock and boulders abundant near the river's edge indicate the resistance of this bedrock to erosion. The shiny surfaces are caused by the "sandblasting" effect of suspended sediments in the river water (Vallier 1998). The bedrock is the dominant surface material in the riparian zone through the canyon. Because of its dominance, the channel and streambanks of Hells Canyon would be nearly static over the life span of riparian plants.

In addition, the longitudinal gradient of the river channel through Hells Canyon is much steeper than the gradient along the upstream reach near Weiser. The channel slopes are 1.9 meters per kilometer (10.0 feet per mile) and 0.4 meters per kilometer (2.0 feet per mile), respectively (Table 9), a 5.1-fold difference. This increased slope, combined with the narrower channel, produces much faster stream velocities through the Hells Canyon reach than along the Weiser reach upstream. These increased velocities are especially relevant to sediment fluxes, since these velocities and the greater turbulence through Hells Canyon would continue to transport suspended sediments entering the river along the Weiser reach. Thus, suspended materials entering Hells Canyon generally pass through the reach to be deposited in downstream reaches with lower channel gradients and flow velocities.

4.1.2. Impounded and Unimpounded Reaches or Rivers

The comparison of impounded and unimpounded river reaches is based on the expectation that adjacent rivers experience generally similar riparian processes (Table 5). A similar climate and geology would support similar vegetation communities and riparian ecosystems. Consequently, differences in riparian processes because of damming and flow regulation would lead to differences between flow-regulated and free-flowing river reaches.

However, the distinctive nature of each stream can confound the comparison. Although particular river reaches may be adjacent, differences in geology, hydrology, and riparian ecology may exist. Processes along the lower reaches of a stream reflect characteristics of the upstream watershed, and these characteristics may vary substantially between adjacent watersheds. Thus, impounded and adjacent unimpounded watersheds must be compared with caution.

4.1.2.1. Applicability to Hells Canyon

The reach of the Salmon River before it joins the Snake River, referred to as the Lower Gorge, shares similar geomorphology with the Hells Canyon reach (Figures 3a and 3b). Both reaches are deeply incised in basalt bedrock, producing narrow canyons with minimal floodplains. Exposed bedrock dominates both landscapes, and steep bedrock walls flank the deep valleys of both rivers.

The fluvial geomorphic characteristics of the Snake and Salmon Rivers are also similar. The channel widths are similar (mean of 75 meters on the Snake River and 72 meters on the Salmon River), as are the valley widths (129 meters on the Snake River and 128 meters on the Salmon River [operationally defined as the width to 1 topographic contour interval of 12 meters, or 40 feet, above the river]) (Table 8 and Figure 2). Longitudinal gradients (river slopes) are also similar at 1.9 meters per kilometer (10.0 feet per mile) for the Snake River from about Hells Canyon Dam to the confluence with the Salmon River and 2.0 meters per kilometer (10.5 feet per mile) for the Salmon River from near White Bird, Idaho, to the confluence with the Snake River (Table 9). The Hells Canyon reach of the Snake River and the Lower Gorge of the Salmon River also share a similar climate and flora (Figures 3a and 3b). Thus, considerable similarities in geomorphology and riparian ecology exist along the adjacent reaches of the Snake and Salmon Rivers.

4.1.2.2. Differences Between the Snake and Salmon River Watersheds

While the adjacent reaches of the Snake and Salmon Rivers appear remarkably similar, the upstream reaches and watersheds differ substantially. The upstream watersheds differ in geomorphology and geology and have experienced substantially different patterns of human impact. In addition, the Snake River changes dramatically with the hydrologic and sediment inputs of the major tributaries upriver of the Hells Canyon reach. These differences, discussed below, argue against a simple contrast and indicate that, if we were to compare these reaches, we should interpret the information cautiously.

Geologic and Geographic Differences

The Snake River originates in western Wyoming and then flows in a wide arc across the Snake River Plain in southern Idaho. The Snake River Plain is composed of extensive erosion-resistant lava beds with little soil cover or vegetation. These areas add limited amounts of natural sediment to the Snake River system. In contrast, the Salmon River and its tributaries flow through extensively forested mountainous regions of the Challis, Salmon, Bitterroot, Payette, and Nez Perce National Forests. These regions support extensive vegetation cover and add mobile sediments to the stream systems.

The Snake River watershed is also much larger than that of the Salmon River (Table 10). However, much of the Snake River watershed is semiarid or arid, whereas the Salmon River watershed is generally wetter. These climatic conditions cause further differences in vegetation cover, which influences patterns of surface runoff, especially following intense precipitation events. The dampening effect that vegetation has on runoff, or snowmelt pulses, influences not only hydrologic patterns, but also the patterns of sediment inputs of both streams.

In addition, typical characteristics of the Snake and Salmon Rivers upstream of the adjacent Hells Canyon reaches differ. The Snake River follows a typical pool-and-drop river style. This pattern is particularly dramatic near Twin Falls, Idaho, as the Snake River cascades over Twin Falls, Shoshone Falls, and a number of smaller waterfalls. This pool-and-drop sequence produces high-energy areas near the falls and subsequent low-energy pools where suspended materials settle. The Salmon River, however, is not a pool-and-drop river; rather, its gradient is relatively consistent from the headwaters near Stanley to Riggins, where it turns north to enter the Lower Gorge. No substantial falls similar to Twin Falls or Shoshone Falls exist along the mainstem of the Salmon River.

However, some characteristics of the Salmon River’s hydrology and sediment features are comparable to those of the five major tributaries of the Snake River (Owyhee, Boise, Malheur, Payette, and Weiser Rivers) located just upstream of the Weiser gauge. These tributaries have geology and climatic regimes similar to those of the Salmon River Basin. Recent USGS studies show that the sediment supplies of these rivers are similar to those of the Salmon and Clearwater Rivers (Osterkamp 1997). Hydrologic inputs from these tributaries account for 40 percent of the average annual flow and 40 to 60 percent of the peak flows recorded at the Weiser gauge (Table 10). The high peak flows of these tributaries are significant since such flows transport relatively high levels of sediment. Additional smaller tributaries below the Weiser gauge (Burnt, Power, and Wild Horse Rivers) provide further hydrologic and sediment inputs comparable to those of the Salmon River. These data indicate that adjacent reaches of the Lower Gorge of the Salmon River and Hells Canyon reaches are not as dissimilar as the characteristics of their upper watersheds may suggest.

The Bonneville Flood

While the overall features of the Hells Canyon reach of the Snake River and the Lower Gorge of the Salmon River are similar, one prominent type of geomorphic feature differs substantially. Elevated terraces are typical where the river valley broadens or tributaries join the

Snake River. These terraces are usually characterized by massive deposits of alluvial gravels and other sediments situated up to tens of meters above the river channel. These terraces were deposited during the massive Bonneville Flood about 14,500 years ago (Vallier 1998). Flood stages and characteristics can be inferred by the terrace elevations and other geographical remnants (O’Connor 1993). Flows through Hells Canyon were estimated to have reached volumes of about 600,000 m^3/s (20 million cfs) and velocities of 15 m/s (30 mi/h). Because these flows dwarf those of any contemporary floods, the Bonneville terraces are functionally disconnected from contemporary Snake River flows.

The Salmon River experienced neither the Bonneville Flood nor any equivalent paleo-period flood; consequently, this river system has no geomorphic features equivalent to the massive terraces of Hells Canyon. The Bonneville Flood would also have had other impacts to the affected reach of the Snake River, especially on sediments through Hells Canyon, along the upstream reaches, and in watershed areas affected by the flood and other geomorphic events of both the glacial and post-glacial periods.

Human Impacts

Human Settlement—Virtually all land uses in a watershed affect patterns of water-surface flow, which, in turn, influence river hydrology and sediment inputs. The immediacy and the extent of these effects are often proportional to the proximity of the land uses to the river. The Snake and Salmon Rivers vary dramatically in accessibility and therefore human history. The Snake River corridor in southern Idaho has been the focus of agricultural development and human settlement of Idaho. In contrast, the Salmon River flows through the Frank Church River of No Return Wilderness Area, one of the least accessible areas of the contiguous United States. Settlement was and is much more substantial along the Snake River than along the Salmon River. The extensive agricultural developments along the Snake River in eastern and southern Idaho dramatically altered aspects of river flow and sediment transport.

Beaver Harvest—Diverse human impacts influence hydrology, fluvial geomorphology, and consequently vegetation ecology through Hells Canyon and the Lower Gorge of the Salmon River. In the early 1800s trappers removed beavers, creating the first major impact on these basins and their tributaries. The Hudson Bay and Northwest Trading Companies attempted to eliminate beaver from Oregon and Idaho as a means of deterring American immigration and territorial claims on the Pacific Northwest (Ott 1997). By 1826, beaver populations were reduced to such low levels that the Owyhee, Weiser, Malheur, and Payette Rivers were largely devoid of the species (Hudson’s Bay Record Society 1979). The annual harvest of beaver pelts for the entire Snake River Basin (including all of its tributaries) was down to only 378 pelts by 1832 (Clark 1995). The removal of beaver and subsequent deterioration of their dams would have significantly decreased floodplain storage capacity, increased peak flows, and altered sediment-supply patterns.

Logging—Timber harvest generally changes the vegetation understory and groundcover. These changes alter rates of snowmelt, surface runoff, and surface sediment erosion. Effects of timber harvest on sediment were considerable for some of the tributaries of the Salmon River. Livestock production can also diminish the vegetation cover, which further influences the rates of water and sediment runoff. Livestock production was considerable in both the Salmon and Snake River watersheds, but historical records of livestock use are incomplete (see section 4.2.5. for details on grazing impacts).

Mining and Other Anthropogenic Activities—Both basins have been substantially mined (NWEA 1992), but as with other uses, the record of historical extent is incomplete. Clearing native vegetation and cultivating agricultural crops were more common along the Snake River and continue to dominate the landscape along the Snake River and its tributaries in much of eastern and southern Idaho. Road construction through the watersheds has been considerable; many of the primitive roads are prone to erosion and alter water and sediment runoff. Railway lines were typically built along rivers since these corridors often provided favorable topographic grades. Finally, most towns and cities of the American West were located along rivers because they provided water, food, building resources, and transportation corridors. In these communities and other domestic settlements, riparian areas were often cleared, and levees or other physical structures were built to influence fluvial processes.

Dams

The Snake and Salmon Rivers present an extreme contrast with respect to river damming. The Salmon River was briefly impounded by the Sunbeam Dam, but is currently unimpounded and remains one of the few free-flowing rivers in the western United States. The absence of dams probably reflects the remoteness of the Salmon River Basin since favorable dam sites exist.

In contrast, the Snake River is one of the most extensively dammed and diverted rivers in North America (Palmer 1991). The first dam on the Snake River from its origin is Jackson Dam, located at Jackson Lake in Grand Teton National Park. Downstream, this dam is followed by Palisades Dam, a sequence of weirs near Idaho Falls. Then several dams—American Falls, Minidoka, Milner, Shoshone Falls, Twin Falls, Upper Salmon Falls, Lower Salmon Falls, Bliss, C.J. Strike, and Swan Falls—lie along the Snake River prior to the Hells Canyon Complex. However, depending on the criteria for inclusion, 41 additional dams are located along the Snake River tributaries upstream of where the Snake River flows into Brownlee Reservoir (NWEA 1992).

Each of these numerous dams affects the patterns and extent of river flow and sediment transport. The smaller dams have less effect, while the larger reservoirs, such as Palisades and American Falls, more greatly influence both flow patterns and sediment passage. Because these dams were built to allow water to be captured, stored, and diverted for irrigation, they alter the hydrograph pattern and reduce the overall flow of the Snake River in some years. Flow reductions in the Snake River are proportionally much greater in dry years when river flows are lower and irrigation demands are higher than they are in the Salmon River.

4.1.3. Temporal Comparisons and the Complexities to be Considered

A temporal comparison of wildlife and habitat conditions in the 1950s with those of the 1990s was chosen for two reasons:

- Problems associated with the two spatial comparisons—comparing upstream and downstream reaches and comparing the Lower Gorge of the Salmon River with the Snake River through Hells Canyon.
- The availability of pre-impoundment photographs, as well as information about wildlife and habitat conditions prior to construction.

However, we also had to consider several complexities associated with evaluating conditions for two different time periods. Those complexities included natural variation, coincidental influences, cumulative and progressive impacts, threshold effects, latent effects, and problems associated with a simple comparison.

4.1.3.1. Natural Variation

Riparian zones are naturally dynamic since river flows vary within and among years. Occasional flood events can dramatically and quickly affect riparian zones through erosion and deposition. Riparian plants often become established as a result of episodic flood events, and the initial destruction of these events can rejuvenate the ecosystem. Droughts also occur naturally, and these droughts reduce riparian vegetation. During dry and wet cycles, riparian vegetation naturally experiences sequences of decline and recovery. Because of these natural cycles, the effects of damming and flow regulation cannot be compared according to a static baseline.

Instead, we might find patterns of natural variation by analyzing historical hydrographs and reports and by studying riparian patterns along adjacent streams. However, even these approaches could provide uncertain outcomes since some natural processes, such as heavy rains or ice jams, could be local and affect specific streams or even reaches, while neighboring reaches are relatively unaffected.

4.1.3.2. Coincidental Influences

Riparian ecosystems are influenced by many natural and anthropogenic factors, a number of which may coincide with damming historically or spatially. For example, exotic weeds have progressively migrated throughout the western United States, and their expansion has often coincided with extensive river damming. In the same period, patterns of livestock production also varied dramatically, affecting riparian vegetation and influencing the encroachment of exotic species.

4.1.3.3. Cumulative and Progressive Impacts

Determining specific effects of a particular water resources project is difficult when the effects of various dams and diversion weirs are combined. Essentially, these effects could be cumulative or progressive. Cumulative impacts “accumulate” temporarily because of dams and diversions located along the stream. Progressive impacts accumulate over time. Some of both types are additive in nature, while others may be more complex. Therefore, the overall consequences may not necessarily be assessed simply as the sum of the parts.

4.1.3.4. Threshold Effects

Threshold effects are related to cumulative impacts. An ecosystem or component may be relatively unaltered by artificial modifications up to a point, or threshold, after which it responds considerably. Particularly, some physiological stresses are tolerable within certain ranges. For example, coldwater fish may thrive until water temperature exceeds a particular point, at which the population may plummet. A similar process probably occurs for riparian shrubs and trees: water stress may have little effect until the xylem cavitation threshold is reached and abruptly leads to shoot mortality.

4.1.3.5. Latent Effects

Latent effects are those effects for which the timing is delayed. For example, a particular alteration in stream flow may retard fish spawning or vegetation recruitment. If the populations of mature fish or trees are being monitored, the impact may not be observed until a substantial fraction of the life cycle has passed. Trapping and removing beavers would have similar latent effects on stream geomorphology. Additionally, higher-order members of the ecosystem may not be affected by a negative impact until the lower-order prey base is substantially diminished.

4.1.3.6. Multiple Comparisons

Each comparative approach strengthens the database and increases the confidence in subsequent interpretations. In the ideal case, investigators would use all comparative approaches, although this practice is rarely possible (Rood and Heinze-Milne 1989). The abrupt geomorphic transition associated with Hells Canyon excludes some comparisons. But the present comparison between pre-construction and current photographs and descriptions suggests that further comparison between Hells Canyon of the Snake River and the Lower Gorge of the Salmon River might be worthwhile.

Because of potentially confounding factors, simple comparisons involving only two river reaches at a single point in time or at a single reach at two times may be particularly vulnerable to errors in interpretation. Conversely, the range of comparative strategies available allows multiple comparisons involving more than two river reaches or more than a single point in time. Such an approach would increase our ability to draw conclusions about the influence of the Hells Canyon Complex. Therefore, this study begins with an assessment of anthropogenic disturbances, continues with a multiple photo point interpretation of riparian and wildlife habitat, and concludes with a comparison of historical and current conditions and a discussion of the effects of the Hells Canyon Complex.

4.2. Influence of Anthropogenic Disturbances on Physical and Biological Processes

The physical and biological processes within Hells Canyon have been affected by a wide variety of factors since European settlement. Settlement patterns in the study area were closely related to topography and water availability. Flatter lands near the Snake River and tributary mouths generally had the highest concentration of people and, therefore, some of the highest levels of human influence on native plant and wildlife communities.

The physical and biological influences occurred through geomorphic and hydrologic processes, settlement, agriculture and irrigation, ranching and grazing, fire, logging, and hunting. The relative level of these activities varied by study reach. However, the general effect of those physical and biological influences on native communities was similar for a given activity, such as grazing or mining. In the following sections, we provide background on the hydrologic and fluvial processes, as well as describe the various anthropogenic disturbances that have affected the physical and biological processes within Hells Canyon.

4.2.1. Description of Hydrologic and Fluvial Processes within Hells Canyon

Fluvial geomorphology is the study of the interaction between rivers and the surficial topography of the earth, including geology, soils, and other sediments. Geomorphic processes continue to occur through erosion and deposition as rivers adjust to hydrologic events and anthropogenic factors. The form of a river (known as river form) significantly affects its hydraulics and habitat for aquatic life, riparian and other vegetation, and terrestrial wildlife. The quality and quantity of habitat is a function of hydraulic variables such as velocity and depth, substrate (sediment size distributions), and relationship between channel/floodplain geometry and flow regarding seasonal patterns of inundation and recession rates of flow hydrographs. All of these important factors are caused directly by the interaction between flow and geomorphology. While other factors may either benefit or adversely affect habitat, the primary factor affecting the quality and quantity of habitat remains the direct relationship between water and the earth’s surface. In some rivers, geomorphic processes are quite dynamic, while in others they are relatively static, but punctuated by rare yet dramatic events that alter the channel to some degree. Despite the relative rate of geomorphic dynamics, the river form dictates riverine hydraulics and plays a significant role in habitat and biological processes.

Most watershed and river systems fit the classic description of the “idealized fluvial system” developed by Schumm (1977) to better understand the key geomorphic zones (Figure 4). The classic idealized fluvial system originates in an upper watershed area where most of the water is produced. This area generally has significant topographic relief consisting of mountains and valleys. In addition to producing water in the form of surface runoff, this area also produces sediment. These fast mountainous streams have high erosive energy and can transport considerable amounts of sediment.

After flowing from the upper watershed area, the classic river system flows through a relatively flat alluvial plain, where gradients are significantly flatter, and energy to carry sediment eroded from the upper watershed is reduced. Here the river tends to deposit the coarser sediment load produced and transported by the steep upper rivers, causing the river to fill and shift repeatedly. This filling and shifting results in a wide multiple-channel, dynamic system classified as a braided river. As the coarser material drops out through the braided reach, the classic river system becomes a relatively stable reach with a narrower, deeper river channel and meandering path. Most of the finer sediments and some of the coarser material passes through this zone, which has been called the transfer zone.

As the river approaches the coastal zone (or lake, reservoir, or flat reaches along the longitudinal profile of the river), it often splits into a number of channels in the classic delta formation. As a river transports sediment into the sea, the velocity of flow decreases and sediment is deposited. Gradually, the deposit builds out into the sea, and the gradient of the river becomes flatter and flatter. More deposition of sediment occurs until the channel becomes sufficiently flat and full of sediment that the river shifts to an alternate route to the sea. This process continues and leads to the classic fan-shaped, multiple-channel delta configuration known as the deposition zone.

The Snake River in the study area is located in the sediment transfer zone, where most of the sediment from the production zone passes through. In this general classification, the tributaries to the Snake River are generally considered sediment production zones. These tributaries—which include the relatively large Powder, Imnaha, and Salmon Rivers, the relatively small Wild Horse River, Pine Creek, Rush Creek, and many smaller tributaries—are steep and periodically erode and produce sediment. The small tributaries that contribute water and sediment directly to the Hells Canyon reach of the Snake River generally produce a significant percentage of their sediment load as coarse sediment (gravel, cobbles, and boulders).

Although the Hells Canyon reach of the Snake River is classified as the sediment transfer zone, coarse material from local tributaries is deposited in this reach. Some of these deposits have formed rapids in the Snake River. Some fine material (primarily sand) have also been deposited in the study area, primarily in isolated areas where river currents reverse and flow upstream in near-shore environments that are sheltered from the stronger, predominantly downstream current. Except for the coarsest material, these deposits may be transitory, with some of the sediment occasionally eroding and flowing downstream, while other sediment from upstream is added. These depositional features may also be transitory since they may grow or shrink in response to both long-term trends in sediment supply and transport capacity as well as to infrequent events that can mobilize and transport substantial sediment, such as the Bonneville Flood.

4.2.1.1. Stream Flows

A number of stream flow gauges are located on the Snake River and tributaries. One of these gauges, in operation since 1910, is located at Weiser, which is the upstream end of the study area at river mile 351.3 (see Figure 5 for a record of total annual flows over the period of record). The drainage area contributing flow to the Weiser gauge is 69,200 square miles.

Frequently, the total annual flow at Weiser ranges from 10 to 15 million acre-feet. The minimum and maximum total annual flows were approximately 6.1 and 23.1 million acre-feet, respectively. Despite significant water resources development in the Snake River Basin, the flow data at Weiser do not reflect any significant long-term trends. The greatest range of extremes is concentrated in the period since about 1970 (Figure 6). Likewise, a significant long-term trend in the peak flow data is difficult to discern. In 1910, the highest peak flow occurred; however, no pattern in the range and distribution of peaks is readily discernible.

Another long-term gauge in the Snake River Basin is located near Murphy (at RM 453.5 and with a drainage area of 41,900 square miles). Data collected at this gauge do appear to show a trend in peak flows over time (Figure 7). From the beginning of the record in 1914 until the 1930s, peak flows steadily decline. Peak flows in the 1930s were probably lower than average because of widespread drought conditions, and there was some rebound to average levels after the 1930s. However, peak flows before the 1930s surpassed most of the higher range of peaks since the 1930s. While this hydrologic trend is not as strong as trends exhibited in other watersheds where significant water resources have been developed, such as the Platte River in Nebraska (Simons and Associates 1990), this particular data set seems to indicate the existence of a trend of decreased peak flows.

In addition, we investigated average monthly flows, representing patterns of flow through the year, for the Weiser gauge for the period from 1910 through 1997 (Figure 8). Flows typically build through the beginning of the year as winter becomes spring. The highest mean monthly flows, typically caused by snowmelt runoff, occurred in May. As spring turned into summer, flows receded fairly rapidly to the lowest flow of the year, usually in August. From summer to fall and early winter, the flows gradually built back up to near what would be the average for the entire year. This flow pattern is typical of the snowmelt-dominated runoff associated with many rivers and streams in the mountainous regions of the West. The typical pattern, represented in Figure 9, uses averaged data, though the actual pattern of flows varies to some degree from year to year.

Peak flow distribution at Weiser was also investigated for two time periods: 1911 to 1950 and 1951 to 1998. The distributions of each period, shown in Figures 10 and 11 respectively, are similar to each other and to the entire period of record. This finding suggests that the timing of the peak flow has not shifted significantly between the two periods. In the recent portion of the record, fewer peaks seem to have occurred in June and more in April and February than in the earlier portion of the record.

The occurrence of multiple peak flows each year was important in our evaluation of the historical hydrographs. Runoff each year tends to peak and recede four or more times, a phenomenon that can probably be attributed to occasional storm events (especially warm rain on the snowpack before the main runoff) or to snowmelt from various upstream watersheds peaking at different times through the runoff season. Below is a comparison of the number of multiple peak flows for the pre- and post-1950 periods.

Occurrences of multiple peak flows between the two time periods are similar. Though their patterns and timing have probably been affected by the development of upstream water resources, the magnitude of such effects has not been quantified. Peak flows and their timing are also affected by several relatively large tributaries—such as the Owyhee, Boise, Malheur, Payette, and Weiser Rivers—that join the Snake River in the reach just upstream of Weiser. Each of these rivers has also been affected by water resources development and other land activities. Except for the Weiser River, all of these rivers have one or more major storage reservoirs.

Another key factor is the rate of recession of the hydrograph. The timing and magnitude of flow recession plays a significant role in establishment and survival of riparian vegetation. The historical pattern of flow recession (Tables 11 and 12) along riverine reaches and water-level recessions in reservoirs yields important data on the potential impacts of fluvial regimes on the establishment and distribution of riparian habitat within the study corridor.

The longitudinal profile of the Snake River upstream and through the study area also provides insight into geomorphology and sediment issues (Figure 12). The longitudinal gradient of the river channel through Hells Canyon is much steeper than the gradient along the upstream reach near Weiser. The channel slopes are 1.9 meters per kilometer (10.0 feet per mile) and 0.4 meters per kilometer (2.0 feet per mile), respectively (Table 9), a 5.1-fold difference. Thus, the river is about four times steeper in Hells Canyon than it is in the upstream reach, which provides its sediment supply from the general Snake River watershed. The transition between the relatively flatter upstream section and the steeper downstream reach occurs about 30 miles downstream of Weiser (Figure 12).

4.2.1.2. Slope

This difference in river slope affects its sediment transport capacity. Sediment transport can be described as a power function of velocity ($Q_s = aV^b$, where Q_s is sediment transport, a is a coefficient, V is the velocity of flow, and b is an exponent). Velocity is related to the square root of slope through the commonly used Manning's equation. We can compare sediment transport capacity by taking the ratio of sediment transport in the canyon over that in the upstream reach. The exponent, b, has typically been found to be from 3 to 4, based on other river systems. Thus, the ratio of sediment transport capacity through the canyon compared with the ratio for upstream simplifies to the ratio of the slopes to the $b/2$ power.

Given that the ratio of slopes above and within Hells Canyon is about 5, and that b is 3 to 4, the sediment transport capacity through the canyon is about 11 to 25 times larger than the sediment transport capacity for the reach upstream. This result means that, in a free-flowing condition, the Hells Canyon reach was generally in a sediment deficit with respect to the upstream supply of sediment transported through the reach immediately upstream. In other words, the river through Hells Canyon can transport about 11 to 25 times more sediment than can be delivered from upstream simply because the canyon reach is steeper. Thus, for every ton of sediment supplied by the upstream watershed via the Snake River past Weiser, the steeper Hells Canyon reach can transport 11 to 25 tons of sediment. The actual sediment transport does not equal the capacity of the river to transport sediment (because of the existence of bedrock areas and a phenomenon known as armoring, by which coarser sediment particles remain on the bed surface and protect the finer sizes of sediment deposited beneath). The sediment produced by the upstream watershed is quite easily transported through Hells Canyon, though, as noted above, some of the coarser sediment and a relatively small percentage of finer sediment is deposited in isolated areas.

Relationships among several key variables provide additional understanding of sediment and geomorphic issues. These relationships were developed by Lane (1955) and Simons and Sentürk (1975), as described in Simons and Sentürk (1992). In its simplest form, the product of flow and slope is proportional to the product of sediment transport (Q_S) and median sediment particle size (D_{50}):

$$QS \sim Q_s D_{50}$$

Over the long term, the flow upstream of the study area is essentially the same as the flow through the study area, except for some general increase due to tributary inflow. However, the slope is significantly steeper in the downstream reach. Thus, either sediment transport increases or the median particle size increases in the downstream reach. This relationship is consistent with the observed transition from the flatter upstream reach with generally smaller bed material to the downstream reach that is dominated by significantly coarser material. While some increase in the actual magnitude of sediment transport is possible because of the steeper slope in the downstream reach, the actual sediment transport does not meet its capacity because of the natural tendency for channel armoring. Through the process of hydraulic sorting, the finer sizes of sediment exposed to the flow are readily transported downstream, while the coarser sizes are left behind.

4.2.1.3. Sediment Transport

The basic geomorphic and hydraulic processes, which are tied to sediment transport, are affected by disturbances in upstream reaches of the Snake River and in upstream reservoirs and drainages. Well before the 1950s, large-scale agricultural development occurred along upstream reaches of the Snake River in eastern and southern Idaho, as well as on the floodplains of the major tributaries. Mining, logging, and especially livestock grazing also influenced many areas of the upstream watershed. Each of these activities generally exposed soil to erosion by removing or damaging vegetative cover. The erosion increased the amount of sediment in tributaries to the mainstem of the Snake River.

Water diversions for the Snake River above Weiser currently irrigate about 3,650,000 acres, of which about 742,000 acres are derived from groundwater withdrawals (USGS 1999). In addition, a considerable amount of acreage is cultivated for dry land farming. Thus, millions of acres are and have been used for agriculture. On a qualitative level, the volume of runoff and sediment has likely increased compared with levels prior to both settlement and the construction of the Hells Canyon Complex.

However, significant development of water resources upstream of the study area has countered the effects of increased sediment loads (Figure 13). Much of the drainage area of the Snake River, which would have otherwise contributed sediment to the system, is located upstream of dams that were constructed before or during the 1950s. In the 1950s, this unimpounded drainage area, contributing sediment to the study area from upstream sources, was roughly 9,000 square miles out of the total Snake River drainage area of 69,200 square miles upstream of the study area (USGS 1999).

In contrast, the size of the drainage area within the study area is relatively small. From Weiser to the Brownlee Dam, the drainage area increases from 69,200 to 72,590 square miles, or 3,390 square miles, over a distance of about 66 miles. This drainage includes the Powder River and numerous small tributaries. From Brownlee Reservoir to Hells Canyon Dam, the drainage area increases by 710 square miles along about 38 miles. From Hells Canyon Dam to the USGS gauge at Johnson Bar, the drainage area increases by only 100 square miles over 17.1 miles. Therefore, the increase in drainage area within the study area from Weiser to just upstream of the Imnaha River at a discontinued gauge on the Snake River near Joseph was estimated to be approximately 4,600 square miles, most of which occurs upstream of Brownlee Dam. Near the downstream end of the study area, the Imnaha and Salmon Rivers join the Snake River and contribute flow and sediment from an area greater than 14,000 square miles.

Since the drainage area contributing sediment within the study area is currently about 4,600 square miles (not including the Imnaha and Salmon Rivers), the total drainage area contributing sediment to the Snake River upstream of the Imnaha River before construction of the Hells Canyon Complex was approximately 13,600 square miles out of a total watershed area of 73,800 square miles. The Hells Canyon Complex reduced the drainage area that contributed sediment upstream of the Imnaha River by about 4,100 square miles. However, other upstream projects reduced the sediment-contributing drainage area by about 50,000 square miles. Therefore, less than 10 percent of the overall sediment-contributing drainage area was cut off by the Hells Canyon Complex, while over 90 percent of the sediment-contributing drainage area was cut off by other upstream water storage projects on the Snake River and its tributaries.

There were also land disturbances within Hells Canyon that affected sediment. The land disturbances accelerated erosion and produced sediments above the natural erosion rate from the canyon hill slopes, floodplain terraces, and tributaries. Just before the Hells Canyon Complex was constructed, the sediment supply from the locally contributing drainage area would have been greater than it would have been under natural, undisturbed conditions. Thus, from this local source, the sediment transport to and through the study area portion of the Snake River would have been increased. There are many documented examples of increases in sediment load caused by various disturbances in the Salmon River drainage basin. Platts (1974) reported disturbances of fire, logging, road construction, and ineffective land rehabilitation. Descriptions accompanying photographs in Platts (1974) show the severity of these activities. The caption of one photograph states, “This area then ‘blew-out’ putting large quantities of fine sediments directly into the South Fork Salmon River immediately upstream from its largest salmon spawning area.” Another caption reads in part, “Logging and construction of roads on these lands were responsible for the main deterioration of the tributary and river environments because of increased sediment accruement.” Yet another states, “Stream blowout resulting from logging roads in the fluvial geologic process group…. Most of these mass failures of soil move sediment directly into the streams.” Similar disturbances and increased sediment production occurred throughout the Snake River Basin.

4.2.1.4. Storage Capacity

The total reservoir storage capacity in the Snake River basin up to Hells Canyon Dam exceeds 10 million acre-feet (USGS 1999). Total reservoir storage capacity of the Hells Canyon Complex (Brownlee, Oxbow, and Hells Canyon Reservoirs) is 1.48 million acre-feet. Thus, from a storage capacity perspective, the Hells Canyon Complex represents only about 15 percent of the total storage capacity in the Snake River Basin.

4.2.2. Settlement

Human occupation affected existing natural processes in Hells Canyon in several ways. The area has been inhabited by humans for at least 8,000 to 12,000 years (Daubenmire 1970, Chatters and Reid 1999 to 2000). These early Americans, including the Nez Perce Tribe, inhabited the Pacific Northwest's intermountain region prior to European settlement and often wintered in Hells Canyon. Generally, these groups lived in an environment offering various and abundant natural food resources at different times of the year. Once the Nez Perce acquired horses in 1730, their herds grazed adjacent to villages along the Snake River (Daubenmire 1970). The impacts of grazing to upland vegetation were probably localized because horses were closely herded. However, impacts on riparian communities near settlements, while probably localized, were more significant. Fire and grazing were apparently of limited importance in the shrub-steppe vegetation of Hells Canyon before Euro-Americans settled the area and grazed their livestock (Daubenmire 1970).

Euro-American settlement of the Hells Canyon area came from three directions: northeast from Missouri, as Oregon Trail emigrants stayed along inviting rivers and valleys instead of continuing to the coast; from the west, as a "backwash" of Oregon Trail travelers returned to less settled lands; and from the south, as California gold seekers followed new strikes in Florence, Pierce, near Baker City, and later in the Boise Basin. Many early settlers ran ferries, operated way stations and hotels, or hauled freight to serve emigrants and miners. Early settlements (1860s) included Brownlee, Olds Ferry, and Pittsburg Landing. In 1863, a ferry was built at Farewell Bend, bringing more traffic through the Weiser Valley. Though most early settlers were white Euro-Americans, Chinese immigrants followed white miners to rework claims in the Hells Canyon area; few stayed. As ranching developed in the 1880s and 1890s, many Basque immigrants found work in the Snake River country as sheepherders.

Most of the Inland Northwest was settled by the mid- to late 1800s. By 1880, the Hells Canyon vicinity was quickly homesteaded after the Nez Perce War of 1877 and subsequent forced removal of Native Americans. The discovery of gold and resulting influx of white settlers probably led to this war.

The Weiser reach was settled in the late 1800s. In fact, 1889 GLO records note settlers in five sections of land along the Brownlee reach in the vicinity of Dennett Creek: "the land along the river is nearly all taken by settlers and a greater portion is in cultivation" and "extensive improvements [have been] made by each settler." Other GLO records mention settlers at flat spots in the next two townships north of Dennett Creek and a house at Cottonwood Creek. A 1909 record describes a number of settlers owning well-improved farms and cultivating the bottomlands along the Wild Horse River. A 1910 entry noted irrigation of some crops along the Wild Horse River. Other settlements with substantial improvements were noted just below the current site of Brownlee Dam and at several locations along the current Oxbow and Hells Canyon Reservoirs. Jones (1989) discussed many early settlers in the canyon. Occupied drainages included Brownlee, Pine, Indian, Steve's, and Bear Creeks and the Wild Horse and Crooked Rivers. Settlers on these creeks had early water rights dating from 1872 to 1895. The towns of Landore, Decorah, and Cuprum were established on Indian Creek. At one point Landore and Decorah had populations of 2,000. Homestead was another thriving community. Other small settlements included Robinette and Home.

4.2.3. Mining

Mining has played a central role in the development of the Hells Canyon area from Farewell Bend to the confluence of the Snake and Salmon Rivers. The 1860s discovery of gold in river bars near either end of what is now the Hells Canyon National Recreation Area (HCNRA) brought a flood of human traffic. A rich copper lode, reportedly 550 feet long and 80 feet wide, was discovered in 1862 in the area known as the Seven Devils. Access to the area was difficult, and interest in copper was limited at the time. However, copper mining in the Seven Devils was helped by the October 1874 discovery of silver along Brownlee Creek. Enough ore was found to create substantial interest in the area. In 1875, the mining district of Heath was organized. That year, copper ore was identified in the district. Eastern mining interests heavily promoted the area in 1876 (Arrowrock Group 1995).

During the 1880s and 1890s, the Seven Devils district became an active mining center. Many mines were in operation, including the Blue Jacket, the Queen, and the Alaska. A railroad was partially built, a smelter was in operation, and three towns—Cuprum, Helena, and Landore—were established. Transporting supplies and ore proved difficult because of steep terrain; this transportation problem was the largest obstacle to profitable mining development.

Mining activity also took place across the river in Oregon. In 1899, gold was discovered near the mouth of the Imnaha River. Also that year, more than 50 claims were taken on Squaw Creek, opposite the Seven Devils mining region. The town of Eureka sprang up in the canyon but died by 1906 because of transportation difficulties and a lack of major strikes. Two more towns, Homestead and Copperfield, were organized. They experienced a brief boom before the onset of World War I forced many mines to close. However, mining production has continued throughout the years: as recently as 1980, new mining efforts occurred in the Seven Devils region.

GLO records for Idaho refer to mining activity at a number of sites between the 1870s and 1920s. Mining was noted at several named and unnamed locations in the Brownlee reach, including Brownlee Creek. Extensive mining was also noted along the Wild Horse River, which enters the Snake River just below Brownlee Dam. GLO records noted three separate mines about 3 miles below the Oxbow Dam site along the Hells Canyon Reservoir subreach and "considerable mining development" apparently along the Deep Creek drainage, which also enters the river right below Hells Canyon Dam. Few GLO records exist for the river below Hells Canyon Dam. However, mining in this reach was noted at Bernard Creek, Eureka Bar, Dug

Bar, Salt Creek, Somers Creek, Temperance Creek, and Big Bar. USDA (1980) indicated that 100 mining sites were located along the Snake River within the then-proposed HCNRA. Apparently the Winchester mine near Battle Creek was one of the more prominent mine sites.

Extensive mining development higher in the drainages of many of the tributaries damaged riparian habitat. Testimony at the Federal Power Commission hearings (Federal Power Commission 1959) noted that there were numerous mining and agricultural diversions from Pine Creek (Pine Creek enters the Snake River a half mile below Oxbow Dam) from the 1930s through the 1950s. Water was diverted from the Powder River for sluice mining as early as 1861 (U.S. Census Office 1896), and Chapman (1940) noted that the Powder River was generally very muddy from above Baker to its mouth because of dredge mining upstream of Baker during the 1940s. Similar activities occurred on many drainages. Undoubtedly, these diversions and increased sediment loads, combined with mining activities adjacent to the Snake River, adversely affected riparian communities within the study area (Arrowrock Group 1995).

Placer mining was the most common form of mining in the study area (D. Turnipseed, *pers. comm.*). Hydraulic mining also took place, as well as hard-rock mining. Most of the placer mining occurred in the lower riparian zones; about half of these sites were flooded when the reservoirs filled. The longest of the placer mining sites covered 900 to 1,200 feet along the Snake River. Virtually all the hard-rock mining occurred higher on the slopes, generally above areas flooded by the reservoirs.

Mining affected wildlife habitat both directly and indirectly. Direct impacts included removal of riparian vegetation from streams so that the gravels could be worked, burial of other vegetation by mine tailings, extensive removal of slopes and streambeds by placer and hydraulic mining techniques, clearing of vegetation, and grading and blasting for roads and facilities (Arrowrock Group 1995). Trees surrounding mining sites were harvested to frame tunnels and power steam engines used by both hard-rock and placer mining operations. In Hells Canyon, wood sources were primarily limited to alder and some cottonwood growing along tributaries and to pines growing mostly at higher elevations. In some areas, trees were cleared along the tributaries, and logs from higher elevations were skidded down these steep channels to mining sites. The resulting absence of riparian vegetation in tributaries to the Snake River can be seen in historical photographs as late as 1934 (Series 25). Removal of woody riparian vegetation by miners and the placer and hydraulic mine operations probably significantly altered the structure and composition of riparian plant communities and severely degraded wildlife habitat quality along affected sections of the Snake River and tributaries.

The support systems required for mines to operate also had direct effects. With dynamite and leveling equipment, miners eventually converted pack trails to the mines into roads. Such construction filled the streams with rocks and debris. Placer miners first used dams, water wheels, flumes, and ditches to divert water. In some areas of Hells Canyon, advanced technology eventually allowed miners to use high-powered hydraulic methods to wash and dredge alluvial sand and gravels. At these sites, hillsides and streambanks were gouged, and rocks and gravel tailings were left behind. The remnants of mine tailings are commonly found on alluvial bars and marginal sandbars along the downstream reach (Chatters and Reid 1999 to 2000).

Indirect damage resulted from widespread water diversion within drainage basins, while mining activity and roads destabilized streambeds, which led to blowouts. Blowouts are debris flows in which water, gravel, rocks, trees, and soil move down a drainage, scouring all fine sediment and vegetation in the path. A streambed scoured of fine sediment and vegetation but with large quantities of coarse debris deposited at the mouth typically remains. Woody riparian vegetation may take 20 to 40 years or longer to recover after a blowout. J. Morrison (IDFG retired, *pers. comm.*) noted that tributary blowouts were common in the 1950s. Arrowrock Group (1995) also noted that mine-related chemical spills killed aquatic life in streams, which would adversely affected other wildlife species that used riparian zones.

4.2.4. Agriculture and Irrigation

Ranching and farming quickly followed on the heels of mining ventures in Hells Canyon. Many would-be prospectors found it more profitable to raise livestock and vegetables to sell to the gold camps and travelers rather than search for gold. The wider valley floor of the Weiser and Brownlee reaches contains larger alluvial terraces and fans more suitable for cultivation than the constrained canyon reaches. These areas were also more accessible to local markets than downriver reaches, such that agricultural activities in the Weiser reach were relatively well established by the 1870s to 1880s (Arrowrock Group 1995). By the early 1900s, most of Weiser Flats had been converted to irrigated crops and orchards. At the same time, only a dozen farms, orchards and ranches could be found along the Snake River banks from Fox Creek/Home, Oregon, to Powder River/Robbinette, Oregon (Densley 1987).

However, environmental conditions within Hells Canyon favored ranching over other agricultural activities. In 1905, homesteaders came to the canyon to establish farms and orchards. But the canyon’s difficult access, limited bottomland, poor access to irrigation, and extreme summer climate made farming exceptionally difficult. This farming boom ended by 1918, leaving only a few scattered and isolated ranches within the canyon (Jordan 1954, Carrey et al. 1979). By the 1930s, about a dozen ranches with hay pastures lay along the Snake River between Granite and Wolf Creeks (Jordan 1954). The more successful operations within the canyon were located at Temperance Creek/Big Bar, Pittsburg Landing, Corral Creek, Five Pine Bar, and Dug Bar. Ranching and livestock grazing occur in these areas today, yet other agricultural activities were abandoned decades ago.

Arrowrock Group (1995) reported that through various land claims, farmer-stockmen acquired benchlands above and upstream from Hells Canyon, especially in the Brownlee reach. They also began appropriating water for agricultural purposes. Irrigation districts formed along the lines of mining districts and used mining laws for appropriation of water rights. No comprehensive study has been done on the area upstream of Hells Canyon, but local histories mention early irrigation efforts. In a 1909 report, J. B. Lafferty, supervisor of the former Weiser National Forest stated that all available water supply had already been appropriated in the Weiser River drainage. He mentioned the need for reservoirs to cultivate additional land. He also expressed a long-time concern about the lack of a fully navigable river and recommended stream flow management on the Snake and Clearwater Rivers (Arrowrock Group 1995). Today, irrigation diversions and ditches have significantly expanded the acreage of irrigated crops and pastures throughout the valley floor in the Weiser reach.

Several of the Snake River tributaries in the study area drain relatively large areas with lands suitable for farming higher in the drainages. Agricultural development and associated irrigation diversion were quite extensive along some of these tributaries and at some locations adjacent to the Snake River. The 1920 census of the Hells Canyon area reflected that the population depended heavily on farming and ranching for their livelihood.

The U.S. Census Office (1896) described extensive agricultural development and irrigation diversion along the Powder River drainage as early as 1889. Apparently, by the 1940s and 1950s, many tributaries of the Powder River were substantially diverted. According to Lillian Densley in her book on the Snake River country, farmer-stockmen west of Halfway, Oregon, formed a ditch company in the 1890s. The Dry Gulch Ditch Company members dug their own ditches to bring water (from the Pine Creek drainage) to hay and alfalfa fields. Testimony before the Federal Power Commission (1959) noted that, by the 1940s, there were substantial agricultural diversions from Pine Creek and that, during the late 1950s, the stream was completely dry (because of diversions) from July through September. Pine Creek enters the Snake River from the west a quarter of a mile below Oxbow Dam. Inspection of historical photographs show that, by the 1950s, arable land along the river in the Weiser to Brownlee pool reach was intensively farmed.

Irrigation of alluvial fans and terraces along the river was primarily limited to the individual efforts of farmers who diverted water from nearby tributaries to irrigate their crops. Within the canyon, irrigation was limited and poorly documented (Arrowrock Group 1995).

As with mining, the impacts of agriculture and farming on riparian plant communities would have been primarily related to the removal of riparian vegetation. Given the limited extent of riparian habitats within the study corridor, such activities would have significantly affected the composition and structure of riparian plant communities. In particular, the absence of riparian vegetation in tributaries to the Snake River is documented in historical photographs of the study corridor (notably, Series 25). In addition, the location of ranching and farming on alluvial fans and terraces would have deterred seasonal wildlife migration patterns within the corridor. Livestock grazing of palatable riparian shrubs, such as sandbar willow (*Salix exigua*) apparently had a far more significant impact on riparian communities than isolated crops and pastures located on elevated terraces adjacent to the river did. Rather, impacts of agricultural developments on wildlife habitat occurred at the site of farmed areas and downstream of diversions.

4.2.4.1. Weiser Reach

Virtually all arable land in the Weiser area was farmed by the 1950s (aerial photograph in Series 1 of the Weiser reach), and the Weiser River had been over-allocated since at least 1909. Similarly, all of the flat bottomland and islands on the Snake River floodplain in the Weiser reach had been converted from native wetland, riparian, and shrub-steppe communities to agriculture well before the 1950s (aerial photograph in Series 2 of Westlake

Island and Snake River floodplain). This land may have already been severely overgrazed before large-scale cultivation began. Native wildlife habitat was lost on a massive scale because of overgrazing; then it was converted to cultivated crops. Pesticide use was widespread during and after the 1950s, adding to wildlife losses. Generally, lands cultivated during the 1950s remain in cultivation today, so the habitat losses persist.

4.2.4.2. Brownlee Reach

The floodplain narrows substantially as the river enters the Brownlee reach. The few flat areas and islands that existed in the upper end of the reach were farmed, but tillable land was limited. Flatter alluvial fans along the river and river bars were farmed by early settlers or used as feedlots for winter livestock (Series 5–7 of the Brownlee reach). Later, flatter benches created by the Bonneville Flood were also farmed, and some were irrigated. An example of a farmed bench can be seen in Series 16 of the Hells Canyon Reservoir subreach. With few exceptions, native wildlife habitat was generally eliminated on the farmed areas.

In this reach, large-scale water diversion for agriculture occurred higher in the larger drainages of tributaries to the Snake River. Extensive diversions were documented on the Powder River drainage in the Baker, Oregon, area. Upper Brownlee Creek and Burnt River had agricultural diversions, as did other tributaries to the Snake River in this reach. The general effect of such diversions on wildlife habitat was progressive, depending on the percentage of the flow that was diverted. Initial, relatively small diversions tended to degrade the quality of riparian and wetland habitats along the drainages below the diversions by removing a portion of the water supply on which these communities depended and by drying fringe areas. Because of water stress, riparian plants grew and reproduced less vigorously and were more susceptible to disease and insects. As irrigation diversions took a larger percentage of the flow, plant stress increased, and more shallow-rooted species died. Finally, if the surface water was removed from the system for a lengthy part of the growing season, all the wetland and riparian species died unless other sources of water entered the drainage below the diversion. By the 1950s, the combination of significant irrigation diversions, excessive grazing, chemical application, and human settlement probably eliminated much of the riparian vegetation along larger streams like the Powder and Burnt Rivers.

Based on casual observations along the Powder River immediately upstream of the influence of Brownlee Reservoir (C. Blair, *pers. obs.*, 1999), the cottonwood trees appeared to be 15 to 25 years old, with few large older trees. This observation supports the scenario presented above for the Powder River. It also suggests that, 15 to 25 years ago, some or all of these practices changed enough, just upstream of the pool, to allow at least one year class of cottonwoods to become established. Farming, agricultural diversions, and grazing continue today along the Powder River drainage, upper Brownlee Creek, and Burnt River. These diversions probably continue to degrade riparian and wetland habitat along reaches of these drainages below the diversions.

4.2.4.3. Oxbow and Hells Canyon Reservoirs Reach

Agricultural development in this reach was probably similar to that of the Brownlee Reach; river bars and benches were generally occupied by settlers raising crops and livestock. Irrigation diversions and farming are documented on the Wild Horse River and its tributaries (Arrowrock Group 1995) and probably occurred at the mouths of the few other drainages that had flatter lands that could support a house and garden or orchard. Pine Creek was reported to be dry from July through September at least during the late 1950s because of agricultural diversions (Federal Power Commission 1959). Agricultural development and irrigation diversions, combined with past heavy grazing, would have had adverse impacts similar to those described for the Brownlee reach during the 1950s. Total withdrawal of all surface water as was reported for Pine Creek probably devastated its riparian vegetation.

Farming and agricultural diversions continue at least on Pine Creek and the Wild Horse River, so ongoing impacts are occurring as discussed for the Brownlee Reach. The few relatively small plots along the river were on benches flooded when the reservoirs were filled.

4.2.4.4. Downstream Reach

The reach of river below Hells Canyon Dam is the narrowest and steepest section of the study area. The narrow canyon limited agricultural development to a few small locations. Federal ownership of most of the land on either side of the river also restricted settlement. Farming and irrigation diversions have occurred at Kirkwood Ranch, Temperance Creek, Kurry Creek at Pittsburg Landing, and upstream of and across the river from Pittsburg Landing at the site of the Tin Shed, Big Bar, and Dug Bar. There was also extensive agricultural development and many irrigation diversions along the Imnaha River, which flows through mostly private lands. Farming and water diversion continue today at Pittsburg Landing and along the Imnaha River. Effects on wildlife habitat would be similar to those described above.

4.2.5. Ranching and Grazing

The effects of ranching and livestock grazing have been extensively documented, probably because of the damage these activities have caused to range conditions. Therefore, much of our discussion of anthropogenic disturbances focuses on these activities.

Cattle and sheep ranching dominated the area in the 1880s because little cultivated land existed below Farewell Bend. Two large sheep operations and two cattle outfits dominated grazing areas along the river during these years, until changing federal laws restricted open grazing. Numerous small operations developed once these laws were passed. In addition to grazing livestock, early settlers planted orchards of apricots, cherries, and peaches along the Snake River. They grew grain crops on benches above Hells Canyon.

With the settlement of Hells Canyon, large numbers of cattle were introduced into the area’s rangelands, and unrestricted grazing continued well into the 1940s. During the 1920s, cattle grazing was mostly replaced by sheep grazing (Tisdale 1986*a*). By the 1940s, however, ranchers shifted back to cattle, and numerous feedlots were developed along the Snake River (Asherin and Claar 1976).

Cattle, sheep, and farm markets boomed during the World War II economy, then dropped dramatically afterward. The number of small-scale ranches and farms had already dwindled because of Depression economics. This trend quickened after the war. Farm and ranch families could no longer divide their property into large enough parcels to accommodate several members of the next generation. Many young adults were attracted to better-paying jobs at urban and coastal locations. The agriculturists who remained bought tracts of land and livestock herds relinquished through sheriffs' sales and public auctions. Those who invested in large-scale agricultural enterprises survived the boom and bust cycle of the 1940s and 1950s. Several pioneer ranching and farming families were able to keep their land and expand their operations. A few lone miners continued scouring the area for gold. However, federal and private plans for Snake River hydroelectric development soon affected many of these farmland and mining claims.

4.2.5.1. 1950s Range Conditions

Our review of historical documents and records did not produce any site-specific details concerning range conditions (or wildlife habitat conditions) for the study area. However, we did find anecdotal references to range conditions. Many sources document general conditions of western rangelands in the 1920s and 1930s, and some address range conditions in southwest Idaho. Other sources of information obtained from IDFG and ODFW contained general references to winter range conditions for mule deer (*Odocoileus hemionus*) and associated mortality (Mack and Thompson 1982, Holechek et al. 1989, Saab et al. 1995, Saab 1998). These agencies presented this information for entire big game management units, which included portions of the study area.

Retired agency biologists generally confirmed that the descriptions of western range conditions before the 1950s would apply to the study area (essentially the same unrestricted grazing occurred in the study area as on other western rangelands). Current and former resource and land management agency personnel indicated that livestock numbers were reduced somewhat between the 1930s and 1950s. However, grazing restrictions were poorly enforced, and range conditions did not improve during this period (P. Grindy, Payette National Forest, *pers. comm.*; J. Morrison, IDFG retired, *pers. comm.*).

Franklin and Dyrness (1988) summarized the impacts of Euro-American settlement on the shrub-steppe vegetation in the Northwest. The introduction of cattle, in 1834, and domestic sheep, about 1860 (Daubenmire 1970), profoundly affected the native steppe and shrub-steppe vegetation in the Inland Northwest. The latter were generally more abundant until 1940. From 1860 through 1870 and 1892 to 1893, cattle and sheep populations rapidly expanded (Galbraith and Anderson 1971). Lands not used for crop production were subjected to various degrees of grazing by livestock, and they generally deteriorated (Tisdale 1986*b*). Overgrazing was already considered to be a serious problem by the early 1900s.

Livestock grazing in the West during the late 1800s and early 1900s was essentially unrestricted and unlimited. The U.S. Secretary of Agriculture (1936) testified to the U.S. Senate that grazing livestock had depleted over half the forage on western rangelands and diminished conditions on 95 percent of the public domain. In addition, he commented on the reduced soil productivity and impaired watersheds. The Secretary then discussed problems for wildlife associated with range depletion (U.S. Secretary of Agriculture 1936): "No one familiar with wildlife requirements will question the statement that the range with little or no impairment in its value for other uses could support a vastly larger wildlife population. The deterioration of habitat through range depletion has destroyed both food supplies and cover for land animals and birds and silted fishing streams." He also noted the conversion from perennial grasses to annual grasses, mentioned problems associated with cheatgrass (*Bromus tectorum*), and cited declines of 65 and 68 percent on the original forage value of rangelands in southern Idaho and eastern Oregon, respectively.

By the late 1800s, the pressure from livestock grazing was extremely heavy along the Oregon Trail (U.S. Census Office 1896), several branches of which crossed the study area in the Weiser and upper Brownlee reaches. Arrowrock Group (1995) briefly described several Oregon Trail routes through the study area. By the 1840s, Oregon Trail emigrants used Wilson Price Hunt's old trade route along the Powder River to the coast. In 1862, Tim Goodale established an alternate trail near Brownlee and Pine Creek, and the Brownlee Ferry was constructed to help emigrants cross the Snake River. In 1863, Rueben Olds built a ferry at Farewell Bend, bringing the Oregon Trail through the Weiser Valley. Yensen (1980) described livestock traversing the Oregon Trail during the peak years of its use. She estimated that emigrants traveling in 10,000 wagons, along with many others driving stock, were accompanied by as many as 250,000 head of livestock crossing the Snake River Plain each year. Perennial grasses within several miles to either side of the Oregon Trail were probably severely damaged by 1860, and some livestock died for lack of forage along the route. Large cattle drives of as many as 100,000 head per year (Oliphant 1946) later moved eastward to rail heads in Wyoming, following the same route as the Oregon Trail and adding to the severe overgrazing (U.S. Census Office 1896, Malheur County Historical Society 1988*a*). River fords for these cattle drives corresponded with the mouths of larger tributaries of the Snake River such as the Burnt and Owyhee Rivers. Large sheep drives followed the same route (Yensen 1980). Another general reference to grazing in the area was found in a history of Malheur County (Malheur County Historical Society 1988*b*), which noted that in 1902 about 1.5 million pounds of wool was shipped out of Ontario, Oregon.

Jones (1989), describing early livestock grazing on the Payette National Forest, noted that Idaho rangelands were severely overgrazed by 1900, but that livestock numbers continued to increase (Malheur County Historical Society 1988*a*). In southwest Idaho, native grasses and forbs were severely depleted by this time (Yensen 1982). Livestock raised to supply miners in the Seven Devils Mountains spent the winters on low slopes and gravel bars and summers in the mountains (Jones 1989). Harris (1972, in Arrowrock Group 1995) concurred, indicating that livestock required three different types of ranges throughout the year: land along the Snake River banks served as winter range or feed lots, lower elevation mountain slopes from 1,000 to 2,500 feet elevation were used for spring and fall ranges, and the top benches and Forest Preserves served as summer ranges.

A history of the Payette National Forest (USDA 1968) discussed the following information about wildlife, livestock grazing, and mining:

1. Large numbers of bighorn sheep were present in the Seven Devils Mountains before mining began.
2. Extensive big game hunting by miners or others supplying food for miners was widespread.
3. Most range was heavily stocked and already damaged by overgrazing by the time the Forest Preserves were established in the early 1900s.
4. Livestock using the Forest Preserves were put under permit by 1915, but it was generally believed that as much stock trespassed as was under permit.
5. Permitted grazing in the Snake River canyon was year-round (that is, no rest or pasture rotation).

C. Quinby (Wallowa-Whitman National Forest, *pers. comm.*) related that similar conditions existed on the Oregon side of the Snake River: extreme overgrazing by the 1930s had caused substantial range damage, some of which was permanent. The Oregon State Game Commission (1948) noted in its bulletin that “the trend of forage on several important eastern Oregon (big game) winter ranges continues downward….”

In a grazing history of southwestern Idaho, Yensen (1980) described practices on both private and public lands: “During the early decades of the open range, the range was not managed. Forage for flocks and herds, especially during times of critical need in winter, was simply obtained by moving the animals to areas not yet grazed. But by 1900, usable ranges in the Intermountain West were fully stocked and no expansion was possible” (Hutchings and Stewart 1953). All seasonal ranges were damaged, and the carrying capacity in many was extensively lowered. However, the numbers of cattle and sheep continued to increase, and the range, especially winter range, suffered. Floating bands of sheep, now very common on southern Idaho ranges, were herded from one good forage area to the next with a “he who gets there first gets all” philosophy (Rinehart 1932). Some of these bands were all wethers (or castrated males), which traveled rapidly and were extremely destructive (Wentworth 1948). Cattlemen, tied to traditional grazing areas and lands near their own claims, bitterly resented the floating sheep bands. Some cattlemen drove their stock to traditionally used areas at a scheduled time, only to find that sheep had been there and eaten all the forage. No evidence suggests that any of the private lands in the study reaches were treated any differently than those that Yensen described.

Gildemeister (1992) discussed conditions along the lower Powder River, noting that tall bunchgrasses, probably basin wild rye (*Elymus cinereus*), were common and many willows and other shrubs grew along the streams before the 1940s. However, agricultural spraying for weed control during the 1940s, combined with severe overgrazing by sheep, eliminated much of the original native vegetation. Gildemeister (1992) also noted extensive draining and filling of wetlands in the lower Powder River valley during the 1940s.

Current and retired agency staff confirmed that range conditions in the study area preceding and during the 1950s were poor (J. Morrison, IDFG retired, *pers. comm.*; P. Grindy, Payette National Forest, *pers. comm.*). Morrison noted that few, if any, trees grew in riparian zones during the 1950s and livestock use of these areas was heavy. Riparian vegetation apparently consisted primarily of shrubby species with very tall sagebrush and mountain mahogany common in many drainages (D. Nadeau, IDFG retired, *pers. comm.*). Nadeau also noted that beavers were common in some tributaries, such as the Wild Horse River and Brownlee Creek. Morrison and Nadeau indicated that tributary blowouts were also common during the 1950s.

In addition, the USFWS (1948) assessment of potential impacts of proposed dams in the Columbia River Basin characterized wildlife habitat quality in Hells Canyon as being in fair to poor condition.

4.2.5.2. 1990s Range Conditions

IPC (1997) summarized recent general information regarding management of public lands and range conditions in the study area. The ecological condition of 85 percent of the public lands administered for grazing were evaluated and classified to describe how closely the present plant community on a range site resembles the potential climax plant community. Only 3 percent of the area was considered to be in climax, 23 percent was in late successional stage, and 61 percent was in middle and early successional stages. This evaluation also indicated that 50 percent of the range was static, 39 percent was improving, and 11 percent was deteriorating (USDI 1986).

Degraded sagebrush-steppe requires considerable time to recover from excessive grazing, especially on drier sites such as the Weiser and Brownlee reaches and all lower elevation portions of the study area. A study on the Idaho National Engineering and Environmental Laboratory in eastern Idaho found that 25 years after the heavily depleted range had been completely closed to cattle and sheep grazing, cover of both perennial grass and big sagebrush had nearly doubled. The most rapid recovery of grasses occurred after a lag period of 15 years once grazing was eliminated (Anderson and Holte 1981). Even if livestock are removed, invasive weeds, overly dense stands of sagebrush, or heavy browsing by rodents and rabbits can inhibit recovery of grasses and forbs (Tisdale and Hironaka 1981).

Our investigation yielded little quantitative information regarding current range conditions or trends. The only quantitative information was included in BLM resource management plans (RMPs) and USFS forest plans, all of which were 10 years old or more. These plans note the general ecological condition of grazing allotments. Discussions with agency staff identified those allotments adjacent to the Snake River. However, allotments can be quite large with relatively small areas adjacent to the river. Information concerning conditions of specific pastures immediately adjacent to the river was not available.

We do know, however, that livestock grazing continues on both private and public lands in the study area. In Idaho, 16 BLM grazing allotments lie adjacent to the Snake River in the upper portions of the study area (Mary Clark, Boise District BLM, *pers. comm.*). Six are located in the Weiser reach, eight in the Brownlee reach, and two in the Oxbow reach. In 1980, all were rated to be in generally fair to poor ecological condition. No quantitative information regarding current trends or conditions in the late 1990s was available for these allotments (M. Clark, Boise District BLM, *pers. comm.*). In addition, 90 percent of BLM's Cascade Resource Area lands adjacent to the study area in Idaho were rated in fair (47 percent) to poor (43 percent) condition (USDI 1987).

S. Mattise (Boise District BLM, *pers. comm.*) worked in the Cascade Resource Area during the late 1980s and early 1990s. He indicated that BLM lands along the river were most recently managed to provide big game winter range and that, with some exceptions, range conditions were generally improving. He also indicated that most of the private lands along the Idaho side of Brownlee and Oxbow Reservoirs were not fenced from BLM lands. The BLM and private lands are jointly managed to try to achieve desired winter range goals. In his opinion, range conditions on private lands were also improving over conditions in the 1950s.

BLM lands on the Oregon side of the study area are managed by the Baker Resource Area. The RMP (USDI 1989) indicates eight allotments along Brownlee Reservoir, one along Oxbow Reservoir, and three along Hells Canyon Reservoir. Livestock grazing on all of these allotments begins in April and extends up to nine months. Ecological conditions and trends were not indicated for these allotments.

In Hells Canyon, riparian zones are generally narrow (less than 10 meters [33 feet]) and constitute less than 1 percent of the total land managed by the BLM. Vegetation condition ratings were conducted over approximately 198 drainage kilometers (123 miles). Woody riparian vegetation was rated in good condition along 63 percent of the drainage distance and in fair condition along 28 percent of drainage distance surveyed. A review of range conditions for only those allotments that abut the Snake River indicated that the largest portion of these areas were in only fair or poor condition, a finding that suggests that the riparian zones in Snake River allotments may not be in condition as good as indicated above for the entire Cascade Resource Area. The apparent trend in 1990 was static (USDA 1990). S. Mattise (BLM, *pers. comm.*) indicated that Idaho BLM riparian zones generally consisted of only shrubby species with few or no trees. About 170 of the 240 miles of perennial streams on the Baker Resource Area were inventoried and rated for condition and trend for the RMP (USDI 1989). At that time, conditions were as follows: 11 percent excellent, 38 percent good, 36 percent fair, and 15 percent poor. The trend ratings for stream condition were 13 percent upward, 75 percent static, and 12 percent downward.

Agency personnel generally believe that range conditions on USFS lands have improved since the 1950s. Plant species diversity has increased, but noxious weeds are more problematic (P. Grindy, Payette National Forest, *pers. comm.*). USFS lands in the study area generally receive higher precipitation than BLM lands, so the potential for recovery from past grazing abuse is greater.

Seven active grazing allotments, covering about 75,000 acres of the Payette National Forest, are located near or adjacent to the Snake River in the Hells Canyon Reservoir subreach (USDA 1988). All but one are cattle allotments. The season of use is from June 1 or 15 through October 15 for the cattle allotments and from May 15 through October 15 for the sheep allotment. When the forest plan was written, the rating of the ecological condition of these lands was 11 percent excellent, 32 percent good, 42 percent fair, and 15 percent poor. These conditions have probably not changed in recent years (P. Grindy, Payette National Forest, *pers. comm.*). Numbers of livestock have decreased substantially from stocking levels of the 1930s and early 1940s. Overall, range conditions on the Payette National Forest improved somewhat between the periods from 1958 to 1965 and 1977 to 1985 (USDA 1988).

C. Quinby (Wallowa-Whitman National Forest, *pers. comm.*) indicated a similar situation in the Wallowa-Whitman National Forest. Actions taken since the 1950s—such as intensified management, pasture rotation, and reduced numbers of livestock—have improved range conditions. He indicated that sheep grazing was eliminated from two major allotments in the 1990s. The two active allotments in the HCNRA are at Pittsburg Landing and Dug Bar. Also, most of the lower-elevation portions of the canyon administered by the Wallowa-Whitman National Forest have no current livestock grazing.

In addition, a stream habitat survey conducted on the Wallowa-Whitman National Forest in 1980 and 1981 ranked streams into three indicators of riparian health: streambank stability, stream surface shaded, and stream-bed sedimentation (USDA 1990). Slightly more than half of the streams had fair or better streambank stability. Based on limited information, there was apparently considerable room for improvement in shade-producing vegetation (USDA 1990). Lastly, sedimentation did not appear to be a significant problem, though there was also room for improvement.

4.2.5.3. General Effects of Grazing on Wildlife Habitat

Saab et al. (1995) reviewed current literature concerning the effects of livestock grazing on wildlife in western North America. Generally, livestock grazing reduces the amount of and degrades wildlife habitat values, and the effects are proportional to the intensity, season, and duration of grazing. Direct effects of grazing include the immediate removal of food and cover for wildlife. Long-term grazing can profoundly affect plant species composition, favoring plants that are less palatable to livestock and completely eliminating species favored or even required by some wildlife species. For example, domestic livestock grazing has caused major changes in plant species composition of shrub-steppe habitats, including loss of the cryptogam layer from trampling, loss of native grasses, reduced perennial grass cover, reduced forb cover, increased shrub cover, and invasion by exotic species, particularly cheatgrass (Yensen 1981). In addition, cattle compact soil, remove plant materials, and indirectly reduce water infiltration, all of which can decrease vegetation density (Holechek et al. 1989), dramatically alter species composition, and increase soil erosion and surface water runoff. Major changes in native shrub-steppe vegetation, particularly the rapid loss of forbs and grasses, took as little as 10 to 15 years under the severe overgrazing that accompanied early settlement of the West (Saab et al. 1995).

Effects of livestock grazing can be especially damaging to those ecosystems where large herds of native grazing ungulates were scarce or absent (Mack and Thompson 1982). Shrub-steppe habitats did not coevolve with large herds of grazing animals, and plant species were not adapted to withstand severe or continuous grazing (Mack and Thompson 1982). Large herds of bison (*Bison bison*) or pronghorn (*Antilocarpa americana*) uncommonly occurred west of the Rockies (Gustafson 1972, Grayson 1977). Few prehistoric bison records exist from the Columbia Plateau (Schroedl 1973), and records are rare elsewhere in the region (Mack and Thompson 1982).

Caespitose grasses depend on seed production rather than rhizomes or stolons to maintain their populations. Therefore, the effects of grazing are more serious for caespitose species than for rhizomotous species (Mack and Thompson 1982). Consequently, shrub-steppe perennial bunchgrass communities are adapted to small, dispersed groups of grazers typified by mule deer and elk (*Cervus canadensis*). This lack of adaptation to concentrations of large herbivores has led to their "striking susceptibility" to the impacts of domestic ungulates (Larson 1940, Tisdale 1961, Dyer 1979, Mack and Thompson 1982).

Livestock grazing has also significantly affected riparian communities, which are used by wildlife far more than any other vegetation type in the West (Thomas et al. 1979). Platts (1991) described that livestock alter, reduce, or remove vegetation and actually eliminate riparian areas through widening channels, aggrading channels, and lowering the water table. Saab et al. (1995) noted that the effects of year-round grazing (as practiced in Hells Canyon for decades) and associated summer concentration of livestock in riparian zones was particularly damaging because of severe trampling and mechanical damage, soil compaction, and plant consumption. Grazing year-round and during the growing-season particularly damages riparian vegetation (Kauffman and Krueger 1984, Platts 1991) and associated bird and other wildlife communities (Crouch 1982). However, spring and summer are the designated grazing periods on Oregon BLM and USFS lands in the study area.

Resource agency personnel reported that riparian zones in the HCNRA that are not currently grazed support more diverse multiple-strata riparian communities than those along grazed tributaries in the Brownlee and Oxbow reaches. Observations of riparian zones along tributaries in the study area confirmed that diversity. Diverse communities of trees and shrubs provide quality habitat for a wider range of wildlife species than grazed, shrubby riparian zones (Platts 1991, Saab et al. 1995).

Livestock grazing benefited some habitat generalists but was directly detrimental to species that nested on the ground or in low shrubs. The grazing degraded nesting habitat, which eliminated nesting sites and increased predation rates (Saab et al. 1995). Other species were adversely affected by changes in arthropod abundance or availability (Wiens and Rotenberry 1981, Wiens 1985). The composition, densities, and distribution of small mammal communities varied with vegetation structure (Feldhamer 1979, Rogers and Hedlund 1980, Gano and Rickard 1982, McGee 1982), and species diversity declined as grazing intensifies (Kochert 1989), possibly harming shrub-steppe raptors. Saab et al. (1995) noted that most plant and animal communities in the western United States, excluding some grasslands, have not evolved with widespread grazing repeated annually in the same locations. Thus, heavy grazing is likely to harm many wildlife species over the long term.

4.2.5.4. Effects During the 1950s and 1990s

Healthy shrub-steppe range conditions are synonymous with a diverse mix of native cryptograms, bunchgrasses, forbs, and shrubs, with species composition depending on local factors such as soil type, aspect, elevation, and precipitation. Healthy range conditions are also synonymous with high native wildlife habitat value. Degraded shrub-steppe range conditions are characterized by depauperate plant communities often dominated by exotic species. Heavily grazed shrub-steppe areas may be dominated by dense stands of mature shrubs with few cryptograms or native bunchgrasses or forbs that constitute poor wildlife habitat for most native species (Page et al. 1978, Saab et al. 1995).

Given these characteristics of degraded conditions, livestock grazing clearly affected wildlife habitat conditions in the Hells Canyon study area. As indicated earlier, many of these impacts had occurred by about 1900 and persisted for decades thereafter. Numbers of livestock grazing in the study area were not restricted until the 1940s, and there was virtually no enforcement for many years once grazing was restricted. Retired agency biologists repeatedly commented on the poor conditions of winter range that existed during the 1950s. J. Morrison noted that little forage remained for deer to consume when they moved into the winter range. He described a location below the Seven Devils Mountains along the Snake River that was not accessible to livestock because of sheer cliffs. Each winter, several deer, already weakened by poor forage conditions, fell off these cliffs while attempting to get to the ungrazed area. The poor condition of the winter range, combined with low hunting pressure because of limited access, regularly caused large die-offs of deer during the late 1950s (J. Morrison and D. Nadeau, IDFG retired, *pers. comm.*). Seventy years of unrestricted grazing extending into the 1940s undoubtedly took a heavy toll on vegetation, wildlife habitat, and associated species.

We found numerous references to severely degraded winter range conditions for deer in game management units, which include the study area, in Oregon State Game Commission (OSGC) and IDFG annual reports. OSGC conducted annual winter range browse utilization surveys for many years, and their record of this type of information is more complete than corresponding information for Idaho. Comments about poor range conditions or heavy winter deer mortality because of depleted winter range were included in OSGC 1950, 1951, 1952, 1953, 1954, 1955, 1956, 1957, and 1958 and IDFG 1951. D. Norrell (IDFG retired, *pers. comm.*) remembered many deer dying on the winter range during the 1950s. More died on the Oregon side since more deer wintered there because of the southerly aspect. He believed that the winter range was in better condition in Idaho during the 1950s because fewer deer wintered there.

While livestock overgrazing was a major factor, it was not the only factor contributing to the degradation of winter range. References to drought and grasshoppers affecting range conditions appeared in some of the annual OSGC reports, and the growing big-game herd size was also a factor. The OSGC (1951) stated: "At the turn of the century (1900) deer and elk were scarce (having been severely reduced by unrestricted hunting). Population increases were encouraged through closed seasons, buck laws, and large legislative refuges. Deer numbers responded and continued to increase until a saturation point was reached on many winter ranges in the 1930s. Surpluses in excess of carrying capacities succumbed to malnutrition. In most cases regulations permitting the harvest of antlerless animals were not adopted in time to prevent malnutrition losses and associated continued range deterioration."

We could not readily determine differences in early grazing pressure and effects on wildlife habitat among the study area reaches from the information sources that we reviewed or the people we interviewed. However, cattle and sheep appeared to have grazed on virtually all parts of the study area. Interviewees commented on poor range conditions at all locations with which they were familiar. However, the greatest habitat degradation would be expected along the Oregon Trail, followed by the more easily accessible Weiser and Brownlee reaches.

Information in BLM and USFS land and resource management plans (BLM 1986, USDA 1988) and discussions with agency personnel suggested that wildlife habitat conditions were probably better in the 1990s than in the 1950s. Undoubtedly, many problems persisted from earlier abuse. Growing-season grazing in riparian zones and trespass grazing were continual problems. However, grazing was regulated, seasons of use and numbers were generally controlled, and many parts of the HCNRA near the river corridor had not been grazed for several years. While range conditions generally improved, deer still died on the winter range, especially during heavy snow years (S. Mattise, BLM, *pers. comm.*). Elk may not have been affected by poor range conditions as much as deer were because elk typically winter at higher elevations with more precipitation. Elk were not common until more recently. USDA (1980) reported that elk were first seen in the Snake River drainage within the HCNRA in 1938. However, their numbers increased and they competed with cattle for forage on the higher-elevation winter ranges.

In recent years, grazing practices and pressure have not changed equally in all parts of the study area. Current grazing effects on wildlife habitat are probably greatest in the Weiser and Brownlee reaches of the study area because more grazing occurs here and there is less annual rainfall. Precipitation increases farther north along the river corridor, providing more opportunity for recovery from past abuse. Range conditions have probably recovered more below Hells Canyon Dam because few parts of the HCNRA in the lower portions of the Snake River corridor are still grazed, though no monitoring data are available for the study area to support this premise.

4.2.6. Exotic Plants

Exotic plants, which include invasive and noxious weeds, were recently ranked as the greatest threat to the composition and structure of native plant communities in the Interior Columbia River Basin (Croft et al. 1997). Current studies identified approximately 30 invasive and noxious plants within the study corridor (Eagle Cap, Inc. 1999). Of these, about one-third were commonly found growing along reservoir shorelines and riparian habitats (Table 13). Population densities of these invasive species appeared to be the highest in the Weiser reach and progressively declined through the reservoir reaches and downriver of Hells Canyon Dam (Eagle Cap, Inc. 1999).

Most of the species identified in the study reach (Table 13) were apparently present in the study corridor before the dam was constructed and flows managed (Invader Database System

2000). During the 1973 to 1975 riparian vegetation studies of Asherin and Claar (1976), only five of these species (Russian olive [*Elaeagnus angustifolia*], common St. Johnswort [*Hypericum perforatum*], perennial pepperweed [*Lepidium latifolium*], reed canarygrass [*Phalaris arundinacea*], and *Tamarix* spp. [saltcedar]) were recorded within the study corridor. However, other species, such as field bindweed (*Convolvulus arvensis*), field horsetail (*Equisetum arvense*), purple loosestrife (*Lythrum salicaria*), and Scotch thistle (*Onopordum acanthium*) were apparently common throughout the Columbia River Basin (Table 13, Invader Database System 2000). During the last 50 years, the number of counties reporting the occurrence of indigobush (*Amorpha fruticosa*), yellow nutsedge (*Cyperus esculentus*), Russian olive, perennial pepperweed, purple loosestrife, Scotch thistle, and *Tamarix* spp. increased significantly. Sightings of these species increased almost exponentially since 1975 (Invader Database System 2000). However, we could not determine whether this increase in reported noxious plant sightings was related to species range extensions or was simply a byproduct of increased funding for noxious weed control programs throughout the region.

The continual spread of exotic plants has steadily degraded wildlife habitat value on both temporal and spatial scales. The most dramatic changes throughout the Intermountain West have occurred since the Hells Canyon Complex was constructed. Operations of the complex appear to both impede the spread of some species and induce the spread of others. For example, preliminary findings shared during ER 2000 suggest that current flow regulation and water-level management practices favor both indigobush and *Tamarix* spp. On the other hand, large barren zones associated with seasonal declines in the water level of Brownlee Reservoir also appear to bar the dispersal of some noxious species downstream of the Weiser reach.

4.2.7. Fire

Native Americans in shrub-steppe areas did not use fire to a significant extent for hunting, compared with those in forest regions. The HCNRA *Draft Environmental Impact Statement* (USDA 1980) noted that fires had occurred in the NRA but provided no information on the frequency or size. The Baker Resource Area RMP (USDI 1989) generally discusses fire occurrence in the Resource Area. Currently, BLM fights fires when valued resources could be destroyed. USDI (1989) indicated that fires historically occurred in the rangeland and forests of the Resource Area (and Hells Canyon). Since fires have been suppressed since the early 1900s, more sagebrush has grown in the area. More frequent fires would result in the loss of native shrubs such as sagebrush that do not resprout after fire but must rather recolonize burned areas from adjacent unburned areas. However, cheatgrass, an exotic species, has also become widely established over the last 80 years and creates suitable conditions for fires earlier in the growing season than uninfested shrub-steppe grasslands would.

Cheatgrass was already well established in the study area by the 1950s. From the limited information we have obtained, the role of fire and its effects on wildlife habitat have apparently not changed much. One generalization that is probably valid is that each fire in shrub-steppe areas results in permanent loss of more shrubs. Wildfires in 1986 changed the vegetative cover on 95,516 acres in the Cascade Resource Area. The major change related to the loss of the sagebrush/bitterbrush (*Purshia tridentata*) component. Having fewer shrubs degrades habitat quality for a variety of species such as shrub-nesting songbirds (loss of nesting cover) and mule deer (loss of browse species).

4.2.8. Logging

The GLO records for the Idaho side of the study area often recorded general notes on vegetation (Appendix 1). Multiple GLO records from 1870 through 1920 indicate that “no timber” grew along the Weiser or Brownlee reaches. GLO records from 1902 to 1910 for the Oxbow Reservoir subreach indicate that scattered pines and cottonwoods were present at some sites. Historical photographs in Series 10, 11, and 13 of the Oxbow Reservoir subreach show occasional ponderosa pines (*Pinus ponderosa*) near the river. The only deciduous trees visible in these photographs appear to be hackberry (*Celtis reticulata*). GLO records for the Hells Canyon Reservoir subreach indicate no timber at some sites and scattered pine and fir at other locations; cottonwood was mentioned in one record. Several of the photographs from the Hells Canyon Reservoir subreach also show conifers present during the 1950s. A few larger deciduous trees are visible in the historical photograph in Series 22 of the Hells Canyon Reservoir subreach, but the species cannot be identified, although white alder (*Alnus rhombifolia*) are visible on the alluvial fan of Kinney Creek.

The presence of mature scattered conifers on many of the 1950s photographs suggests that they were not widely logged for structures or mine timbers beyond the immediate areas occupied by miners or settlers. Arrowrock Group (1995) commented that trees near mining sites quickly disappeared. The lack of easy transportation probably restricted logging to sites near settled areas. These areas near mining sites or other settlements would have been poor wildlife habitat during the 1950s since trees were logged and other land disturbance was extensive.

A comparison of historical photographs with current photographs indicates that, except for trees inundated by reservoir waters, most of the conifers in the 1950s photographs were also present in 1999. Therefore, for sites not affected by mining, other settlements, or inundation, wildlife habitat quality of these open pine stands probably differed little during the 1950s and the 1990s, though the trees would be more mature in the 1990s, which could cause minor changes in the associated wildlife community. Many of the lower sites in the reservoir reaches were flooded and the mining inventory is not complete, making direct comparisons between conditions in the 1950s and 1990s impossible for individual study area reaches.

4.2.9. Hunting

We reviewed several general references to subsistence hunting. Accounts of early Hells Canyon settlers reported mule deer, elk, mountain goats (*Oreamnos americanus*), bighorns (*Ovis canadensis*), and grizzly bears (*Ursus horribilis*) (Arrowrock Group 1995), although elk were apparently not common. Jones (1989) noted heavy hunting pressure to feed miners. These animals were heavily hunted, and there were no limits on the time of year or the number of animals that could be killed. USDA (1968) reported that hide hunting accounted for a substantial amount of deer mortality. By 1900, big game numbers had plummeted, and by 1910, grizzly bears were extinct in Hells Canyon (Arrowrock Group 1995).

The Black Lake State Game Preserve was established on the Weiser National Forest in 1912 to help reestablish the depleted deer and elk populations. The preserve was abolished by an act of legislature in 1935 when these populations had rebounded. As cited earlier (OSGC 1951), deer numbers increased dramatically in the 1930s, further degrading winter range conditions.

USDA (1968) noted that bighorn sheep were quite common in the Seven Devils Mountains before and during the mining rush there. Ratti and Lucia (1998), citing several sources, stated that bighorn sheep were extinct in Hells Canyon by 1945. Subsistence hunting and disease from domestic sheep were major factors in this local extinction. The reintroduction of bighorns began in 1971.

Current big game hunting is regulated by the states of Idaho and Oregon. Big game numbers fluctuate in response to habitat conditions and other factors, and populations are generally held below levels that could severely deteriorate winter range conditions.

4.3. Condition of Wildlife Habitat

4.3.1. Weiser Reach

Based on our analysis of historical photographs and accounts, the overall wildlife habitat quality and quantity of riparian communities in most of the Weiser area in 1999 appeared to have increased since the 1950s, even though the riparian community was dominated by exotic species. In the Farewell Bend area, slightly more riparian and wetland habitat was associated with backwater areas during the 1950s than during 1997. Agricultural development was similar between the two time periods. However, habitat quality was limited by the long history of unrestricted livestock grazing. Earlier discussion of grazing practices indicated that range conditions for unfarmed uplands were probably somewhat better today than in the 1950s.

4.3.1.1 Hydrologic and Fluvial Processes

Figures showing the total annual and peak flows at Weiser were discussed in section 4.2.1. No discernible temporal patterns were evident.

4.3.1.2. Historical Photographic Analysis

As described in the methods section, we compared historical and current oblique and aerial photographs to identify riparian vegetation patterns. The following photograph series were included in our analysis (see Table 14 for details about location, vegetation, and geomorphology of each photo point):

- (WR-1) Weiser Bridge crossing of the Snake River (Series 1)
- (WR-2) Westlake Island ferry crossing (Series 2)
- (WR-3) Farewell Bend/Olds Ferry crossing (Series 3)

A 1908 oblique photograph in Series 1 of the Weiser reach shows hackberry and sandbar willow along the edge of the river channel and highly eroded banks. Higher flows during early March, when the photograph was taken, may have obscured islands within the main channel. The 1999 oblique photograph in Series 1 shows exotic woody and herbaceous plants along the entire riverbank, with low-lying channel islands visible in the foreground. Today, riparian communities are dominated by silver maple (*Acer saccharium*), elm (*Ulmus pumila*), European willow (*Salix × rubens* and *Salix alba*), native willows (*Salix exigua* and *S. amygdaloides*), and poison hemlock (*Conium maculatum*). River-channel substrates for both periods ranged from fines to fine-cobble.

A 1955 aerial photograph in Series 1 showed irrigated crops and pastures on the Weiser Flats floodplain, with few areas supporting woody riparian vegetation. Presence of paleo-channels suggested that this area was dominated by dense stands of sandbar willows before it was cleared and cultivated. The 1997 photograph showed irrigated fields near Weiser, but a narrow fringe of dense woody vegetation was visible along the main river channel. Channel morphology was comparable between aerial photographs.

A 1908 oblique photograph of the Westlake Island ferry crossing showed riparian vegetation patterns similar to those found at the Weiser Bridge (Series 2 of the Weiser reach). Upland habitats consisted of sagebrush-steppe vegetation and barren soils (compacted by ferry traffic) dominated by annuals, such as cocklebur (*Xanthium strumarium*). The 1999 photograph in Series 2 showed riparian woody habitats composed of European willow trees, with saltcedar or tamarisk (*Tamarix* spp.) along the lower bank. Russian olive with dense areas of reed canarygrass (and Eurasian herbs (*Amaranthus* spp., *Portulaca oleracea*) were common at irrigation seeps along the riverbanks. In both photographs, the channel was wide and lacked small channel islands.

The 1955 aerial view of Westlake Island in Series 2 showed surrounding irrigated fields and upland sagebrush-steppe habitats. Riparian woody plants were notably absent, and the island was under cultivation. The conditions were nearly identical in the 1997 aerial photograph, but a narrow riparian fringe of woody plants was more visible. Channel morphology appeared to be similar in both aerial views.

A 1902 oblique photograph of the Farewell Bend/Olds Ferry Crossing showed widely scattered sandbar willow and hackberry along the opposite riverbanks (Series 3 of the Weiser reach). The 1999 photograph in Series 3 showed wide swaths of cocklebur along the banks of the river. In both photographs, the channel was wide and open, with gentle, sloping banks of fine substrates. However, the shoreline in the 1999 photograph showed more fine-cobble to cobble substrates.

In both the 1955 and 1997 aerial photographs in Series 3 of Farewell Bend, water levels were comparable, and channel morphology appeared somewhat similar. However, large barren zones associated with fluctuating water levels were visible in the post-impoundment aerial view.

4.3.1.3. Riparian Vegetation Patterns

We also evaluated public land survey and photographic records for three locations along the Weiser reach of the Snake River (Table 14, and Series 1, 2, and 3). Early GLO records from the 1870s to 1890s indicated that riparian zones in this area were dominated by dense stands of willows grading upslope to sagebrush-steppe vegetation. Surveyors' notes did not record the presence of trees, and later GLO records (1901 to 1936) specifically mention the lack of timber (Table 14). The historical Weiser reach photographs showed a very sparse riparian community of scattered willow and hackberry, suggesting that, by the early 1900s, riparian habitats had been heavily impacted by grazing and other agricultural activities. Riparian trees were notably absent from all historical photographs. The apparent lack of channel migration within this reach was a critical factor in limiting the extent of riparian habitats. Fluvial substrates were primarily fine silts and sands.

Only a few isolated margins along the river appeared to have woody vegetation in the 1950s aerial photographs of this reach. Sparsely wooded areas were common near the town of Weiser yet absent below Porter's Ferry. Most of the historical floodplain was converted to irrigated crops and pastures, with farming on many of the islands.

By 1997, aerial photographs showed a thin, dense band of trees along the channel margins adjacent to irrigated fields. Oblique photographs taken during the 1999 growing season showed relatively mature riparian trees growing along the river channel (Series 1 and 2). These riparian forests are dominated by nonnative trees, such as silver maple, Chinese/Siberian elm, Russian olive, and European willow. The ages of maple, elm, and Russian olive range from 10 to 28 years old and up to 40 years old for European willow (Braatne and Rood *unpubl. data*), suggesting that these species only recently established in this area. In areas further downstream of the Westlake Island ferry crossing, saltcedar or tamarisk is common and locally dominates riparian zones in the vicinity of Farewell Bend. The age of these saltcedar stands ranges from 6 to 10 years old (Braatne and Rood *unpubl. data*). Herbaceous plants associated with riparian habitats, irrigation seeps, and diversion-return flows are dominated by exotic and noxious species. Though irrigated agricultural fields near Weiser largely displaced upland sagebrush communities, sagebrush-steppe and sand dune communities are still common on the hill slopes adjacent to the lower sections of this river reach (Series 3). These sand dunes are the fluvial deposits of a large backwater pool that arose at Farewell Bend during the Bonneville Flood 14,500 years ago.

4.3.1.4. Wildlife Habitat Quality

Riparian habitat visible in the historical photographs taken at Weiser and Westlake Island in the Weiser reach between 1899 and 1908 consisted of a fringe of hackberry and some willow along some sections of the riverbanks and virtually no riparian vegetation along most other banks. This finding is consistent with historical accounts of several decades of unrestricted grazing and clearing for farming. GLO records from as late as 1936 specifically noted the absence of trees in this reach. Near the mouth of the Weiser River and immediately downriver of this location, the riparian vegetation appeared to be more robust than at other locations in the vicinity and appeared to include a tree layer.

Aging of the dominant riparian species in 1999 indicated that the woody riparian trees and shrubs in the Weiser reach today were not present during the 1950s (Braatne and Rood *unpubl. data*). This apparent lack of older trees, combined with the historical photographs and narratives, suggested that both the quality and quantity of riparian wildlife habitat in most of the Weiser reach of the study area may have been limited during the 1950s. The vicinity of the Weiser River mouth would have provided better quality habitat than was available along most of this reach.

Riparian habitat communities appeared to occupy most of the river and island banks in the 1997 aerial photographs. Oblique photographs taken during the 1999 growing season showed relatively mature nonnative riparian trees growing along the river channel. A well-developed riparian community consisting of multiple-aged native trees and shrubs would provide optimal wildlife habitat. However, the nonnative species are not without wildlife habitat value. Silver maple, the most abundant tree, attracts large numbers of insects that provide food for neotropical migrants and summer resident species. Chinese/Siberian elm produces many seeds, which are consumed by a variety of species. Maple, elm, and European willow all provide cover and nest sites, including suitable locations for heron rookeries. In addition, waterfowl nesting habitat was limited by the lack of riparian vegetation during the 1950s. But those conditions improved by the 1990s with the increase in the extent and cover of riparian vegetation along the riverbanks and islands.

Generally, the extent of agricultural development appeared similar between the two periods. However, the photographs clearly showed a changing landscape. Most of the historical floodplain, including islands, had already been converted to agriculture by the 1950s. There were fewer unfarmed corners and fencerows in the 1997 photographs. The 1950s photographs showed former river meanders that were taken into cultivation; these features were not discernable in the 1997 photographs. Small patches of brushy habitat were more abundant within farmed areas in the 1950s, and these areas would provide some cover for a few species such as pheasants or rabbits. However, the small size of these areas would limit their value for most native wildlife. Also, the widespread use of agricultural chemicals such as DDT during the 1950s posed another set of problems for wildlife.

Photographs of the Farewell Bend area (Series 3) appeared to be fairly similar. Both sets showed some riparian vegetation along the edge of the wetted area. In the 1950s photographs, this vegetation grew along the riverbank and backwater channels and probably consisted mostly of willow. In the 1997 photographs, the riparian vegetation was composed largely of exotic species and grew along the edge of the reservoir high-water mark, primarily along the Idaho side of the Snake River. The channel was more complex in the 1950s photographs, with more area suitable for riparian vegetation and other wetland habitat types. Island interiors were generally barren during both periods, but in the 1950s photographs, more riparian vegetation grew along the island edges. Willow provides habitat for a limited number of species because it is short and its branches are not stout enough to support larger nesting birds. However, because willows support large insect populations, they provide important food resources for local and migratory avian populations (Brunsfeld and Johnson 1985). Willow probably provides better quality habitat than tamarisk and is certainly better habitat than indigobush. Willow flycatchers (*Empidonax traillii*) and beavers are among the species that show a strong preference for the native willow rather than the exotics.

4.3.2. Brownlee Reach

Hydrologic and fluvial processes change in the Brownlee reach as the reservoir is fluctuated. Historically, inundation of the Snake River flooded many islands. The primary difference in vegetation and wildlife habitat quality between the 1950s and 1990s was the heavy grazing of scattered riparian vegetation during the 1950s. Such vegetation was not present in the 1990s because of reservoir inundation and pool fluctuations.

4.3.2.1. Hydrologic and Fluvial Processes

Currently, the water level in Brownlee Reservoir fluctuates and the reservoir responds to the varying inflow and reservoir operation rules that constrain hydroelectric production, flood control, fisheries, and other uses (Table 15).

Before impoundment, several islands were present in the Snake River. For example, an island is found on a December 1957 photograph that shows the area of the river inundated by Brownlee Reservoir from Bay Horse Rapids to Raft Creek. This reach is upstream of the Powder River confluence and generally in the upstream portion of what is now Brownlee Reservoir. A range of vegetation conditions existed on these islands. On smaller islands that were typically lower in elevation and more frequently inundated, there appeared to be little, if any, vegetation. Some of the islands had areas of woody shrubs or small trees typically along relatively narrow elevation bands adjacent to the river channel. Above this riparian band on higher and larger islands, there appeared to be significant coverage of upland vegetation. Photographs of this Snake River reach therefore indicated that, before impoundment, the combination of seasonal flow variations, scouring flow events, and limited suitable substrate limited the extent of riparian vegetation on these islands.

4.3.2.2. Historical Photographic Analysis

We analyzed six oblique and aerial photograph series for the Brownlee reach (see Table 16 for details about location, vegetation, and geomorphology of each photo point):

- (BR-1) Burnt River/railroad bridge (Series 4)
- (BR-2) Morgan Creek confluence with the Snake River/Brownlee corridor (Series 5)
- (BR-3) Hibbard Creek confluence with the Snake River/Brownlee corridor (Series 6)
- (BR-4) Soda Creek confluence with the Snake River/Brownlee corridor (Series 7)

- (BR-5) Powder River confluence with the Snake River/Brownlee corridor (Series 8)
- (BR-6) Brownlee Dam site (Series 9)

An 1899 oblique photograph of the Burnt River and railroad bridge in Series 4 showed sparse riparian zone of sandbar willow and herbaceous plants. Fine substrates were abundant, particularly along the opposite bank, because of alluvial deposits associated with the confluence of two rivers. One hundred years later in 1999, barren reservoir shorelines are dominated by exotic annuals, such as cocklebur, purslane (*Portulaca oleracea*), and pigweed (*Amaranthus albus*). The lack of woody vegetation shown in the 1999 photograph of Series 4 is a consequence of fluctuating reservoir water levels. Today, shoreline substrates consist of fine-cobble to cobble substrates.

The 1955 aerial photograph in Series 4 of the Brownlee reach showed the confluence of the Burnt and Snake Rivers. Upland sagebrush-steppe vegetation dominated the landscape, and woody riparian plants were limited to a scattered fringe of hackberry. Islands and sandbars were common geomorphic features. In 1997, an aerial view of the confluence of the Burnt River with the upper Brownlee corridor showed extensive barren zones along the reservoir shorelines (Series 4). Upland sagebrush-steppe vegetation extended down the slope to the reservoir high-water mark. Former islands and sandbars were inundated when Brownlee Reservoir was filled.

Series 5 of the Brownlee reach contains a 1952 oblique photograph of the alluvial fan associated with the confluence of Morgan Creek with the Snake River. A narrow fringe of sandbar willow with scattered hackberry grew along the riverbank, and steep upland habitats extended downslope to an open river valley with scattered sandbar deposits and channel islands. In the 1999 photograph of Series 5, steep upland habitats of sagebrush and bitterbrush drop abruptly to barren reservoir shorelines, and substrates consist of cobble and bedrock. The former alluvial fan, low-lying river terraces, and channel islands were inundated by the reservoir. In Series 5, no aerial photograph was available to show the 1950s view of the Morgan Creek confluence with Brownlee Reservoir. However, the 1997 aerial view showed extensive barren zones along the reservoir shorelines, with an abrupt transition to upland habitats.

The only oblique photograph of the Hibbard Creek confluence with the Snake River in the Brownlee reach is a 1950s snapshot showing the Idaho riverbank in the background (Series 6). A sparse, narrow fringe of sandbar willows is visible along the lower riverbank. The bench above the riverbank appeared to have been cultivated, perhaps as irrigated alfalfa or grains. No recent photograph is available for comparison. The only aerial photograph in Series 6 graph is the 1997 photograph that showed the same barren zones as the aerial photograph in Series 5.

In Series 7 of the Brownlee reach a 1952 oblique photograph showed a sparse fringe of sandbar willows adjacent to an overgrazed, pastured river terrace or alluvial fan near the Soda Creek confluence with the Snake River. The 1999 view of the reservoir corridor near Soda Creek showed that the river terrace or alluvial fan and valley bottoms were inundated. Steep upland habitats of sagebrush-steppe vegetation dropped to barren reservoir shorelines. No pre-impoundment aerial photograph is available in Series 7, and the 1997 photograph has the same barren shoreline and abrupt transition to upland habitats that Series 5 and 6 show.

Series 8 has a 1946 winter photograph of the Powder River confluence with the Snake River. Fine sands abounded in this confluence zone, and most of the visible sandbar is barren. Scattered hackberry and sandbar willows grew along the riverbanks. Adjacent upland slopes ranged from moderate to steep. In the 1999 oblique photograph of Series 8, the confluence was permanently inundated. As with previous photographs, upland sagebrush-steppe habitats extended down steep slopes to barren reservoir shorelines. The 1999 aerial photograph is similar to the previous aerial photographs in the Brownlee reach (Series 4–7), and no pre-impoundment aerial photograph was available.

At the Brownlee Dam Site in Series 9, a 1953 photograph showed the right abutment for the new dam. An open, scattered stand of pines grew on a low river terrace or alluvial fan, with sandbar willow along portions of the river's edge. The slopes were moderate to steep with substrates ranging from fines to cobble and bedrock. Sunflowers showed in the foreground of the photo, suggesting that portions of the site were recently disturbed. The 1999 photograph in Series 9 showed cobble to bedrock substrates and steep upland habitats of sagebrush-steppe communities dropping to barren reservoir shorelines. In addition, a 1955 aerial photograph in Series 9 showed the Snake River corridor near the Brownlee Dam site. Low river terraces or alluvial fans, sandbars, and islands were common throughout this corridor, as well as a scattered fringe of hackberry and sandbar willow along the riverbanks. Islands did not appear to support riparian vegetation, and one larger island had several conifers. The 1997 aerial view showed cobble and bedrock substrates and inundation of the islands and riparian areas by the reservoir.

4.3.2.3. Riparian Vegetation Patterns

We evaluated public land survey and photographic records for six locations along the Brownlee reach of the Snake River (Table 16, Series 4–9). GLO records (1890s to 1905) indicated that willow and hackberry were common along the river channel, whereas upland habitats were composed of sagebrush-steppe vegetation with scattered pockets of ponderosa pine (Table 16). The riparian vegetation visible in historical photographs (1899 to 1950s, Series 4–9) was limited to sparse and scattered stands of willow and hackberry, though some pines grew on the terraces and slopes adjacent to the river. Steep canyon walls were only sparsely vegetated by upland grasses and shrubs. The geomorphic context of the river canyon naturally constrained channel migration, historically limiting the extent of riparian habitats. The establishment of riparian vegetation on these confined floodplains was also limited by periodic scouring flows associated with the melting and runoff of heavy snowpacks. Fluvial substrates ranged from fine sands/silt to cobble and bedrock, and channel-margin sandbars and islands were relatively abundant before the dam was constructed (aerial photographs in Series 4–9).

Evidence of riparian vegetation was not discernible in the recent photographs (1999) of the Brownlee reach (Series 4–9). Steep slopes of sagebrush-steppe vegetation extend downslope to barren reservoir shorelines. Upland habitats end abruptly at the water's edge when the reservoir is full. At seasonal low-water levels, large barren zones are exposed (Series 4–9) and colonized by annuals, such as cocklebur and a number of Eurasian species (*Amaranthus* sp., *Portulaca oleracea*) (Braatne and Rood *unpubl. data*). In a few areas, semi-transitional zones are composed of nonnative species, such as indigobush or reed canarygrass, which have some affinity for wetland or riparian habitats. Islands and lowland terraces visible in pre-impoundment photographs (Series 4, 8, and 9) were inundated after the dam was built and the reservoir filled. Fine-cobble to cobble substrates and bedrock dominated reservoir shorelines. The lack of fine substrates along these shorelines also limited plant recruitment.

4.3.2.4. Wildlife Habitat Quality

The most obvious difference in wildlife habitat quality between the two periods is the presence of scattered riparian vegetation along the river during the 1950s and the lack of such vegetation during the 1990s because of inundation and reservoir fluctuations. However, the habitat quality of the 1950s riparian vegetation was severely degraded by grazing and mining. The islands visible in the 1950s photographs appeared to support little or no riparian vegetation, although other islands not visible in these photographs were also present. Islands probably provided foraging habitat for a few migrating shorebirds, although Hells Canyon was not a major shorebird migratory route. Islands also provided nesting habitat for a few species, such as the killdeer (*Charadris vociferous*) and especially the spotted sandpiper (*Actitis macularia*), although early-season nests were probably flooded by later spring runoff during some years. Habitat quality for wintering waterfowl was limited on the 1950s free-flowing river. The reservoirs, on the other hand, provide secure loafing habitat for wintering waterfowl (section 4.4.).

Scattered pines growing on some river terraces during the 1950s were inundated by Brownlee Reservoir. In addition, the quality of upland habitat was probably worse in the 1950s than in the 1990s. A cultivated field and badly overgrazed pasture were visible in the 1952 oblique photograph in Series 7. The few alluvial fans and Bonneville Flood-era benchlands that would have allowed big game to move easily were flooded by the reservoir. However, these sites were not continuous, and the remaining slopes were not too steep to preclude big game movement.

4.3.3. Oxbow and Hells Canyon Reservoirs Reach

The Oxbow and Hells Canyon Reservoirs reach also experienced flow fluctuations because of hydroelectric operations. Riparian vegetation and habitat for songbirds and other wildlife may be more widespread along some reaches of Oxbow and Hells Canyon Reservoirs today than during the 1950s. However, most of the increased habitat appears to be the result of exotic rather than native species.

4.3.3.1. Hydrologic and Fluvial Processes

Currently, the water level in Oxbow and Hells Canyon Reservoirs fluctuates in response to the varying inflow and reservoir operation rules that constrain hydroelectric production, flood control, fisheries, coordinated operations with Brownlee Reservoir, and other uses (Tables 17 and 18).

4.3.3.2. Historical Photographic Analysis

We analyzed the Oxbow and Hells Canyon Reservoirs reach using two sets of photographs (see Table 19 for details about location, vegetation, and geomorphology of each photo point):

- Oxbow Reservoir subreach
    - (OX-1) Upriver of Scorpion Creek and Oxbow Dam site (Series 10)
    - (OX-2a) Above Scorpion Creek and Oxbow Dam looking upriver (Series 11)
    - (OX-2b) Above Scorpion Creek and Oxbow Dam looking downriver (Series 12)
    - (OX-3a) Looking downriver from the tip of the oxbow (Series 13)
    - (OX-3b) Looking upriver toward the tip of the oxbow (Series 14)
    - (OX-1 to 3) Aerial views of the oxbow (Series 15)
- Hells Canyon Reservoir subreach:
    - (HC-1) Below Kleinschmidt Grade (Series 16)
    - (HC-2) Ballard Bridge/Hells Canyon Park (Series 17)
    - (HC-1 to 2) Aerial views of the Hells Canyon corridor associated with Kleinschmidt Grade/Hells Canyon Park (Series 18)
    - (HC-3) McGraw Creek confluence with the Snake River/Hells Canyon Reservoir (Series 19)
    - (HC-4) Spring Creek confluence with the Snake River/Hells Canyon Reservoir (Series 20)
    - (HC-3 to 4) Aerial views of the confluence of McGraw and Spring Creeks with the Snake River (Series 21)
    - (HC-5) Kinney Creek Rapids (Series 22)
    - (HC-6) Eagle Bar Landing (Series 23)

Oxbow Reservoir Subreach

The 1953 photograph in Series 10 showed the Oxbow Dam site and alluvial fan of Scorpion Creek. Sandbar willow (far bank) and hackberry (near shore) were scattered along the river's edge with upland habitats of pine and sagebrush-steppe vegetation. The riverbanks were composed of fines to fine-cobble substrates. The late summer river stage was several feet below the normal spring high-water level, as noted by the location of the hackberry, willow, and edge of cobble on the far bank. The 1999 photograph in Series 10 showed upland habitats extending down steep slopes to the water surface, while former river terraces, sandbars, and islands were inundated by the reservoir.

Series 11 of Scorpion Creek and Oxbow Dam contains a 1953 photograph of broad low terraces and barren sandbars, with scattered stands of pine and hackberry. The terraces supported pines and upland shrubs. The riverbanks were composed of fines to cobble and bedrock substrates. The 1999 photograph in Series 11 also showed inundation of low terraces and sandbars. A few hackberry bushes were widely scattered along the reservoir shoreline, and upland habitats extended downslope to the surface of the reservoir. Shoreline substrates consisted of cobbles and bedrock.

Photographs in Series 12 were taken downriver from the same point as those in Series 11. A 1953 photograph showed steep, rocky slopes, and a large sandbar with scattered pine and hackberry growing along the river. No willow was apparent. In the 1999 oblique photograph in Series 12, steep rocky slopes and a dewatered channel were situated directly below the spillway of the dam. A few scattered hackberry and pines were located at the downstream end of the photograph and appeared to predate the dam. The channel bed lacked fine substrates and appeared to be heavily armored.

In Series 13 looking downriver from the tip of the oxbow, a 1953 photograph showed the river flowing through the lower half of the oxbow. There were upland habitats of sagebrush-steppe vegetation with scattered pines and hawthorn (*Crataegus douglasii*) and a riparian fringe of hackberry. On higher portions of the alluvial fan, the vegetation appeared to have been heavily grazed. Riverbanks were composed of fines to fine-cobble and bedrock. The 1999 photograph in Series 13 showed partial inundation of the oxbow by Hells Canyon Reservoir. Upland and riparian habitats appear similar to pre-impoundment conditions, although alternating cycles of inundation and drawdown have armored the channel bed. The shoreline consists of cobble and bedrock.

The tip of the oxbow is also shown in Series 14. The 1953 oblique photograph showed upland habitats of sagebrush steppe with a fragmented fringe of hackberry along the river. The broad river terraces were composed of fines to fine-cobble and bedrock, and a browse line was evident on tall shrubs (possibly *Purshia* or *Cercocarpus* spp.). The 1999 photograph in Series 14 showed inundated river terraces similar to those in Series 13. Upland and riparian habitats appeared similar to those before inundation, although the extent of hackberry, thornberry, and serviceberry (*Amelanchier alnifolia*) increased considerably.

Aerial views of the oxbow (Series 15) were used to complete the record provided by the oblique photographs in Series 13 and 14. The 1955 aerial photograph in Series 15 showed that barren sandbars, islands, and low river terraces were common as the Snake River flowed through the oxbow. Riparian habitats consisted of a scattered fringe of hackberry and sandbar willow. In 1997, the oxbow features had been inundated by reservoir operations. Riparian habitats are now limited to a fragmented fringe of hackberry.

Hells Canyon Reservoir Subreach

Series 16 of the Hells Canyon Reservoir subreach includes only one 1950s photograph of the riverbank below Kleinschmidt Grade, near the present location of Hells Canyon Park. A narrow, continuous band of sandbar willow grew along the lower riverbank, with sagebrush-steppe vegetation on the upper riverbank and surrounding canyon slopes. A cultivated field (alfalfa, grasses, and grains) was on the adjacent river terrace.

Series 17 contains a 1953 photograph of large stands of sandbar willow with scattered pine and hackberry below Ballard Bridge. The 1999 photograph of the reservoir showed the corridor below Hells Canyon Park (Series 17). Former river terraces and riparian habitats are inundated; however, shrub communities composed of hackberry, Himalayan blackberry (*Rubus discolor*), serviceberry, and indigobush grow along the reservoir shorelines. Large trees in the background are associated with Hells Canyon Park and private residences.

Aerial photographs in Series 18 were used to evaluate photographs in Series 16 and 17. A 1955 aerial photograph in Series 18 showed the Kleinschmidt Grade and Ballard Bridge crossing of the Snake River. Islands, sandbars, and terraces associated with alluvial fans of tributaries were common throughout this reach, and only a fragmented fringe of hackberry grew along the river channel. Islands generally did not appear to support riparian vegetation. The 1999 view of Hells Canyon Park and the associated reservoir corridor shows that the islands, sandbars, and alluvial fans are inundated (Series 18). Upland habitats end abruptly, and scattered patches of hackberry grow at the reservoir shoreline.

In Series 19, a 1953 photograph of the McGraw Creek confluence with the Snake River showed that white alder dominated the lower reach, with scattered hackberry and sandbar willow on the alluvial fan adjacent to the Snake River. The riverbank was composed of fines to fine-cobble and bedrock. The 1999 photograph in Series 19 showed inundation of the alluvial fan. A flood-related debris flow during winter 1997 scoured McGraw Creek, removing all riparian vegetation along the lower reach of this creek. Shoreline substrates consist of cobble and bedrock.

At the Spring Creek confluence shown in the 1953 photograph in Series 20, the vegetation and substrate were identical to those in Series 19. As indicated in the 1999 photograph in Series 20, some white alder and pine along Spring Creek appear to have survived the 1997 debris flow. The shoreline consists of cobble and bedrock substrates and limited vegetation.

One series of aerial views (Series 21) cover the McGraw Creek and Spring Creek confluences with the Snake River in Hells Canyon Reservoir (Series 19 and 20). As shown in the 1955 aerial view in Series 21, this corridor is noted for steep canyon walls with scattered sandbars and alluvial fans. The riparian zone was limited to scattered fragments of hackberry, and riparian stands of white alder along Spring Creek were much more extensive than along McGraw Creek. The 1997 aerial view shows that the reservoir inundated sandbars and alluvial fans associated with these tributaries, along with other fluvial and channel features. The area affected by storm-related debris flows can be seen along the lower reaches of Spring and McGraw Creeks. Higher coverage of riparian habitats along Spring Creek may be related to higher base flows in summer than McGraw Creek experiences.

A 1953 oblique photograph of the Kinney Creek Rapids in Series 22 showed a diverse mosaic of riparian and upland habitats. White alder dominated the lower reaches of Lynch Creek in Oregon and the alluvial fan of Kinney Creek in Idaho, with a fragmented fringe of hackberry and sandbar willow growing along the river. An extensive stand of pine along the Oregon side of the river gradually transitioned to sagebrush-steppe communities on the steeper canyon slopes. Riverbanks were composed of fines to cobble and bedrock substrates; separation bars and channel-margin sandbars were present below the rapids. In the 1999 photograph in Series 22, the riparian habitats in the corridor and the stand of pines are inundated. Himalayan blackberry is now the dominant shrub along the shoreline. The steep shorelines consist of bedrock and cobble substrates.

The 1955 aerial photograph in Series 22 of the Snake River corridor near Kinney Creek showed that alluvial fans and sandbars, along with scattered hackberry and pine, were common. The 1999 photograph in Series 22 showed that alluvial features and scattered stands of pine and hackberry are inundated. Himalayan blackberry dominates the shrub layer along the shoreline.

The 1953 photograph in Series 23 showed the Snake River corridor near Eagle Bar Landing. Steep canyon walls extended downslope to sparsely vegetated riverbanks of bedrock and cobble. The low-elevation bedrock is inundated in the 1999 photograph, and the sparsely vegetated slopes appear similar to conditions before dam construction. The 1955 and 1999 aerial views of Eagle Bar in Series 22 both showed the steep canyon walls. In 1955, the riverbanks were sparsely vegetated. In 1999, the upland habitats extend down toward reservoir shorelines.

4.3.3.3. Riparian Vegetation Patterns

We evaluated public land survey and photographic records for nine locations along the Oxbow/Hells Canyon Reservoirs reach of the Snake River (Table 19, Series 10–23). GLO records (from 1901 to 1936) indicate that willow and hackberry were common along the river channel, with upland habitats consisting of overgrazed sagebrush-steppe vegetation. Near the confluence of the Snake River and Pine Creek, some cottonwoods grew along the mainstem. The riparian vegetation visible in historical photographs (1901 to 1950s, Series 10–23) was limited to scattered stands of willow and hackberry along the riverbank. Pines were relatively common on adjacent terraces and slopes. Steep canyon walls were sparsely vegetated by sagebrush-steppe plants. The geomorphic context of the river canyon naturally constrained channel migration, limiting the extent of riparian habitats. Periodic scouring flows also limited the establishment of riparian vegetation on these confined floodplains. Fluvial substrates ranged from fine sands and silt to cobble and bedrock. Channel-margin sandbars and islands appeared to be relatively abundant before the dams were constructed (Series 10–23).

Recent photographs of the Oxbow/Hells Canyon Reservoirs reach revealed scattered patches of woody vegetation along reservoir shorelines (Series 13, 14, and 17). Given minimal water-level fluctuations (diurnal and seasonal, ± 1.0 to 1.5 meters), deciduous shrubs and trees were relatively common along these reservoir shorelines. The most common species included hackberry, indigobush, Russian olive, Chinese elm, Himalayan blackberry, and serviceberry, with some sandbar willow on alluvial fans. Emergent vegetation developed in a few areas, often on gradually sloping alluvial fans. However, steep canyon walls are the dominant geologic feature of this reach, and sagebrush-steppe communities extend downslope to reservoir shorelines. Eurasian and noxious annuals appear to be less common than in the Brownlee and Weiser reaches. Islands and lowland terraces visible in pre-impoundment photographs (Series 10–23) are inundated. Fine-cobble to cobble substrates and bedrock dominate reservoir shorelines. The lack of fine substrates along these shorelines is an important factor limiting plant establishment.

4.3.3.4. Wildlife Habitat Quality

Observations in the field and from the aerial photographs suggested that shoreline vegetation may be more widespread along some reaches of Oxbow and Hells Canyon Reservoirs today than in the 1950s. Many islands did not support riparian vegetation during the 1950s because of regular scouring flows. And species diversity appears to be greater in today's shoreline community; however, much of this vegetation is derived from exotic species. Sandbar willow is much less common today, and numerous stands of scattered pines are inundated. Wildlife habitat values of the riparian zones between the two periods are difficult to compare because the dominant plant species have changed and the photographic record is incomplete. Species that used sandbar willow may have declined since the 1950s. However, some of these species, such as the song sparrow (*Melospiza melodia*), may find that blackberry provides suitable habitat. Others, such as the spotted towhee (*Pipilo erythrophthalmus*), may also find suitable habitat in the dense shrub riparian vegetation. The addition of elms to the riparian community benefits wildlife because of its large size and profuse seed production. Finally, reduced grazing pressure has improved both riparian and upland communities to the general benefit of a wide range of wildlife species.

Overall, it appeared that shoreline habitat values in 1999 are somewhat greater than they were in the 1950s. Upland habitat conditions probably improved, especially on the Oregon side of Hells Canyon Reservoir, where there is little grazing adjacent to the Snake River. Changes in wintering waterfowl habitat between the two periods would be similar to those described for the Brownlee reach.

4.3.4. Downstream Reach

Hydrologic processes in the Snake River downstream of Hells Canyon Dam have been influenced by several factors, such as steeper gradient, increased drainage area, and operation of upstream dams that regulate seasonal peak flows. However, the primary change in vegetation and wildlife habitat quality between the 1950s and 1990s has been the dramatic increase in tributary riparian canopy cover values, canopy height, and woody plant species diversity. Eliminating grazing on most HCNRA allotments that border the river probably caused these changes.

4.3.4.1. Hydrologic and Fluvial Processes

Downstream of Hells Canyon Dam, the Snake River geomorphology is dominated by bedrock canyon walls and colluvial boulder slopes. These types of features and materials are not typically mobilized by the current flow regime. Other geomorphic features include fans, bars, terraces, and occasional islands, some of which consist of materials that may be affected by the current flow regime. Less finer-sized sediment is present in this river reach, and islands and fluvial features are limited by the dominance of canyon-type features and associated materials; increased gradient, which increases velocity and sediment transport; and effects of upstream dams, including the Hells Canyon Complex. The effect of increased gradient, which has played a role in the decreased amount of fine sediment deposition, may also play some role in potentially limiting the extent of riparian vegetation in this portion of the study area.

Annual flow patterns at the Hells Canyon gauge were similar to upstream inflows at Weiser. However, flows at Hells Canyon are generally greater than they are at Weiser because of the increase in drainage area related to various tributaries below Weiser (Figures 14 and 15, respectively). Peak flows at Hells Canyon are also typically higher than those at Weiser, again because of increased drainage area. In some cases, though, peak flows may be lower because of reductions in flood peaks by Brownlee Reservoir. The timing of flow recession depends on annual operations and can differ from Weiser to Hells Canyon. These changes in peak flow and recession timing may affect plant germination and establishment.

4.3.4.2. Historical Photographic Analysis

We analyzed the following 12 photograph series for the downstream reach (see Table 20 for details about location, vegetation, and geomorphology of each photo point):

- (SR-1) Deep Creek to Hells Canyon Creek (RM 247.5) (Series 24)
- (SR-2) Confluence of Saddle Creek with the Snake River (RM 236) (Series 25)
- (SR-3) Upriver overview of Johnson Bar (RM 230) (Series 26)
- (SR-4) Downriver overview of Sheep Creek Rapids (RM 229.5) (Series 27)
- (SR-3 to 4) Aerial views of Johnson Bar and Sheep Creek Rapids (Series 28)
- (SR-5) Sturgeon Rock and Alum/Pine Bar (RM 227.5) (Series 29)
- (SR-6) Downriver view of the Snake River at Pittsburg Landing (RM 215/OR) (Series 30)
- (SR-7) Downriver view of the Snake River at lower Pittsburg Landing (RM 214.5/ID) (Series 31)
- (SR-6 to 7) Aerial views of the Snake River at Pittsburg Landing (Series 32)
- (SR-8) Downriver view of High Range and Getta Creeks (RM 206) (Series 33)
- (SR-9) Ragtown Bar area (RM 205) (Series 34)
- (SR-10) Basalt columns at Dug Bar (RM 196.5) (Series 35)
- (SR-11) Eureka Bar/Imnaha Landing (RM 191.5) (Series 36)
- (SR-12) Upriver of the confluence of the Snake and Salmon Rivers (RM 188.5) (Series 37)

A 1951 oblique photograph in Series 24 of Deep Creek to Hells Canyon Creek showed steep canyon walls with bedrock and talus slopes. The riparian zone was limited, although some hackberry and serviceberry grew above a small side-channel bar with pines scattered along the base of talus slopes. In the 1999 oblique photograph in Series 24, banks on the Oregon side of the river below Hells Canyon Dam are heavily armored with revetments, while the Idaho side of the river does not differ from pre-impoundment conditions. Riverbanks are composed of cobbles, boulder, and bedrock. A 1955 aerial photograph in Series 24 showed steep, rocky canyon walls and talus slopes and limited sediment deposition and riparian habitats. In the 1997 aerial photograph, the channel morphology and shoreline conditions appear similar to conditions in the earlier aerial photo.

Series 25 of the downstream reach contains a 1934 oblique photograph of the lower reach and alluvial fan of Saddle Creek. This stretch had been largely cleared of white alder and other woody vegetation, but some scattered hackberry and willow remained on the alluvial fan. The 1999 oblique photograph in Series 25 showed a diverse, dense stand of riparian woody vegetation dominated by white alder and with hackberry and other shrubs growing along the margins of the alluvial fan. In both photographs, the riverbank is composed of cobble and bedrock. No pre-impoundment aerial photograph is available, but the 1997 aerial view in the series supports patterns revealed in the oblique photo.

The 1953 photograph in Series 26, an upriver overview of Johnson Bar, showed a widely scattered riparian fringe of hackberry and channel-margin sandbars. The broad, sloping terraces adjacent to the river were deposited 14,500 years ago by the Bonneville Flood. Riverbanks consisted of fines to cobble and bedrock. The 1999 oblique photograph in Series 26 showed a continuous riparian fringe of hackberry. The relative growth rate of hackberry during the last 50 years can be determined by comparing the size of individual trees growing along the river's edge and those on the adjacent terraces. Fine sands have eroded from the channel-margin sandbars, and riverbanks are composed of fine-cobble to bedrock. A close-up photograph of the riverbank showed that hackberry is generally extending downslope by root suckers. This downslope expansion may be related to the lack of extreme scouring flows (such as the 120,000 cfs peak flow at the Weiser gauge in 1910) and in part to the construction and operation of the American Falls Reservoir (1927) and other water developments upriver of the Hells Canyon Complex. A 1997 aerial view in Series 26 showed an extensive stand of riparian hackberry. No pre-impoundment aerial photograph is currently available.

Series 27 includes a 1953 oblique photograph of Sheep Creek Rapids with scattered pines and hackberry and fine sand to coarse gravel along the channel margin. Some form of agricultural activity (hay or pasture) was evident along the lower terrace (alluvial fan and Bonneville Flood deposits). The alluvial fan of Sheep Creek also lacked woody riparian vegetation. The 1999 photograph in Series 27 showed an increase in the growth and canopy development of hackberry. Re-establishment of white alder and associated shrubs is also evident along the alluvial fan of Sheep Creek. Fine sands have eroded from the channel-margin sandbars, and the riverbanks consist of fine-cobble to bedrock. The 1997 aerial photograph in Series 28 supports patterns revealed by the oblique photo, although no pre-impoundment photograph is available.

The large sandbar in a 1930s to 1940s photograph of Sturgeon Rock and Alum/Pine Bar (Series 29) supported a large stand of sandbar willow with some hackberry upslope of the bar. Scattered pines and sagebrush-steppe vegetation grew on the lower canyon walls. The 1999 photograph in Series 29 showed sandbar erosion and the loss of sandbar willow and hackberry. The riverbank consists of fine sands in both photographs. The 1997 aerial photograph in the series showed the same vegetation patterns as those described for the oblique photograph (no pre-impoundment aerial photograph is available).

A 1928 to 1929 photograph in Series 30 of the riverbank opposite of Pittsburg Landing showed steep upland slopes of sagebrush-steppe vegetation dropping abruptly to the edge of the river. Scattered hackberry grew along the steep rocky banks and draws. Bright high-water marks were visible on the rocks adjacent to the river. The riverbanks consisted of cobble and bedrock. No changes showed in the 1999 photograph in Series 30, and the high-water mark appears at a similar river stage. The shrub coverage has increased moderately near seeps and in draws, especially because of the colonization and growth of Himalayan blackberry. A 1997 aerial view of Pittsburg Landing is provided (Series 32), but no pre-impoundment photograph is available.

The riparian zone in a 1953 photograph of lower Pittsburg Landing (Series 31) is limited to a few hackberry growing at the toe slope of Bonneville Flood depositions. By 1999, the riparian fringe of hackberry had expanded significantly, and a healthy stand of sandbar willow is now visible along the Oregon side of the river. The riverbanks in both oblique photographs of Series 31 consist of cobble substrates. The only aerial photograph available was taken in 1997 (Series 32).

An oblique photograph looking downriver toward High Range and Getta Creeks was taken in 1928 or 1929 (Series 33). The steep, rocky riverbanks and canyon walls supported only a few upland shrubs and grasses. Seasonal high-water marks are visible along the lower riverbanks. In a 1999 photograph in Series 33, no significant changes in vegetation or shoreline conditions are apparent; high-water marks also appear at a similar river stage.

At the Ragtown Bar Area shown in Series 34, there appeared to be no significant difference between the two periods. The 1928 or 1929 photograph in the series showed an open valley with sparse riparian vegetation. Only a few scattered hackberry were visible along the upper riverbanks. The 1999 photograph in Series 34 showed larger hackberry trees and riverbanks that still consist of cobble and bedrock. A 1997 aerial photograph is provided in Series 34, but a pre-impoundment photograph is unavailable.

The basalt columns and talus slopes on the banks opposite of Dug Bar were shown in a 1928 or 1929 photograph in Series 35. A few scattered hackberry and upland shrubs and grasses grew on the lower talus slopes. The 1999 photograph in Series 35 showed no clear differences. Substrates in both periods are primarily cobble. A 1955 aerial view of Dug Bar showed the river reach highly constrained by steep canyon walls upriver of the bar. Downriver, the canyon opens to a broad terrace of Bonneville Flood deposits. Channel-margin sandbars appeared to have been common along the Dug Bar corridor, and woody riparian vegetation was limited to a few scattered hackberry. Channel morphology is similar in the 1997 aerial photograph in Series 35, yet there are few channel-margin sandbars. Therefore, margins of the river channel appear smoother and less complex. The extent of hackberry increased slightly along the reach.

In Series 36 of the downstream reach, a pre-impoundment photograph of the Imnaha steamboat docked at Eureka Bar showed sparsely vegetated rocky slopes and sandbars in protected channel margins. The 1999 photograph in Series 36 also showed Eureka Bar. Canyon walls support only limited plant cover, and a healthy stand of sandbar willow grows along the upper margin of Eureka Bar. In both photographs in Series 36, the riverbanks consisted of fine sands to bedrock. The 1955 aerial view of the corridor between Imnaha and Eureka Bars showed a channel that was confined by steep canyon walls, although small channel-margin sandbars were common. Hackberry and other woody riparian vegetation were scarce. In the 1997 photograph in Series 36, channel morphology was similar, although the extent of channel-margin sandbars (such as Eureka Bar) had decreased. The extent of hackberry and other woody vegetation remained extremely limited.

A 1928 or 1929 photograph in Series 37 showed that the reach upriver of the confluence of the Snake and Salmon Rivers had steep canyon walls and lacked riparian vegetation. The riverbanks consisted of bedrock and boulders, and high-water marks were readily visible along the riverbank. No apparent differences in vegetation, shoreline conditions, substrate, or the high-water mark were evident in the 1999 photograph in Series 37. The only aerial photograph currently available is from 1997 (Series 37).

4.3.4.3. Riparian Vegetation Patterns

We evaluated public land survey and photographic records for 12 locations along the downstream reach of the Snake River (Table 20, Series 24–37). GLO records (1901 to 1936) indicated that willow and hackberry were common along the mainstem of the river, with upland habitats having sagebrush-steppe vegetation. Surveyors recorded the presence of scattered pines and fir along lowland terraces; otherwise, no other trees were noted. In many instances, surveyors recorded dangerous cliffs and basalt ledges rather than plant cover types. The riparian habitats visible in historical photographs (1920s to 1950s, Series 24–28, 30, and 33–37) were limited to scattered stands of willow and hackberry along the riverbank. Before intensive livestock grazing, sandbar willow would have been more common along the margins of sandbars and islands. The steep walls of the canyon and tributaries were only sparsely vegetated. Since the geomorphic context of the river canyon naturally constrained channel migration, the extent of riparian habitats has always been limited. Fluvial substrates historically ranged from fine sands/silt to cobble and bedrock; channel-margin sandbars and islands were relatively abundant before the dams were constructed (all aerial photographs in Series 24–37).

Recent photographs of the Hells Canyon reach of the Snake River showed a fragmented riparian fringe of hackberry, with only small, scattered populations of sandbar willow. Steep canyon walls remain sparsely vegetated. The growth and canopy development of hackberry appears to have increased over the last several decades. In several areas, hackberry has expanded downslope toward the channel through the initiation and growth of root suckers (Series 26, 27, and 35). The riparian habitats of tributaries also support a much more diverse and continuous cover of trees and shrubs than they did before impoundment when trees were largely absent from tributary riparian communities and emergent plant communities were rare (Series 25 and 27). Some of the common species found along these tributaries include white alder, water birch (*Betula occidentalis*), hackberry, syringa (*Philadelphus lewisii*), and a few cottonwoods. Channel morphology is similar to conditions before impoundment, although the extent of separation bars and channel-margin sandbars declined. Riverbank substrates consisted of fine-cobble to cobble and bedrock. This lack of fine substrates following dam construction appeared to limit the recruitment of sandbar willow.

4.3.4.4. Wildlife Habitat Quality

The greatest apparent change in wildlife habitat quality between the 1950s and 1999 has been the substantial improvement in the condition of tributary riparian zones. Canopy cover values, canopy height, and woody plant species diversity in these areas appears to have increased dramatically in many of the drainages. These changes are largely attributed to the elimination of grazing on most HCNRA allotments along the river. Also, with the exception of the Imnaha River, because most of these drainages in Oregon are entirely within the HCNRA or Hells Canyon Wilderness, there were few, if any, upstream diversions. The absence of diversion structures and grazing has allowed many of the riparian zones along tributaries to recover from the effects of clearing and heavy grazing. A wide variety of wildlife and fish species benefit from higher quality riparian zones and associated cooler water temperatures.

Debris flows down tributaries occurred during both periods; however, information to compare the frequency of these events is unavailable.

Backwater areas, sandbars, and islands were always limited by the narrow, rocky canyon. Fewer of these areas, especially smaller sites, may exist today than in the 1950s, and they may have changed in extent. However, Beck et al. (2000) reported that western toads (*Bufo boreas*) bred in relatively permanent major backwater areas below Hells Canyon Dam. These major backwater areas existed when the dam was constructed. Sandbar willow was never very common, but it appears to be less so today than in the 1950s.

Generally, areas supporting hackberry in the 1950s also support hackberry today. However, individual plants and overall canopy cover have increased substantially in many locations. Hackberry provides dense nesting habitat for neotropical migrants, and the fruits are eaten by robins (*Turdus migratorius*), evening grosbeaks (*Coccothrasustes vespertina*), and various woodpeckers, among other species. Mule deer have also been reported to browse on hackberry in Utah (Martin et al. 1951), although there is no evidence of this behavior in the study area.

As we noted for the other river reaches, upland range conditions have improved since the 1950s, especially in those parts of the HCNRA adjacent to the Snake River that are no longer grazed. This trend is likely to continue. Improved range conditions translate into a greater abundance of native grasses and forbs and fewer shrubs. This abundance would tend to favor wildlife species that prefer higher grass/forb cover values, such as elk, which are primarily grazers. Ground-nesting birds and those nesting in low shrubs would also benefit from higher ground-cover values (Saab et al. 1995). These shifts in vegetation patterns would be detrimental to browsing species, such as mule deer, particularly where there is a lower incidence of shrubs, as is generally the case in Hells Canyon.

4.4. Effects of the Hells Canyon Complex

To fully analyze wildlife habitat, we had to evaluate the effects of hydrology, geomorphology, and sediment, as they have been affected by the construction and operation of the Hells Canyon Complex, on wildlife habitat. River form, as it has developed over geologic and historic time, significantly affects the river hydraulics that provide habitat for aquatic life, riparian and other vegetation, and habitat for terrestrial wildlife.

Disregarding other nonhydraulic factors and influences, the quality and quantity of habitat is a function of hydraulic variables such as velocity, depth, and substrate (sediment size distributions) and of the relationship between channel and floodplain geometry and flow in seasonal patterns of inundation and recession rates of flow hydrographs. For example, riparian vegetation provides variable-quality wildlife habitat compared with barren substrate. However, the existence of vegetation depends on the quality of substrate and whether, how, and when it is flooded during periods of seed dispersal and germination. Vegetation establishment also depends on the recession rates of the water level and the strength of the current that might erode the substrate or the vegetation itself. These complex interactions play a significant role in the development and maintenance of wildlife habitat. Furthermore, they are a direct result of the interaction between flow and geomorphology. While other interactions may either benefit or adversely affect habitat, the primary factor in establishing and maintaining habitat remains the direct relationship between water and the earth’s surface and how this interaction combines to create habitat.

Constructing three hydroelectric projects in the study area immediately converted terrestrial and riparian vegetation types and farmed and mined lands to permanently or temporarily flooded aquatic habitats. Based on the information discussed in the previous sections, the lands directly affected by dam and reservoir construction could be characterized as badly overgrazed and abused by more than 70 years of mostly unrestricted human and livestock use, mining, and more recently, cheatgrass invasion. Winter range at lower elevations, already badly overgrazed by the early 1900s, suffered further deterioration during the 1930s as deer numbers rebounded significantly but the pressure from livestock grazing was not reduced. Given only 10 years of limited grazing regulation but little enforcement on federal lands, range conditions had not recovered by the 1950s (P. Grindy, Payette National Forest, *pers. comm.*). Depending on winter severity, deer mortality on winter ranges was common in the 1950s. The lowest-elevation winter ranges were flooded by the reservoirs. However, deer mortality still occurs today on the winter range above the reservoirs, especially during heavy snow years. Absolute numbers of animals dying on the winter range or the percent of the wintering population affected were not consistently reported for either period, so we could not compare those numbers.

Riparian zones impacted by the IPC dams and flooding were also in poor condition because of overgrazing, mining, timber harvesting, and water diversion. No immediate effects of constructing the dams were identified for wildlife habitat downstream of Hells Canyon Dam.

One large-scale operational change in the Brownlee and Oxbow/Hells Canyon Reservoirs reaches was the conversion of a flowing river that was several hundred feet wide to three reservoirs that were up to several thousand feet across. The wide reservoirs probably made crossing the river more perilous for large animals and virtually impossible for smaller species that do not fly. Mule deer occasionally break through the ice and drown, while a few others apparently succumb to exhaustion and drown. J. Morrison (IDFG retired, *pers. comm.*) related an incident during the late 1950s when he observed several weakened deer swimming across Brownlee Reservoir during late winter. As the deer approached the far shore, people in a passing car stopped to watch. They were apparently too close because the deer turned around to swim back to the near shore. A couple of these deer drowned. Such occurrences are probably rare, but they do increase mortality.

Critical mule deer winter range is associated with Brownlee and Oxbow Reservoirs (Christensen 2001). These reservoirs bisect critical winter habitat and increase the likelihood of deer mortality. During 1999–2001, 255 radio-marked deer were monitored to identify mortality rates and sources (Edelmann 2001). Total winter (1 January to 15 March) and spring green-up (16 March to 15 April) mortality estimates respectively averaged 17.9% (range = 20.6–16.2%) and 7.2% (range = 5.2–7.7%). Mortality rates of deer due to interactions with the reservoirs averaged 5.8% (range = 2.9–7.7%) during winter and 2.5% (range = 1.0–3.9%) during green-up.

Thirty-three deer deaths were associated with the reservoirs. Twenty-eight (85%) deer died along steep shorelines where predators (mostly coyotes) captured these animals in broken terrain or water. Deer were relatively concentrated in low-elevation habitats adjacent to the reservoirs during winter and green-up. The shorelines formed abrupt boundaries in the lower extents of the winter range, which interrupted escape terrain for the deer. Furthermore, predators often trapped deer against shoreline cliffs and on steep rocky shorelines where escape was nearly impossible. Coyotes were also observed first pursuing deer into the reservoirs and then capturing the deer as they attempted swimming to shore. Four deaths (12%) occurred during reservoir crossings. Two deer drowned, and cougars killed the other two deer as they came ashore. Deer observed completing reservoir crossings typically appeared to be exhausted, relatively incapacitated, and vulnerable to predation. Therefore, the reservoir crossings may have contributed to the observed cougar predations. One deer attempted to escape coyotes by crossing a frozen section of the Powder River Arm of Brownlee Reservoir. The deer apparently lost footing on the ice and was killed by several coyotes.

In conclusion, Brownlee and Oxbow Reservoirs appear to increase winter and green-up mortality rates of mule deer in Hells Canyon. Overall, however, mortality not associated with the reservoirs more heavily influenced deer survival. It is also unclear what proportion of deer mortality attributed to interactions with the reservoirs is compensatory with other mortality sources. Nonetheless, Brownlee and Oxbow Reservoirs appeared to increase predator efficiencies and decrease overall deer survival in habitats adjacent to the reservoirs.

Another large-scale effect of converting the flowing river to reservoirs was a substantial improvement in wintering waterfowl habitat. IPC (1997) described winter waterfowl habitat of the study area reach as follows: “The Snake River is centrally located in relation to waterfowl habitat areas of major concern in western North America (Bildstein et al. 1991). Much of the winter waterfowl habitat in eastern Oregon and Washington and western Idaho is associated with the Snake River and related impoundments. Development of impoundments along the Snake River has influenced the presence, characteristics, and habitat values of water bodies for waterfowl. Historically, strong currents in the river would have made flocking on open water a difficult strategy for avoiding hunting in the unimpounded system (Ball et al. 1989). However, rafting on open water is a dominant strategy today. Rivers widened and slowed by impoundment provide increased security, although waterfowl may be exposed to rough water during windy weather.”

Operation of Brownlee Reservoir has affected the ability of vegetation to establish. This reservoir is drawn down each year to control floods and facilitate summer hydroelectric generation. Aquatic vegetation cannot grow in the drawdown zone because of the annual exposure. Except for a few exotic annual plants, the annual flooding also prevents upland or shoreline vegetation from establishing. Operation of Oxbow and Hells Canyon Reservoirs causes only minor changes in water level, thereby maintaining a fairly stable wetted perimeter along the shoreline. This mode of operation appears to have positively affected the abundance of shoreline riparian vegetation along portions of these reservoirs. There also appears to be greater species diversity in today’s shoreline community, though much of this diversity is attributed to exotic species. In fact, we had difficulty comparing wildlife habitat values of the shoreline zones between the two periods because the dominant species had changed so much and the photographic record was incomplete. Still, based on casual observations of the structural diversity of the riparian community, shoreline habitat values in 1999 appear to be greater than in the 1950s.

Another landscape-level change in wildlife habitat resulting from higher summer base flows (attributed to project operations) is related to the riparian community downstream of Hells Canyon Dam. Hackberry is much more prominent in riverside riparian zones today than it was before the dam was constructed. Individual plants are larger, and the overall canopy cover is greater today, substantially so in some locations. However, sandbar willow and other native herbaceous riparian vegetation below Hells Canyon Dam appear to be less common today.

In addition, regular activity by recreationists can change wildlife-use patterns in a variety of settings. In the study area, recreation has increased significantly since the 1950s, especially use during the summers. Because the highest levels of big game activity occur during winter and spring, the increases in recreation activity have probably not caused substantial changes in big game use or habitat quality. In the downstream reaches, float and jet boat use has also caused only relatively minor loss of wildlife habitat at popular campsites.

5. Discussion

A wide variety of factors affected fluvial processes, vegetation, and wildlife along the Snake River from Weiser to the confluence with the Salmon River. These factors include basinwide development of water resources, agriculture, mining, grazing, timber harvest, and other development. In many instances, differentiating the effects of general development from the effects of the Hells Canyon Complex is extremely difficult. Also, the Hells Canyon Complex is not operated strictly for hydroelectric production. Some operational criteria, including such factors as flood control or flow augmentation, are dictated by parties other than IPC. For example, Brownlee Reservoir is typically drawn down to provide some incremental storage for flood control at the direction of the U.S. Army Corps of Engineers.

Before Euro-American settlement of the Hells Canyon area, the riparian community varied considerably from the upper to the lower end of the study area with differences probably evident between the Weiser reach, Brownlee reach, Oxbow/Hells Canyon Reservoirs reach, and the reach downstream of Hells Canyon Dam. Low river gradient and abundant fine sediments probably promoted a relatively continuous and variable-width riparian fringe in the upper reaches, after which riparian habitats became fragmented as the valley floor narrowed and the channel gradient increased within the canyon. All of these areas were substantially affected by multiple anthropogenic factors beginning in the mid- to late 1800s.

Today, longitudinal changes in riparian vegetation patterns vary in response to flow regulation and historical patterns of agricultural impacts (such as grazing, crops, and orchards). The Weiser reach is an unimpounded system with a narrow forested riparian fringe consisting of largely exotic species. The Brownlee reach consists of a barren drawdown zone with almost no shoreline vegetation. The Oxbow/Hells Canyon Reservoirs reach is a reregulating section (subject to Brownlee releases), with minimal pool fluctuation and a diverse shoreline community composed of native and exotic species. Below Hells Canyon Dam, the downstream reach is again a riverine canyon, but with substantially diminished sediment loads compared with those before settlement and, to a much lower degree, before construction of Brownlee Dam. Larger tributaries below Hells Canyon Dam, including the Salmon River, contribute an increased sediment load related to changes in upstream land use and sediment and water discharge properties.

Before the dams were constructed, riparian zones throughout the study area were heavily impacted by grazing and land-clearing activities that decreased the extent of willow habitats along the Snake River. General development of the watershed and associated disturbances had likely increased the amount of sediment produced and supplied to the Snake River from upstream sources by the late 1800s. However, primarily in the early to mid-1900s, this trend was reversed by numerous reservoirs on the Snake River and its tributaries. Reduced sediment loads were further extenuated by additional sediment trapping in the reservoirs of the Hells Canyon Complex. Snake River riparian zones in the downstream reach were altered because of the reduced sediment supply and because of daily fluctuations from hydroelectric generation. The resulting lack of fine and coarse sands further decreased the extent of willow habitat and areas suitable for the recruitment of willow seedlings; it may have also impacted small emergent wetland communities. However, hackberry leaf canopies are more extensive and robust, perhaps because of higher base flows during growing season. And through root suckers and sprouts, hackberry has been encroaching on the shoreline zone formerly occupied by willows.

The elimination of grazing and other agricultural activities, including some irrigation diversions, within much of the lower canyon has led to substantial recovery of riparian zones on tributaries in the HCNRA and perhaps the recovery and growth of some scattered willow populations along the Snake River. However, recovery of riparian and upland habitat is limited in those parts of the HCNRA that are still grazed, such as the Pittsburg Landing area.

Upland habitat values throughout the study area had been severely degraded by unrestricted livestock grazing beginning in the 1860s and continuing for more than 70 years. Regulations restricting livestock grazing on public lands were not enforced until the 1940s or 1950s, and there is no evidence of improved range conditions by the late 1950s. Generally, upland range conditions have improved somewhat between the 1950s and 1990s. However, continued spring and summer grazing on some BLM and USFS allotments probably limits potential recovery of these lands, especially in riparian areas because of the limited access to water at any distance from the Snake River.

Mining occurred at many sites in the study area until the 1940s. Mine areas were generally cleared of vegetation, and tailings were haphazardly placed adjacent to mining areas. Trees near mine sites, including upslope areas, were cut, and water was diverted from streams. Mining generally destroyed wildlife habitat around mine sites.

5.1. Weiser Reach

Public land survey and photographic records of the Weiser reach of the Snake River showed that riparian vegetation was affected by a number of changes in land use and flow regime. Native Americans traditionally camped and traded goods at the confluences of the Weiser and Payette Rivers with the Snake River. This reach was also frequented by fur trappers in the early 1800s (1810 to 1835) and by settlers traveling the Oregon Trail (1850s to 1870s). Large numbers of horses and cows were moved along the Oregon Trail during this time. Since land surveys did not begin until the 1870s, we do not fully know how these early travelers affected upland and riparian vegetation.

Agricultural clearing and grazing along Weiser Flats, however, was extensive by the late 1800s to the early 1900s, and affected virtually all flat areas along the Snake River, including islands. The expansion of irrigated pasture, crops, orchards, and livestock grazing during the early 1900s further damaged riparian habitats. Large numbers of livestock affected shrub-steppe grasses and forbs. On the basis of available records, riparian plant communities apparently shifted from dense stands of sandbar willow in the 1870s to a highly fragmented and sparse riparian zone of willow and hackberry by the late 1800s to early 1900s. Today, irrigated fields dominate this landscape. In addition, nonnative and exotic woody plants have colonized riverbanks.

The significant increase in use of DDT and other chemicals after World War II further affected wildlife habitat in agricultural areas in the Weiser reach. Wildlife habitat values on river bottomlands in the Weiser reach were low in the 1950s and, for the most part, remain so today. Within the last 20 to 30 years, nonnative woody plants have established a narrow, but often dense, fringe of riparian forest. The recruitment patterns of these nonnative species were not limited by current land-use practices and flow regimes in the Weiser reach. In the Farewell Bend area, slightly more shrubby riparian and wetland habitat was associated with backwater areas during the 1950s than during 1997. However, habitat quality was limited by the long history of unrestricted livestock grazing. Regulated livestock grazing continues on private and BLM lands in the Weiser reach today. Spring and early summer grazing has restricted recovery of some riparian communities in the Weiser reach.

5.2. Brownlee Reach

The Brownlee reach was the second most heavily settled section of the study area after the Weiser reach. Topography restricted farming and orchards to alluvial fans, benchlands caused by the Bonneville Flood, and small valleys on some tributaries. Historical records indicated that willow and hackberry were common along portions of the river channel and that all lands were heavily grazed. The riparian vegetation visible in historical photographs (1899 to 1950s) was limited to sparse and scattered stands of willow and hackberry, with some pines on the terraces and slopes adjacent to the river. Steep canyon walls were only sparsely vegetated by upland grasses and shrubs. The narrow river canyon naturally constrained channel migration, substantially limiting the extent of riparian habitats. The establishment of riparian vegetation on these confined floodplains was also limited by periodic scouring flows associated with melting and runoff of heavy winter snowpacks and, since the late 1800s, by livestock grazing. Channel-margin sandbars and islands were relatively abundant before the dams were constructed, but many appear to have supported little permanent vegetation. By contrast, islands created by the Bonneville Flood were well vegetated with upland plant species. Operation of Brownlee Reservoir limited the formation of shoreline communities primarily because of relatively large stage fluctuations.

Although the current operations of Brownlee Reservoir cause extensive barren shorelines during seasonal drawdowns for hydroelectric generation, these barren zones may act as an effective barrier to the downstream dispersal of Eurasian exotic, noxious, and nonnative plant species. Under current operations, water levels are lowered during late winter and early spring, exposing barren shorelines for colonization by exotic annuals. Water levels are then raised to full pool by late July, inundating many of these plants before they can set seeds. By late August to early September, water levels decline, allowing limited recruitment by exotic annuals. Then, water levels rise again during winter, although not necessarily to full-pool conditions. Annual water fluctuations have also progressively removed or decreased the finer portion of soil substrates necessary for seed germination and root growth by many species. Only a small number of annual species can adapt to these poor rooting substrates and seasonal patterns of water-level fluctuation. Current inventory data for noxious and nonnative plants appear to support this conclusion, since population densities of noxious plants are very high in the Weiser reach with progressive declines through the other reservoir reaches. Therefore, many noxious and exotic plants appear unable to use Brownlee Reservoir shorelines as a migration corridor to downstream reaches within the study area. A notable exception to this trend would be indigobush, which is relatively common throughout the study corridor.

Apparently, human activities in the Brownlee reach severely degraded wildlife habitat quality on alluvial fans, benchlands, and adjacent slopes well before Brownlee Dam was constructed. Diversion of water to irrigate some alluvial fans and benchlands degraded riparian communities on streams from which water was diverted. In addition, irrigation diversions farther upstream on the Burnt and Powder Rivers adversely affected riparian habitat quality in downstream areas. Deer died regularly during winters in the 1950s because winter-range conditions were severely degraded from the late 1800s through the 1950s by human settlement, livestock grazing, and expanding deer herds in the 1930s. These poor winter ranges were inundated by the reservoirs. The scattered riparian habitats in the 1950s were also inundated by the reservoir, and fluctuating water levels have prevented these riparian habitat from re-establishing. Surrounding upland range conditions appear to have improved somewhat since the 1950s.

5.3. Oxbow/Hells Canyon Reservoirs Reach

Historical records and photographs of the Oxbow/Hells Canyon Reservoirs reach indicated that willow and hackberry were common along the river channel, with upland habitats consisting of heavily overgrazed shrub-steppe vegetation. Riparian vegetation visible in historical photographs (1901 to 1950s) was limited to sparse, fragmented stands of willow and hackberry along the riverbank and scattered pines on adjacent terraces and slopes. Surveyors noted cottonwood trees growing along the mainstem of the river near the confluence of Pine Creek. These cottonwood trees were probably just a small stand on the large alluvial fan of Pine Creek. Given the relatively late date of survey records (post-1900), these cottonwoods could have also been planted by local settlers. We found no other records of cottonwoods occurring historically. There are no signs of cottonwood along the mainstem of the river today, though they do grow in some tributaries. Eurasian and noxious annuals appear to be less common in this reach than in the upper reaches of the study corridor.

Channel-margin sandbars, islands, and lowland terraces were inundated. Minimal water-level fluctuations on the reservoirs (1 to 2 meters) are a significant factor in supporting woody vegetation along the shorelines; this vegetation appears to be more extensive today than before the dams were constructed. Overall, it appeared that shoreline habitat values in 1999 were somewhat higher than in the 1950s. However, these higher habitat values can be attributed to the presence of several exotic species in the riparian zone. Upland habitat conditions have probably improved, especially on the Oregon side of Hells Canyon Reservoir, which is part of the HCNRA where most grazing adjacent to the river was eliminated. Tributary riparian communities in the HCNRA benefited substantially from reduced grazing.

5.4. Downstream Reach

Riparian habitats visible in historical photographs (1920s to 1950s) were limited to hackberry and scattered stands of sandbar willow along the riverbank. Pines were relatively common on adjacent terraces and slopes. The steep walls of the canyon and tributaries were only sparsely vegetated, with much of the canyon walls consisting of bedrock or coarse, colluvial rock not suitable for vegetation. The narrow, confined river canyon always constrained channel migration and the extent of riparian habitats. Riparian vegetation growing on the confined floodplains was also subjected to periodic scouring flows associated with heavy snowpack runoff.

Recent photographs and field reconnaissance reveal a fragmented riparian fringe of hackberry, with small, scattered populations of sandbar willow and sparsely vegetated steep canyon walls. The growth and canopy development of hackberry has increased during the last several decades. In several areas, hackberry has expanded significantly downslope toward the channel through the initiation and growth of root suckers. The riparian habitats of tributaries also support a much more diverse and continuous cover of trees and shrubs than they did before impoundment. Because of the large-scale trend of sediment trapping in upstream reservoirs (including the Hells Canyon Complex) and the greater sediment-transport capacity through the Hells Canyon reach, the lack of fine substrates apparently limits the recruitment of sandbar willow.

Though all study area reaches have been affected by anthropogenic factors since the late 1800s, the steep canyon and difficult access may have limited intensive human activity, except for livestock grazing, more in the downstream reach than farther upstream. The greatest apparent change in wildlife habitat quality between the 1950s and 1999 is the substantial improvement in the condition of tributary riparian zones because grazing has been eliminated on most HCNRA allotments that border the river. Many species of wildlife and fish species have benefited from the higher-quality riparian zones and associated cooler water temperatures in these tributaries (Platts 1991, Saab et al.1995).

Backwater or side channels are relatively rare and limit breeding habitat for amphibians. We know of no mechanism by which this habitat would have changed since the fluvial condition of such areas is relatively stable. Sandbar willow was limited, and may be even more limited, by the reduced sediment supply since the 1950s. However, hackberry stands have increased both in size and extent, substantially in some locations. Upland range conditions have also improved since the 1950s in those parts of the HCNRA that are no longer grazed. These improved upland range conditions benefit many wildlife species but may be detrimental to mule deer that browse on shrubs. Upland shrubs have probably declined in response to reduced grazing and increased grass cover.

5.5. Summary of Major Findings and Conclusions

Construction of the Hells Canyon Complex undoubtedly caused immediate large-scale loss of wildlife habitat in areas inundated by reservoirs. However, the quality of all of these affected habitats, and even the extent of riparian habitats, had been substantially reduced by over 70 years of unrestricted and abusive land-use practices prior to construction of the complex.

Improvement in the quality of upland and riparian habitats after livestock grazing was eliminated in the HCNRA demonstrates how a portion of the habitat values that existed before Euro-American settlement could be recovered in parts of the study area that receive relatively more precipitation. However, in northerly portions of the study area, even without any livestock grazing, habitat values in low-elevation uplands are less likely to be recovered to levels that occurred before Euro-American settlement because of past land use, low precipitation, and widespread presence of cheatgrass and its associated problems. In addition, the potential for improving riparian habitats is directly related to the presence of water in the major tributaries and the effective control of grazing livestock.

Adverse effects downstream are associated with a reduction in fine sediments, a reduction that is partially caused by operations of the Hells Canyon Complex and resulting water-level fluctuations. Overall, the loss of sediment has probably resulted in declines in sandbar willow. The effects of water-level fluctuations must also be considered in the context of natural variations in stream flow between high spring runoff and late summer base flows that occur on western rivers. And also because of operations of the Hells Canyon Complex, summer base flows that have increased compared with pre-impoundment conditions have apparently permitted hackberry to expand in this reach.

6. Acknowledgments

The authors gratefully acknowledge the contributions of Madeline Buckendorf of the Arrowrock Group to the anthropogenic history discussions contained in this report. In addition, the report benefited substantially from the contributions of A. M. A. (Toni) Holthuijzen of Idaho Power Company and his insight into the project area. We also appreciate the editorial assistance of Natalie Chavez during preparation of the final report. The formatting efforts of Josie McDonald, Idaho Power Company, Corporate Publishing Department, are much appreciated.

7. Literature Cited

Anderson J. E., and K. E. Holte. 1981. Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in southeastern Idaho. Journal of Range Management 34:25-29.

Arrowrock Group. 1995. Idaho Power Company Hells Canyon oral history report. Idaho Power, Boise, ID.

Asherin, D. A., and J. J. Claar. 1976. Inventory of riparian habitats and associated wildlife along the Columbia and Snake Rivers. College of For., Wildl., Range Sci., University of Idaho, Moscow, ID. 556 p.

Ball, J., R. D. Bauer, K. Vermeer, and M. J. Rabenberg. 1989. Northwest riverine and Pacific coast. Pages 429449 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech Univ. Press, Lubbock, TX.

Beck, J. M., C. R. Peterson, M. Gerber, and N. J. S. Turley. 2000. Species occurrence and distribution of amphibians and reptiles in Hells Canyon. In: Technical appendices for Hells Canyon Hydroelectric Project. Idaho Power, Boise, ID. Technical Report E.3.2-36.

Bildstein, K. L., G. T. Bancroft, P. J. Dugan, D. H. Gordon, R. M. Erwin, E. Nol, L. X. Payne, and S. E. Senner. 1991. Approaches to the conservation of coastal wetlands in the western hemisphere. Wilson Bulletin 103:218-254.

Brunsfeld, S. J., and F. D. Johnson. 1985. Field guide to the willows of East-Central Idaho. Forest, Wildlife and Range Experiment Station, University of Idaho. Bulletin 39, Moscow, ID.

Bureau of Land Management [BLM]. 1986. Draft Baker resource management plan environmental impact statement. Baker Resource Area, Vale District, U.S. Dept. Int., Baker, OR. 120 p.

Bush, J. H., and W. P. Seward. 1992. Geologic field guide to the Columbia River Basalt, northern Idaho and southeastern Washing. Information Circular 49. Idaho Geological Survey, University of Idaho, Moscow, ID. 35 p.

Carrey, J., C. Conley, and A. Barton. 1979. Snake River of Hells Canyon. Backeddy Books, Cambridge, ID.

Chapman, W. M. 1940. Report of a field trip to the Snake River drainage in Idaho and Eastern Oregon. Washington Department of Fisheries, Olympia, WA.

Chatters, J. C., and K. C. Reid. 1999-2000. Unpublished progress reports on the archaeological inventory of Hells Canyon. Prepared for Idaho Power, Boise, ID.

Christensen, A. (Rocky Mountain Elk Foundation, Missoula, MT). 2001. Delineation and assessment of big game winter range associated with the Hells Canyon Hydroelectric Complex: mule deer, elk, mountain goats, and rocky mountain bighorn sheep. In: Technical appendices for Hells Canyon Complex Hydroelectric Project. Idaho Power, Boise, ID. Technical Report E.3.2-31.

Clark, R. 1995. River of the west: a chronicle of the Columbia. Picador Press, New York, NY.

Croft, L. K., W. R. Owen, and J. S. Shelly. 1997. Interior Columbia Basin ecosystem management project: analysis of vascular plants. U.S. Forest Service, Portland, OR. 122 p.

Crouch, G. L. 1982. Wildlife on ungrazed and grazed bottomlands on the South Platte River, Northeastern Colorado. Pages 188-197 *in* Wildlife-livestock relationships symposium. Forest Wildlife and Range Experiment Station, Moscow, ID.

Daubenmire, R. 1970. Steppe vegetation of Washington. Washington Agricultural Experiment Station Technical Bulletin 62. 131 p.

Densley, L. C. 1987. Saints, sinners and Snake River secrets. Courier Printers, Baker, OR.

Dyer, M. I. 1979. Consumers. Pages 73-86 *in* R. T. Coupland, editor. Grassland ecosystems of the world: analysis of grasslands and their uses. Cambridge University Press, Cambridge, England.

Eagle Cap, Inc. 1999. Preliminary results of invasive, noxious and threatened plant inventories of the Hells Canyon Study Corridor. A preliminary report prepared for Idaho Power.

Edelmann, F. B. (Editor). 2001. Wintering mule deer ecology in the reservoir reach of the Hells Canyon Hydroelectric Complex. In: Technical appendices for Hells Canyon Complex Hydroelectric Project. Idaho Power, Boise, ID. Technical Report E.3.2-32.

Federal Power Commission. 1959. Project 1971, Federal Power Commission hearings, December 10, 1959: Testimony of Mr. Murray and Mr. Day. Idaho Power Company files.

Feldhamer, G. A. 1979. Vegetative and edaphic factors affecting abundance and distribution of small mammals in southeast Oregon. Great Basin Naturalist 39:207-218.

Fitzgerald, J. F. 1982. Geology and basalt stratigraphy of the Weiser Embayment, west-central Idaho. Pages 137-141 *in* B. Bonnichsen and R. M. Breckenridge, editors. Cenozoic geology of Idaho. Idaho Bureau of Mines and Geology, University of Idaho, Moscow, ID.

Franklin, J. F., and C. T. Dyrness. 1988. Natural vegetation of Oregon and Washington. Oregon State University Press, Corvallis, OR. 452 p.

Galbraith, W. A., and W. E. Anderson. 1971. Grazing history of the Northwest. Journal of Range Management 24:6-12.

Gano, K. A., and W. H. Rickard. 1982. Small mammals of a bitterbrush-cheatgrass community. Northwest Scientist 56:1-7.

General Land Office Records. 1890-1905; 1901-1936. U.S. General Land Office (currently U.S. Bureau of Land Management), Washington, D.C.

Gildemeister, J. 1992. Bull trout, talking grouse and buffalo bones: Oral histories of northeast Oregon fish and wildlife. Oregon Department of Fish and Wildlife, LaGrande, OR.

Grams, P., and J. Schmidt. 1991. Degradation of alluvial sand bars along the Snake River below Hells Canyon Dam, Hells Canyon National Recreation Area, Idaho. Middlebury College, Middlebury, VT.

Grayson, D. K. 1977. Paleoclimatic implications of the Dirty Shame Rockshelter mammalian fauna. Tebiwa Misc Pap Mus Nat Hist 9; Idaho State University, Pocatello, ID.

Green, T. J. 1988. White man comes to Snake River. Idaho State Historical Society, Boise, ID.

Gustafson, C. E. 1972. Faunal remains from the Marmes Rockshelter and related archaeological sites in the Columbia Basin. Washington State University, Pullman, WA.

Harris, K. W. 1972. Topping out. A. H. Logan. Idaho State Historical Society, Boise, ID.

Holechek, J. L., R. D. Piper, and C. H. Herbel. 1989. Range management: principles and practices. Prentice-Hall, Englewood Cliffs, NJ.

Holmstead, G. 2001. Vegetation of the Snake River corridor in Hells Canyon—Weiser, Idaho, to the Salmon River. In: Technical appendices for Hells Canyon Hydroelectric Project. Idaho Power, Boise, ID. Technical Report E.3.3-1.

Hudson’s Bay Record Society. 1979. Ogden’s Snake Country Journals, 1824-1826. Publications of the Hudson’s Bay Record Society, London. Kraus reprint. Nendeln, Liechtenstein.

Hutchings, S. S., and G. Stewart. 1953. Increasing forage yields and sheep production on intermountain winter ranges. USDA Forest Service. Circ. No. 925. 63 pp.

Idaho Department of Fish and Game [IDFG]. 1951. Idaho game population census and range study. A Pittman-Robertson Study. Project 85-R. June 1949 to June 1951.

Idaho Power Company [IPC]. 1997. Formal consultation package for relicensing: Hells Canyon Project (FERC No. 1971). 3 volumes. Environmental Affairs Department, IPC, Boise, ID.

Invader Database System. 2000. Online database for invasive and noxious species of Idaho, Oregon, Montana, Washington and Oregon. http://invader.dbs.umt.edu. Maintained by Dr. Peter Rice, Department of Biological Sciences, University of Montana, Missoula, MT.

Johnson, C. G., and S. A. Simon. 1987. Plant associations of the Wallowa-Snake province, Wallowa-Whitman National Forest. U.S Forest Service. PNR. R-6 ECOL-TP-225A-86. 272 p.

Jones, M. 1989. History of early livestock grazing in the area of the Payette National Forest. U.S. Forest Service, Payette National Forest, McCall, ID.

Jordan, G. 1954. My home below Hells Canyon. Crowell, New York, NY.

Kauffman, J. B., and W. C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications: a review. Journal of Range Management 37:430-438.

Kochert, M. N. 1989. Responses of raptors to livestock grazing in the western United States. Pages 194-203 *in* Proceedings of the Western Raptor Management Symposium Workshop. National Wildlife Federation, Washington, D.C.

Lane, E. W. 1955. Design of stable channels. Transactions ASCE, Volume 120, Paper No. 2776.

Larson, F. 1940. The role of the bison in maintaining the short grass plains. Ecology 21:113-121.

Mack, R. N., and J. N. Thompson. 1982. Evolution in steppe with few large, hooved mammals. American Naturalist 119:757-773.

Malheur County Historical Society. 1988*a*. Malheur Country History Volume 2. Taylor Publishing, Dallas, TX.

——————. 1988*b*. Malheur Country History Volume 1. Taylor Publishing, Dallas, TX.

Martin, A. C., H. S. Zim, and A. C. Nelson. 1951. American wildlife and plants, a guide to wildlife food habits. New Dover Publications, New York, NY. 500 p.

McGee, J. M. 1982. Small mammal populations in an unburned and early fire successional sagebrush community. Journal of Range Management 35:177-180.

Northwest Environmental Advocates[NWEA]. 1992. Columbia River—troubled waters. Map. Northwest Environmental Advocates, Portland, OR.

O’Connor, J. 1993. Hydrology, hydraulics, and geomorphology of the Bonneville Flood. Geological Society of America, Boulder, CO. Special Paper 274.

Oliphant, J. O. 1946. The eastward movement of cattle from the Oregon country. Agri. Hist. 20:14-43.

Oregon State Game Commission [OSGC]. 1948. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

——————. 1950. Annual Report. Oregon Department of Fish and Wildlife. Portland, OR.

__________. 1951. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1952. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1953. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1954. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1955. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1956. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1957. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1958. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

Osterkamp, W. 1997. Expert witness testimony of Waite Osterkamp before the district court of the fifth judicial district of the State of Idaho, in and for the county of Twin Falls. U.S. Department of Justice, Environment and Natural Resources Division, Denver, CO.

Ott, J. S. 1997. Clearing the country: a history of the Hudson's Bay Company's fur desert policy. University of Montana, Missoula, MT. 127 p.

Page, J. L., N. Dodd, T. O. Osborne, and J. A. Carson. 1978. The influence of livestock grazing on non-game wildlife. Cal-Neva Wildlife 1978:159-173.

Palmer, T. 1991. The Snake River: window to the West. Island Press, Washington, D.C.

Parkinson, S. K., K. Anderson, J. Connor, and J. Milligan. 2001. Sediment transport, supply, and stability in the Hells Canyon reach of the Snake River. In: Technical appendices for Hells Canyon Hydroelectric Project. Idaho Power, Boise, ID. Technical Report E.1-1.

Platts, W. S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification—with application to ecosystem classification. Surface Environment and Mining Program, USDA, U.S. Forest Service.

——————. 1991. Livestock grazing. Influences of forest and rangeland management on salmonid fishes and their habitat. American Fisheries Society Special Publication 19:389-423.

Ratti, J. T., and M. B. Lucia (University of Idaho, Moscow, ID). 1998. Literature and status review of big game species in Hells Canyon. In: Technical appendices for Hells Canyon Hydroelectric Project. Idaho Power, Boise, ID. Technical Report E.3.2-34.

Rinehart, E. F. 1932. The Idaho range, past and present. M.Sc. Thesis. University of Idaho, Moscow, ID. 55 pp.

Rogers, L. E., and J. D. Hedlund. 1980. A comparison of small mammal populations occupying three distinct shrub-steppe communities in eastern Oregon. Northwest Science 54:183-186.

Rood, S., and S. Heinze-Milne. 1989. Abrupt downstream forest decline following river damming in southern Alberta. Canadian Journal of Botany 67:1744-1749.

Saab, V. A. 1998. Effects of recreational activity and livestock grazing on habitat use by breeding birds in cottonwood forests along the south fork Snake River. USDA, Forest Service, Rocky Mountain Research Station, Boise, ID.

Saab, V. A., C. E. Bock, T. D. Rich, and D. S. Dobkin. 1995. Livestock grazing effects in western North America. Pages 311-353 *in* T. E. Martin and D. M. Finch, editors. Ecology and management of neotropical migratory birds: a synthesis and review of critical issues. Oxford University Press, New York, NY.

Schroedl, G. F. 1973. The archaeological occurrence of bison in the southern plateau. Washington State University, Pullman, WA.

Schumm, S. A. 1977. The idealized fluvial system. The Fluvial System. John Wiley & Sons.

Simons & Associates. 1990. Platte River system hydrologic analysis and addendum responding to agency comments. Prepared for Nebraska Public Power District and Central Nebraska Public Power and Irrigation District.

Simons, D. B., and F. Sentürk. 1975. Sediment transport technology. Water Resources Publications.

——————. 1992. Sediment transport technology. Water and Sediment Dynamics.

Thomas, J. W., C. Maser, and J. E. Rodiek. 1979. Wildlife habitats in managed rangelands the great basin in southeastern Oregon. USDA Forest Service Gen. Tech. Rep. PNW-80. Pacific Northwest Forest and Range Experiment Station, Olympia, WA.

Tisdale, E. W. 1961. Ecological changes in the Palouse. Northwest Science 35:134-138.

——————. 1986*a*. Canyon grasslands and associated shrublands of west central Idaho and adjacent areas. University of Idaho, Moscow, ID. For. Wildl. and Range Exp. Sta. Bulletin 40. 42 p.

——————. 1986*b*. Native vegetation of Idaho. Rangelands 8:202-207.

Tisdale, E. W., and M. Hironaka. 1981. The sagebrush-grass region: a review of the ecological literature. University of Idaho, Moscow, ID. For. Wildl. and Range Exp. Sta. 31 p.

U.S. Census Office. 1896. Agriculture by irrigation in the western part of the United States at the eleventh census, 1890. House of Representatives Miscellaneous Documents 340 part 20, first session of the fifty-second Congress. Report on the statistics of agriculture in the United States at the eleventh census: 1890. U.S. Government Printing Office, Washington, D.C.

U.S. Department of Agriculture [USDA]. 1968. History of the Payette National Forest. Payette National Forest, McCall, ID.

__________. 1980. Final environmental impact statement, Hells Canyon National Recreation Area, comprehensive management plan. Wallowa-Whitman, Nez Perce, and Payette National Forests, Washington, D.C.

__________. 1988. Payette National Forest final environmental impact statement. Payette National Forest, McCall, ID.

__________. 1990. Land and resource management plan. Wallowa-Whitman National Forest, Baker City, OR.

U.S. Department of Interior [USDI]. 1986. Baker resource management plan, draft environmental impact statement. U.S. Department of the Interior, Bureau of Land Management, Vale District, Vale, OR. 120 p.

__________. 1987. Cascade Resource Area resource management plan. Bureau of Land Management, Boise, ID.

__________. 1989. Baker Resource Area resource management plan. Baker Bureau of Land Management, Baker City, OR.

U.S. Fish and Wildlife Service [USFWS]. 1948. Review report on Columbia River and tributaries. Appendix P, Fish and Wildlife. Prepared for Corps of Engineers, North Pacific Division.

U.S. Geological Survey [USGS]. 1999. Water resources data, Idaho, water year 1999. Washington, D.C.

U.S. Secretary of Agriculture. 1936. The western range: letter from the Secretary of Agriculture in response to Senate Resolution No. 289. A report on the western range—a great but neglected natural resource. U.S. Senate, 74th Congress, 2nd session. Document 199. U.S. Government Printing Office, Washington, D.C.

Vallier, T. L. 1998. Islands and rapids: a geological story of Hells Canyon. Confluence Press, Lewiston, ID.

Wentworth, E. N. 1948. America's sheep trails. Iowa State College Press, Ames, IA. 667 p.

Wiens, J. A. 1985. Habitat selection in variable environments: shrub-steppe birds. Pages 227-251 *in* M. Cody, editor. Habitat selection in birds. Academic Press, London, England.

Wiens, J. A., and J. T. Rotenberry. 1981. Habitat associations and community structure of birds in shrub-steppe environments. Ecological Monographs 51:21-41.

Yensen, D. 1980. A grazing history of southwestern Idaho with emphasis on the Birds of Prey Study Area. U.S. Bureau of Land Management Snake River Birds of Prey Research Project, Boise, ID.

__________. 1981. The 1990 invasion of alien plants into southern Idaho. Great Basin Naturalist 41:176-182.

__________. 1982. A grazing history of southwestern Idaho with emphasis on the Birds of Prey study area. U.S. Bureau of Land Management, Boise, ID.

Table 1. Background information on and location of historical photograph points, Hells Canyon Study Area.

USGS Quad	Photo ID	Riverbank A	Riverbank B	Azimuth	General Area	T, R, S (Photo Point/ Riverbank A)	T, R, S (Landscape View/ Riverbank B)
Weiser South	WR-1	Oregon	Idaho	NE	Weiser Bridge	T15S, R47E, S21	T11N, R5W, S31/T10N, R5W, S5
Moores Hollow	WR-2	Idaho	Oregon	S	Westlake Island Ferry Crossing	T11N, R7W, S27/28	T15S, R46E, S24/25
Olds Ferry	WR-3	Idaho	Oregon	W	Farewell Bend Crossing	T11N, R7W, S8	T14S, R45E, S33, 34
Olds Ferry	BR-1	Oregon	Idaho	E	Burnt River Confluence/R.R. Bridge	T14S, R45E, S9	T12N, R7W, S19, 20
Olds Ferry NW	BR-2	Oregon	Idaho	NE	Morgan Creek Confluence	T12S, R45E, S32/33	T14N, R7W, S33/T13N, R7W, S4
Conner Creek	BR-3	Oregon	Idaho	E	Hibbard Creek/Bastian Ranch	T12S,R45E,S27	T14N,R7W,S33
Conner Creek	BR-4	Oregon	Idaho	E	Soda Creek Confluence	T11S, R46E, S?	T14N, R7W, S12/13
Sturgill Creek	BR-5	Oregon	Idaho	S	Powder River Confluence	T9S, R46E, S25/26	T16N,R6W,S11/18
Brownlee Dam	BR-6	Oregon	Idaho	N/NE	Right Dam Abutment	T8S, R47E, S25/26	T17N, R5W, S1
Oxbow	OX-1	Oregon	Idaho	N/NE	Oxbow Dam Site/Scorpion Ck	T7S	T19N,R4W,S20/21
Oxbow	OX-2a/b	Oregon	Idaho	NE	The Oxbow-Pine Ck to Cottonwood Ck	No T, S, R/Oregon	T19N, R4W, S16/17
Oxbow	OX-3a/b	Idaho	Oregon	SW	The Oxbow-Blue Ck to Scorpion Ck	T19, R4W, S20/21	No T, S, R/Oregon
Homestead	HC-1	Oregon	Idaho	SW	Kleinschmidt Grade	T20N, R4W, S14/22/23/27	No T, S, R/Oregon
Homestead	HC-2	Idaho	Oregon	SW	Ballard Bridge/Hells Canyon Park	T20N, R4W, S14/22/23/27	No T, S, R/Oregon
Homestead	HC-3	Idaho	Oregon	W	McGraw Creek Confluence	T20N, R4W, S1	No T, S, R/Oregon
Homestead	HC-4	Idaho	Oregon	W	Spring Creek Confluence	T21N, R4W, S36	No T, S, R/Oregon
White Monument	HC-5	Idaho	Oregon	S	Kinney Creek Rapids	T21N, R3W, S17/20	No T, S, R/Oregon
White Monument	HC-6	Idaho	ID/OR	N	Eagle Bar	T22N,R3W,S21/28	No T, S, R/Oregon
White Monument	SR-1	Oregon	ID/OR	N	Deep Creek to Hells Canyon Creek	No T, S, R/Oregon	T22N, R3W, S15
Old Timer Mountain	SR-2	Idaho	Oregon	W	Saddle Creek Confluence	T24N, R2W, S30	No T, S, R/Oregon
Old Timer Mountain	SR-3	Idaho	ID/OR	S	Johnson Bar	T25N, R2W, S35	T25N, R2W, S34/T24N, R2W, S3
Old Timer Mountain	SR-4	Idaho	ID/OR	N	Sheep Creek Rapids	T25N, R2W, S35	T25N, R2W, S35, 26
Temperance Creek	SR-5	Idaho	ID/OR	E	Sturgeon Rock/Alum-Pine Bar	T25N, R2W, S14	T25N, R2W, S14
Grave Point	SR-6	Idaho	ID/OR	N	Pittsburg Landing (OR)	T27N, R1W, S29, 32, 33	T2S,51E,S20/29
Grave Point	SR-7	Idaho	ID/OR	N	Lower Pittsburg Landing (ID)	T27N,R1W,S29,32	T27N
Lord Flat	SR-8	Idaho	ID/OR	N	Getta/High Range Creek	T27N, R1W, S23	T27N, R1W, S23
Wolf Creek	SR-9	Idaho	ID/OR	NW	Ragtown Bar Area	T27N, R1W, S15, 23	T27N, R1W, S15, 23
Cactus Mountain	SR-10	Oregon	Idaho	E	Dug Bar: basalt Columns	No T, S, R/Oregon	T29N, R3W, S34
Deadhorse Ridge	SR-11	Oregon	Idaho	N	Eureka Bar/Imnaha Landing	No T, S, R/Oregon	T29N, R4W, S25, 26
Deadhorse Ridge	SR-12	ID/OR	ID/OR	N	Salmon River Mouth	T29N, R4W, S14	T29N, R4W, S11

Notes: View/Orientation: Riverbank A to Riverbank B
T, R, S = Township, Range, and Section

Table 2. Summary of aerial photographs taken pre- and post-impoundment.

Photo point	Location	River Mile	Pre-dam photo date	ID No#	Approx. Scale	Mean daily discharge at Weiser gauge (cfs)*	Photo point	Location	River Mile	Post-dam photo date	ID No#	Approx. Scale	Mean daily discharge at Hells Canyon Dam (cfs)*	Mean daily discharge at Weiser gauge (cfs)*
WR-1	Weiser Bridge	342	08/23/1955	DIA-5P-38	1 to 20000	9,970 (300)	WR-1	Weiser Bridge	342	05/07/1997	IP-Brownlee 1-2	1 to 8400	46,056 (1,200)	40,400 (100)
WR-2	Westlake Island Ferry Crossing	344.5	08/23/1955	DIA-5P-81	1 to 20000	9,970 (300)	WR-2	Westlake Island Ferry Crossing	344.5	05/07/1997	IP-Brownlee 3-4/5	1 to 8400	46,056 (1,200)	40,400 (100)
WR-2	Westlake Island Ferry Crossing	344.5	06/07/1956	ENV076BA4,5	1 to 12000	53,400(2,000)	WR-3	Farewell Bend Crossing	333.5	05/07/1997	IP-Brownlee 8-3/1	1 to 8400	46,056 (1,200)	40,400 (100)
WR-3	Farewell Bend Crossing	333.5	08/23/1955	DIA-5P-124	1 to 20000	9,970 (300)								
WR-3	Farewell Bend Crossing	333.5	07/16/1953	ENV020BR5,5	1 to 20000	12,900 (1,100)	BR-1	Burnt River/R.R. Bridge	328	05/07/1997	IP-Brownlee 10B-4	1 to 8400	46,056 (1,200)	40,400 (100)
							BR-2	Morgan Ck Confl	318	05/07/1997	IP-Brownlee 12A-11	1 to 8400	46,056 (1,200)	40,400 (100)
BR-1	Burnt River/R.R. Bridge	328	08/23/1955	DIA-5P-142	1 to 20000	9,970 (300)	BR-3	Hibbard Ck	317	05/07/1997	IP-Brownlee 13-3	1 to 8400	46,056 (1,200)	40,400 (100)
BR-1	Burnt River/R.R. Bridge	328	07/16/1953	ENV048BR6,3	1 to 20000	12,900 (1,100)	BR-4	Soda Ck Confl	307	05/07/1997	IP-Brownlee 19-1	1 to 8400	46,056 (1,200)	40,400 (100)
BR-2	Morgan Ck Confl	318	12/23/1957	ENV042BR7,6	1 to 8000	15,400 (3,800)	BR-5	Powder River Confl	295.7	05/07/1997	IP-Brownlee 25-1	1 to 8400	46,056 (1,200)	40,400 (100)
BR-3	Hibbard Ck	317	12/23/1957	ENV046BR6,4	1 to 8000	15,400 (3,800)	BR-6	Brownlee Dam	285	05/07/1997	IP-Brownlee 29-6	1 to 8400	46,056 (1,200)	40,400 (100)
BR-4	Soda Ck Confl	307	12/23/1957	ENV039BR1,2	1 to 8000	15,400 (3,800)								
BR-4	Soda Ck Confl	307	09/04/1953	ENV029BR4,10	1 to 29000	12,000 (500)	OX-1	Scorpion Ck: Dam Site	273	08/09/1997	IP-Snake R 5-4	1 to 8400	19,903 (700)	13,500 (600)
BR-5	Powder River Confl	295.7	07/16/1953	ENV027BR9,2	1 to 20000	12,900 (1,100)	OX-2a/b	The Oxbow	273	08/09/1997	IP-Snake R 5-4/6-2	1 to 8400	19,903 (700)	13,500 (600)
BR-6	Brownlee Dam	285	08/22/1955	DYU-3P-164	1 to 20000	9,930 (100)	OX-3a/b	The Oxbow	271.5	08/09/1997	IP-Snake R 6-2/3	1 to 8400	19,903 (700)	13,500 (600)

Table 2. (Cont.)

Photo point	Location	River Mile	Pre-dam photo date	ID No#	Approx. Scale	Mean daily discharge at Weiser gauge (cfs)*	Photo point	Location	River Mile	Post-dam photo date	ID No#	Approx. Scale	Mean daily discharge at Hells Canyon Dam (cfs)*	Mean daily discharge at Weiser gauge (cfs)*
OX-1	Scorpion Ck: Dam Site	273	08/22/1955	DYU-3P-148	1 to 20000	9,930 (100)	HCR-1	Klein-schmidt Grade	264	08/09/1997	IP-Snake R 10A-7	1 to 8400	19,903 (700)	13,500 (600)
OX-2a/b	The Oxbow	273	08/22/1955	DYU-3P-148	1 to 20000	9,930 (100)	HCR-2	Ballard Bridge/ Hells Canyon Park	262-264	08/09/1997	IP-Snake R 10A-8	1 to 8400	19,903 (700)	13,500 (600)
OX-3a/b	The Oxbow	271.5	08/22/1955	DYU-3P-148	1 to 20000	9,930 (100)	HCR-3	McGraw Ck Confl	259	08/09/1997	IP-Snake R 12-2	1 to 8400	19,903 (700)	13,500 (600)
OX 1-3	The Oxbow	270-273	07/16/1953	ENV017H1,5	1 to 20000	12,900 (1,100)	HCR-4	Spring Ck Confl	258.5	08/09/1997	IP-Snake R 12-2	1 to 8400	19,903 (700)	13,500 (600)
							HCR-5	Kinney Ck Rapids	254	08/09/1997	IP-Snake R 14-3	1 to 8400	19,903 (700)	13,500 (600)
HCR-1	Klein-schmidt Grade	264	08/22/1955	DYU-3P-133	1 to 20000	9,930 (100)	HCR-6	Eagle Bar Landing	249.5	08/09/1997	IP-Snake R 15-2	1 to 8400	19,903 (700)	13,500 (600)
HCR-2	Ballard Bridge/ Hells Canyon Park	262-264	08/22/1955	DYU-3P-133	1 to 20000	9,930 (100)								
HCR-1/2	Klein-schmidt/ Ballard Bridge	264	05/08/1959	ENV005H,6	1 to 6000	13,000 (1,200)	SN-1	Deep Ck to Hells Canyon Ck	247	08/09/1997	IP-Snake R 15-7/8	1 to 8400	19,903 (700)	13,500 (600)
HCR-1/2	Klein-schmidt/ Ballard Bridge	264	09/04/1964	ENV006H1,4	1 to 2400	14,700 (500)	SN-2	Saddle Ck Confl	236	08/09/1997	IP-Snake R 18-3	1 to 8400	19,903 (700)	13,500 (600)
HCR-3	McGraw Ck Confl	259	08/22/1955	DYU-3P-96	1 to 20000	9,930 (100)	SN-3	Johnson Bar	230	08/09/1997	IP-Snake R 21-6	1 to 8400	19,903 (700)	13,500 (600)
HCR-3	McGraw Ck Confl	259	05/08/1959	ENV002H4,45	1 to 6000	13,000 (1,200)	SN-4	Sheep Ck Rapids	229.5	08/09/1997	IP-Snake R 21-6	1 to 8400	19,903 (700)	13,500 (600)
HCR-4	Spring Ck Confl	258.5	08/22/1955	DYU-3P-96	1 to 20000	9,930 (100)	SN-5	Sturgeon Rock/Pine Bar	227.5	08/09/1997	IP-Snake R 22-6	1 to 8400	19,903 (700)	13,500 (600)
HCR -3/4	McGraw/ Spring Ck	258-59	07/16/1953	ENV004HS13,5	1 to 20000	12,900 (1,100)	SN-6	Pittsburg Landing (OR)	215	08/09/1997	IP-Snake R 28-6	1 to 8400	19,903 (700)	13,500 (600)

Table 2. (Cont.)

Photo point	Location	River Mile	Pre-dam photo date	ID No#	Approx. Scale	Mean daily discharge at Weiser gauge (cfs)*	Photo point	Location	River Mile	Post-dam photo date	ID No#	Approx. Scale	Mean daily discharge at Hells Canyon Dam (cfs)*	Mean daily discharge at Weiser gauge (cfs)*
HCR-5	Kinney Ck Rapids	254	08/22/1955	DYU-3P-85	1 to 20000	9,930 (100)	SN-7	Lower Pittsburg Landing (ID)	214.5	08/09/1997	IP-Snake R 28-6	1 to 8400	19,903 (700)	13,500 (600)
HCR-5	Kinney Ck Rapids	254	07/16/1953	ENV004HS14,9	1 to 20000	12,900 (1,100)	SN-8	High Range/ Getta Ck	206	08/09/1997	IP-Snake R 31-2,3	1 to 8400	19,903 (700)	13,500 (600)
HCR-5	Kinney Ck Rapids	254	05/08/1959	ENV003H19,20	1 to 6000	13,000 (1,200)	SN-9	Ragtown Bar Area	205	08/09/1997	IP-Snake R 31-3	1 to 8400	19,903 (700)	13,500 (600)
HCR-6	Eagle Bar Landing	249.5	08/22/1955	DYU-3P-89	1 to 20000	9,930 (100)	SN-10	Dug Bar: basalt	196.5	08/09/1997	IP-Snake R 34-5	1 to 8400	19,903 (700)	13,500 (600)
HCR-6	Eagle Bar Landing	249.5	05/08/1959	ENV003H1,2	1 to 6000	13,000 (1,200)	SN-11	Eureka Bar	191.5	08/09/1997	IP-Snake R 37-2	1 to 8400	19,903 (700)	13,500 (600)
HCR-6	Eagle Bar Landing	249.5	05/08/1959	ENV003H1,3	1 to 6000	13,000 (1,200)	SN-12	Salmon River Confl	188	08/09/1997	IP-Snake R 39-1	1 to 8400	19,903 (700)	13,500 (600)
SN-1	Deep Ck to Hells Canyon Ck	247	08/22/1955	DYU-3P-30	1 to 20000	9,930 (100)		* Discharge variability for pre-ceding 24 hrs (cfs)						
SN-2	Saddle Ck Confl	236	na	na	na									
SN-3	Johnson Bar	230	na	na	na									
SN-4	Sheep Ck Rapids	229.5	na	na	na									
SN-5	Sturgeon Rock/Pine Bar	227.5	na	na	na									
SN-6	Pittsburg Landing (OR)	215	na	na	na									
SN-7	Lower Pittsburg Landing (ID)	214.5	na	na	na									
SN-8	High Range/ Getta Ck	206	08/03/1955	DYV-7P-178	1 to 20000	9,970 (100)								

Table 2. (Cont.)

Photo point	Location	River Mile	Pre-dam photo date	ID No#	Approx. Scale	Mean daily discharge at Weiser gauge (cfs)*	Photo point	Location	River Mile	Post-dam photo date	ID No#	Approx. Scale	Mean daily discharge at Hells Canyon Dam (cfs)*	Mean daily discharge at Weiser gauge (cfs)*
SN-9	Ragtown Bar Area	205	na	na	na									
SN-10	Dug Bar: basalt	196.5	08/03/1955	DYV-7P-176	1 to 20000	9,970 (100)								
SN-11	Eureka Bar	191.5	08/03/1955	DYV-7P-183	1 to 20000	9,970 (100)								
SN-12	Salmon River Confl	188												

* Discharge variability for pre-ceding 24 hrs (cfs)

Table 3. Assessment approaches for evaluating impacts of river impoundment and flow regulation on downstream riparian ecosystems.

Assessment Approach	Description
Spatial Comparison	
Upstream vs. Downstream	River reaches are compared upstream versus downstream of a dam and reservoir. These comparisons use direct field measurements or indirect means such as repetitive ground surveys or aerial photographs.
Impounded vs. Free-flowing	A river reach downstream of a dam is compared with a reach of a neighboring river that is free flowing or experiences different patterns of flow regulation. These comparisons use direct field measurements or indirect means such as repetitive ground surveys or aerial photographs.
Temporal Comparison	
Pre- vs. Post-impoundment	Conditions along a reach for periods before and after impoundment are compared. These comparisons use direct field measurements or indirect means such as repetitive ground surveys or aerial photographs.
Progressive Post-impoundment	Conditions are monitored or assessed over time after impoundment. Assessments of progressive conditions use direct field measurements or indirect means such as repetitive ground surveys or aerial photographs.
Process-based Analysis	The physical conditions and particularly hydrologic and geomorphic patterns are assessed. This information is combined with knowledge of the native and exotic flora and fauna to permit predictions about ecosystem status. The analysis involved appropriate modeling and particularly hydrogeomorphic assessments of the riparian zone and ecophysiological analyses of the local plant species. All of the modeling must be validated, a process that may involve model development and refinement with different contemporary data samples. Because many of the hydrogeomorphic and ecophysiological processes are broadly applicable, model development and refinement involve a number of different rivers and river reaches.

Table 4. Published reports describing impacts of river impoundment and flow regulation by comparing reaches upstream to those downstream of a dam and reservoir.

Year	Author	River / Region
1984	Williams & Wolman	21 dammed rivers, USA
1986	Bradley & Smith	Milk River, AB, MT
1989	Rood & Heinze-Milne	St. Mary, Waterton, Belly rivers, AB
1990	Rood & Mahoney	western North America
1995	Rood & Mahoney	Marias River, MT
1995	Rood et al.	St. Mary River, AB
1996	McKay	Nisqually, Cowlitz Rivers, WA
1996	Imbert & Stanford	Crow Creek, MT
1998	Friedman et al.	35 dams: Great Plains & Central Lowlands, USA
1999	Rood et al.	Bow River, AB

Table 5. Published reports describing impacts of river impoundment and flow regulation by comparing impounded to comparable free-flowing reaches.

Year	Author	River / Region
1989	Rood & Heinze-Milne	St. Mary, Waterton, Belly rivers, AB
1990	Rood & Mahoney	western North America
1992	Stromberg & Patten	Bishop, Pine creeks, CA
1994	Dynesius & Nilsson	northern hemisphere
1995	Nilsson & Jansson	northern Sweden
1997	Nilsson et al.	northern and central Sweden

Table 6. Published reports describing impacts of river impoundment and flow regulation by comparing conditions prior to and after damming along the same reach.

Year	Author	River / Region
1984	Bradley & Smith	Milk River, AB, MT
1984	Williams & Wolman	21 dammed rivers, USA
1990	Rood & Mahoney	western North America
1990	Stromberg & Patten	Rush Creek, CA
1992	Johnson	Missouri River, ND
1992	Stromberg & Patten	Bishop, Pine creeks, CA
1993	Mahoney & Rood	Oldman River, AB
1993	Noble	Yampa River, CO
1994	Merigliano	Snake River, ID
1995	Rood & Mahoney	Marias River, MT
1995	Schmidt et al.	Snake River, ID; Colorado River, AZ
1995	Sear	North Tyne River, UK
1996	Merigliano	Snake River, ID
1997	Auble et al.	Boulder Creek, CO
1997	Barnes	Chippewa River, WI
1997	Cordes et al.	Red Deer River, AB
1999	Rood et al.	Bow River, AB

Table 7. Published reports describing impacts of river impoundment and flow regulation by monitoring conditions over time following impoundment.

Year	Author	River / Region
1984	Williams & Wolman	21 dammed rivers, USA
1989	Rood & Heinze-Milne	St. Mary, Waterton, Belly rivers, AB
1990	Rood & Mahoney	western North America
1995	Church	Peace, Kemano rivers,
1995	Rood et al.	St. Mary River, AB
1995	Schmidt et al.	Snake River, ID; Colorado River, AZ
1995	Sear	North Tyne River, UK
1997	Johnson	Platte River, NB
1998	Johnson	Great Plains, USA

Table 8. River channel and valley widths (km) for the Snake River above (near Weiser) and below (through Hells Canyon) the Hells Canyon Complex and the Salmon River (near White Bird to the confluence).

Snake-Weiser			**Snake-Hells Canyon**			**Salmon River**		
River Mile	**River Width**	**Valley Width**	**River Mile**	**River Width**	**Valley Width**	**River Mile**	**River Width**	**Valley Width**
362	0.19	3.12	247	0.10	0.12	67	0.06	0.12
361	0.19	3.33	245	0.08	0.12	66	0.08	0.17
360	0.19	1.24	243	0.06	0.10	65	0.05	0.14
359	0.21	2.38	241	0.10	0.17	64	0.07	0.19
358	0.19	3.40	239	0.05	0.10	63	0.08	0.14
357	0.43	3.50	237	0.12	0.19	62	0.12	0.19
356	0.36	4.69	236	0.10	0.14	61	0.10	0.23
355	0.33	4.88	234	0.06	0.10	60	0.07	0.17
354	0.24	4.55	232	0.05	0.08	59	0.13	0.15
353	0.33	3.95	230	0.06	0.10	58	0.07	0.12
352	= confluence Weiser R.		228	0.06	0.11	57	0.07	0.14
351	0.21	(off the sheet)	227	0.08	0.12	56	0.07	0.12
350	0.19	2.21	225	0.11	0.21	55	0.05	0.12
349	0.43	2.38	223	0.07	0.13	54	0.05	0.24
348	0.45	2.86	221	0.05	0.12	53	0.07	0.12
347	0.31	4.05	219	0.10	0.15	52	0.07	0.14
346	0.20	3.10	217	0.08	0.12	51	0.07	0.12
345	0.21	3.81	215	0.12	0.29	50	0.06	0.10
344	0.29	3.69	213	0.05	0.08	49	0.07	0.12
343	0.24	3.81	211	0.07	0.12	48	0.07	0.11
342	0.74	1.95	209	0.10	0.15	47	0.08	0.11
341	0.27	1.83	207	0.06	0.07	46	0.10	0.17
			205	0.07	0.24	45	0.07	0.13
			203	0.07	0.10	44	0.10	0.12
			201	0.07	0.12	43	0.05	0.08
			199	0.10	0.12	42	0.07	0.13
			197	0.05	0.10	41	0.08	0.12
			195	0.11	0.14	40 - 17	(sheet not available)	
			193	0.06	0.08	16	0.05	0.08
			191	0.07	0.17	15	0.05	0.08
			189	0.04	0.07	14	0.05	0.10
			188.5	= confluence Salmon R.		13	0.07	0.10
						12	0.10	0.14
						11	0.07	0.10
						10	0.07	0.12
						9 - 8	(sheet not available)	
						7	0.10	0.13
						6	0.07	0.13
						5	0.10	0.13
						4	0.07	0.08
						3	0.06	0.08
						2	0.05	0.07
						1	0.04	0.10
						0	= confluence Snake R.	

	Snake—Weiser		Snake—Hells Canyon		Salmon River	
	River width	Valley width	River width	Valley width	River width	Valley width
Average:	0.296	3.237	0.075	0.129	0.072	0.128
S.D.:	0.133	0.999	0.023	0.049	0.020	0.037

Table 9. Reach gradients for the Snake River above (near Weiser) and below (through Hells Canyon) the Hells Canyon Complex and the Salmon River (near White Bird to the confluence).

River Reach	R. Mile at start	Elev. (ft) at start	R. Mile at end	Elev. (ft) at end	Distance (miles)	Change in Elev. (ft)	Gradient (ft/mile)	Gradient (m/km)
Snake-Weiser	341.0	2,080	362.0	2,110	21.0	30	1.4	0.3
Snake-Hells Canyon	189.0	920	247.0	1,480	58.0	560	9.7	1.8
Salmon	1.0	880	50.5	1,400	49.5	520	10.5	2.0

(imperial to metric conversion: 1 ft = 0.3048 m, 1 mile = 1.6093 km)

Table 10. Hydrological characteristics for reaches and tributaries of the Snake and Salmon Rivers.

Snake & Salmon river Gauges	Years of Record	Drainage Area (sq. mi)	Annual Flow (cfs)			Avg Peak Flow (cfs)		
			Ave	Max	Min	Ave	Max	Min
Snake R. at Murphy	1914-98	41,900	11,100	19,176	6,744	24,924	47,300	10,800
Major tributaries above Weiser[a]	1914-98	27,300	7,006	17,224	1,684	20,935[b]	37,200[b]	4,100[b]
Snake R. at Weiser	1914-98	69,200	18,106	36,400	8,428	45,859	84,500[c]	14,900
Snake R. at Hells Canyon Dam	1965-97	73,300	20,649	36,555	9,746	47,893	98,081[d]	20,400
Salmon R. at Whitebird	1914-98	13,550	11,149	17,870	5,812	63,488	130,000	21,800
Snake R. at Murphy	1973-98	41,900	11,526	19,176	6,744	24,185	40,300	11,300
Major tributaries above Weiser[a]	1973-98	27,300	7,285	17,224	1,684	21,346[b]	43,800[b]	3,600[b]
Snake R. at Weiser	1973-98	69,200	18,811	36,400	8,428	45,531	84,100	14,900
Snake R. at Hells Canyon Dam	1973-97	73,300	20,432	36,555	9,746	47,515	98,081[d]	20,400
Salmon R. at Whitebird	1973-98	13,550	11,362	17,820	5,820	62,450	130,000	21,800

Hells Canyon gauge data were provided by IPC, other data were derived from USGS gauging stations.

[a] Owyhee, Boise, Malheur, Payette, and Weiser Rivers

[b] Estimated peak flows are based on data from Weiser and Murphy gauges; therefore, values may not reflect the dynamics of hydraulic routing associated with peak flows along these tributaries.

[c] Peak of the USGS record is 120,000 cfs for March 3, 1910.

[d] This value is lower than the USGS record of 103,0000 cfs for January 2, 1997.

Table 11. Flow recession of the Snake River at the Weiser gauge, 1911−1959.

Year	Qpeak	Qp Date	Recess. Peak if different than Qp	Date	Date Q last 60k	Date Q last 50k	Date Q last 40k	Date Q last 30k	Date Q last 20k	Q end of recession	Qend Date	Rate of recession (cfs/day)
1911	67200	06/21/1911			06/25/1911	07/01/1911	07/03/1911	07/09/1911	07/14/1911	7040	08/07/1911	1280.0
1912	73800	06/15/1912			06/19/1912	06/23/1912	06/30/1912	07/08/1912	07/13/1912	9780	08/01/1912	1362.1
1913	66500	05/31/1913			06/06/1913	06/18/1913	06/21/1913	07/09/1913	08/04/1913	7430	08/19/1913	738.4
1914	50800	04/17/1914			—	05/26/1914	06/15/1914	06/21/1914	06/30/1914	7440	07/29/1914	421.0
1915	28600	11/18/1914	26700	06/02/1915	—	—	—	—	06/12/1915	7470	07/13/1915	469.0
1916	58400	03/22/1916	56900	06/21/1916	—	06/27/1916	06/30/1916	07/11/1916	07/19/1916	9610	07/31/1916	1182.3
1917	69400	05/28/1917	70400	05/29/1917	06/26/1917	06/29/1917	07/08/1917	07/14/1917	07/19/1917	8870	08/06/1917	891.7
1918	62400	06/24/1918			06/24/1918	06/28/1918	07/02/1918	07/03/1918	07/05/1918	8870	07/26/1918	1672.8
1919	53800	04/05/1919			—	0407/1919	05/01/1919	06/01/1919	06/05/1919	6810	07/09/1919	494.6
1920	36800	05/24/1920			—	—	—	06/18/1920	06/25/1920	6810	07/25/1920	483.7
1921	83100	05/23/1921			06/17/1921	06/19/1921	06/23/1921	06/26/1921	07/02/1921	8510	07/19/1921	1308.6
1922	67100	05/27/1922			05/29/1922	06/16/1922	06/22/1922	06/24/1922	06/30/1922	7810	07/16/1922	1185.8
1923	41500	06/13/1923			—	—	06/29/1923	07/01/1923	07/05/1923	9660	07/15/1923	995.0
1924	28900	02/09/1924			—	—	—	—	02/19/1924	7480	06/03/1924	186.3
1925	63100	02/06/1925	53000	05/23/1925	—	05/28/1925	06/01/1925	06/07/1925	07/08/1925	8510	07/31/1925	644.8
1926	34700	02/07/1926			—	—	—	02/08/1926	04/22/1926	7540	06/12/1926	217.3
1927	56300	06/17/1927			—	06/27/1927	07/08/1927	07/10/1927	07/12/1927	9860	07/23/1927	1290.0
1928	62300	05/12/1928			05/29/1928	05/31/1928	06/02/1928	06/08/1928	06/30/1928	9970	07/10/1928	886.9
1929	31300	04/15/1929			—	—	—	04/15/1929	06/20/1929	8870	07/04/1929	280.4
1930	21100	12/17/1929	19000	06/02/1930	—	—	—	—	—	8680	06/28/1930	396.9
1931	19000	03/19/1931			—	—	—	—	—	8290	06/07/1931	133.9
1932	53300	03/20/1932	34200	06/18/1932	—	—	—	06/19/1932	06/28/1932	8480	07/10/1932	1169.1
1933	39500	06/13/1933			—	—	—	06/19/1933	06/22/1933	9970	07/06/1933	1283.9
1934	20500	01/03/1934	19400	03/30/1934	—	—	—	—	—	7350	06/19/1934	148.8
1935	24300	06/03/1935	23700	06/03/1935	—	—	—	—	06/11/1935	8560	07/01/1935	540.7
1936	60700	04/25/1936	48200	06/08/1936	—	—	06/10/1936	06/15/1936	06/17/1936	8690	06/30/1936	1795.9
1937	36900	04/16/1937	35000	04/16/1937	—	—	—	04/16/1937	05/20/1937	7980	07/04/1937	342.0
1938	67200	05/03/1938			05/04/1938	05/08/1938	06/09/1938	07/11/1938	07/13/1938	9780	07/23/1938	708.9
1939	39500	03/26/1939	38900	03/26/1939	—	—	—	04/06/1939	05/12/1939	8870	06/27/1939	322.9
1940	49600	04/01/1940	48400	04/01/1940	—	—	04/02/1940	04/07/1940	06/03/1940	8580	06/27/1940	457.7
1941	28000	06/09/1941	27600	06/09/1941	—	—	—	—	06/20/1941	8690	07/10/1941	610.0
1942	44300	06/01/1942	42700	06/02/1942	—	—	06/03/1942	06/11/1942	06/19/1942	9970	07/13/1942	798.3
1943	69300	04/21/1943	56400	06/07/1943	—	06/21/1943	07/06/1943	07/12/1943	07/14/1943	12000	07/28/1943	870.6
1944	37000	06/17/1944	36500	06/17/1944	—	—	—	06/19/1944	06/25/1944	9600	07/09/1944	1222.7
1945	44100	06/14/1945	42900	06/14/1945	—	—	06/14/1945	06/18/1945	07/04/1945	9940	07/12/1945	1177.1
1946	57300	04/18/1946	57000	04/30/1946	—	05/01/1946	05/02/1946	06/08/1946	06/25/1946	10300	07/14/1946	622.7
1947	44600	06/11/1947	44100	06/15/1947	—	—	06/17/1947	06/19/1947	06/26/1947	10100	07/09/1947	1416.7
1948	48300	06/04/1948	47400	06/04/1948	—	—	06/12/1948	06/27/1948	07/02/1948	10600	07/12/1948	968.4
1949	34300	03/19/1949	29600	05/20/1949	—	—	—	—	06/13/1949	10300	07/02/1949	448.8

Table 11. (Cont.)

Year	Qpeak	Qp Date	Recess. Peak if different than Qp	Date	Date Q last 60k	Date Q last 50k	Date Q last 40k	Date Q last 30k	Date Q last 20k	Q end of recession	Qend Date	Rate of recession (cfs/day)
1950	40400	04/14/1950	38000	07/01/1950	—	—	—	07/05/1950	07/16/1950	10900	07/23/1950	1231.8
1951	45900	05/17/1951	45200	05/18/1951	—	—	05/30/1951	06/08/1951	07/01/1951	12100	09/04/1951	303.7
1952	84500	04/29/1952	83800	04/28/1952	05/14/1952	05/16/1952	06/12/1952	07/03/1952	07/06/1952	14700	07/10/1952	946.6
1953	56900	06/14/1953	56400	06/14/1953	—	06/15/1952	06/22/1953	06/26/1953	07/04/1953	10800	07/21/1953	1232.4
1954	30000	04/15/1954	27600	06/02/1954	—	—	—	—	06/29/1954	10100	07/14/1954	416.7
1955	28000	04/23/1955	25900	04/23/1955	—	—	—	—	05/02/1955	10100	07/13/1955	195.1
1956	56400	06/06/1956	55400	06/06/1956	—	06/09/1956	06/12/1956	06/24/1956	06/27/1956	11300	07/06/1956	1470.0
1957	66400	05/24/1957	65600	05/24/1957	05/25/1957	05/30/1957	06/06/1957	06/12/1957	06/18/1957	13600	06/26/1957	1575.8
1958	43100	04/19/1958	40900	05/22/1958	—	—	05/22/1958	06/14/1958	06/21/1958	11300	07/02/1958	722.0
1959	21600	09/16/1959										

Table 12. Flow recession of the Snake River at the Weiser gauge, 1966−1997.

Year	Qpeak	Qp Date	Recess. Peak if different than Qp	Date	Date Q last 60k	Date Q last 50k	Date Q last 40k	Date Q last 30k	Date Q last 20k	Q end of recession	Qend Date	Rate of recession (cfs/day)
1966	24200	03/09/1966										
1967	33300	06/22/1967	31500	06/22/1967	—	—	—	06/24/1967	07/02/1967	11100	07/14/1967	927.3
1968	34100	02/24/1968	31500	02/24/1968	—	—	—	02/24/1968	03/02/1968	11700	03/19/1968	825.0
1969	49300	04/07/1969	47500	04/07/1969	—	—	4/26/1969	05/16/1969	06/15/1969	11500	07/07/1969	395.6
1970	44700	05/26/1970	39400	06/19/1970	—	—	—	07/05/1970	07/06/1970	10600	07/16/1970	1066.7
1971	64000	01/20/1971	61500	05/14/1971	05/14/1971	05/21/1971	07/03/1971	07/06/1971	07/11/1971	13000	07/15/1971	782.3
1972	63000	03/14/1972	46400	06/11/1972	—	—	06/15/1972	06/21/1972	07/01/1972	11000	07/09/1972	1264.3
1973	28500	04/18/1973	27300	04/18/1973	—	—	—	—	04/23/1973	10600	06/12/1973	303.6
1974	57600	04/02/1974	39000	06/27/1974	—	—	—	07/03/1974	07/12/1974	12000	07/19/1974	1227.3
1975	57000	05/16/1975	55900	05/16/1975	—	05/21/1975	06/08/1975	06/14/1975	06/28/1975	10500	07/21/1975	687.9
1976	52600	04/14/1976	52100	04/14/1976	—	04/16/1976	05/20/1976	06/03/1976	06/22/1976	10600	07/01/1976	532.1
1977	21300	12/05/1976										
1978	45600	04/28/1978	44400	04/29/1978	—	—	05/02/1978	05/09/1978	06/12/1978	10200	07/17/1978	432.9
1979	36500	02/14/1979	29000	03/17/1979	—	—	—	—	04/20/1979	9450	06/09/1979	232.7
1980	48000	06/06/1980	47700	06/06/1980	—	—	06/12/1980	06/14/1980	06/26/1980	10200	07/12/1980	1041.7
1981	39300	06/13/1981	38000	06/13/1981	—	—	—	06/16/1981	06/18/1981	9760	06/25/1981	2353.3
1982	69600	02/17/1982	57600	04/14/1982	—	04/21/1982	05/28/1982	07/10/1982	07/17/1982	11300	07/25/1982	453.9
1983	62600	05/07/1983	62300	05/08/1983	05/10/1983	06/13/1983	06/21/1983	07/08/1983	07/19/1983	11300	07/27/1983	637.5
1984	80000	04/20/1984	70500	05/21/1984	06/12/1984	06/27/1984	07/01/1984	07/05/1984	07/13/1984	12200	07/18/1984	1005.2
1985	42000	04/12/1985	41400	04/11/1985	—	—	04/12/1985	04/22/1985	06/07/1985	10900	06/17/1985	455.2
1986	78500	02/25/1986	45400	06/08/1986	—	—	06/14/1986	06/20/1986	06/28/1986	12600	07/04/1986	1261.5
1987	25900	11/01/1986										
1988	14900	06/03/1988										
1989	39000	03/12/1989	32200	04/23/1989	—	—	—	04/23/1989	04/29/1989	11100	06/23/1989	345.9
1990	21400	06/02/1990	20900	06/02/1990	—	—	—	—	06/02/1990	8430	06/24/1990	566.8
1991	16500	05/18/1991										
1992	17100	02/22/1992										
1993	54200	03/19/1993	40400	06/12/1993	—	—	06/12/1993	06/18/1993	06/24/1993	10600	07/02/1993	1490.0
1994	16900	03/03/1994										
1995	41600	06/12/1995	40700	06/12/1995	—	—	06/13/1995	06/17/1995	07/05/1995	10600	07/20/1995	792.1
1996	54400	04/11/1996	51969	05/19/1996	—	05/19/1996	06/11/1996	06/20/1996	07/03/1996	13605	07/08/1996	767.3
1997	84100	01/03/1997	60435	06/18/1997	06/18/1997	06/24/1997	06/30/1997	07/03/1997	07/06/1997	14773	07/01/1997	3512.5

Table 13. Invasive and noxious plants along reservoir shorelines and riparian habitats.

Scientific Name	Common Name	Family Name	First Regional Record	Study Area: Year of Record	County, State	Total Number of Counties[a]
Amorpha fruticosa	indigobush	Fabaceae	1952: Umatilla County, OR	1989	Ada, ID	22
Convolvulus arvensis	field bindweed	Convolvulaceae	1886: Unknown, OR	1910	Ada, ID	125
Cyperus esculentus	yellow nutsedge	Cyperaceae	1877: Clackamac County, OR	1928	Malheur, OR	16
Elaeagnus angustifolia	Russian olive	Elaeagnaceae	1923: Whitman County, WA	1963	Owyhee, ID	35
Equisetum arvense	field horsetail	Equisetaceae	1880: Klickitat County, WA	1911	Ada, ID	100
Hypericum perforatum	St. Johnswort	Clusiaceae	1886: Multnomah County, OR	1923	Idaho, ID	95
Lepidium latifolium	perennial pepperweed	Brassicaceae	1932: Yakima County, WA	1968	Canyon, ID	55
Lythrum salicaria	purple loosestrife	Lythraceae	1929: King County, WA	1954	Malheur, OR	90
Onopordum acanthium	Scotch thistle	Asteraceae	1945: Washington County, ID	1945	Malheur, OR	95
Phalaris arundinacea	reed canarygrass	Poaceae	1875: Multnomah County, OR	1937	Idaho, ID	15
Tamarix spp.	saltcedar	Tamaricaceae	1938: Washington County, ID	1938	Owyhee, ID	45
Tribulus terrestris	puncturevine	Zygophyllaceae	1922: Unknown, OR	1938	Malheur, OR	48

Source: Invader Database System, http://invader.dbs.umt.edu

[a] Total number of counties from Idaho, Montana, Oregon, Washington, and Wyoming reporting species occurrence.

Table 14. Vegetation and geomorphic descriptions of the Weiser reach as derived from general land surveys and photographic records.

Photo Point	General Location	T, R, S	GLO Records (1870-1900)	GLO Records (1901-1936)	Historic Photo: Plant Communities	Historic Photo: Geomorphic Features	Current Photo (1999): Plant Communities	Current Photo (1999): Geomorphic Features
WR-1	Weiser Bridge	T11N, R5W	rich bottomland (1870)	dense willow, no timber (1907)	fringe of hackberry & some willow (1908)	steep banks (1–2m) fine substrates	nonnative silver maple and Chinese elm w/ exotic spp.	steep to gradual-sloping banks fine to fine-cobble substrates
WR-2	Westlake Island Ferry Crossing	T11N, R7W	dense willow (1883)	—	sparse hackberry & some willow (1902)	gradual-sloping banks fines w/sandbars	nonnative silver maple and Chinese elm w/ exotic spp.	gradual-sloping banks fine to fine-cobble substrates
WR-3	Farewell Bend Crossing	T12N, R7W	dense willow, rose, sage (1899)	sagebrush and no timber (1920)	sparsely vegetated w/ some willow (1902?)	gradual-sloping banks fines w/sandbars	exotic false indigo/tamarisk, annuals in barren zones	gradual-sloping banks fine to fine-cobble substrates

Notes: T, R, S = Township, Range, and Section, GLO = General Land Office

Table 15. Annual fluctuation data for Brownlee Reservoir, 1959−1999.

Year	Abs. Max	Abs. Min	Max Apr-Sep	Min Apr-Sep	Yearly Mean	Decline (ft)
1959	2077.1	2017	2077.1	2017	2056.77	60.10
1960	2077.6	2017.81	2077.6	2045.8	2063.60	59.79
1961	2078.12	2003.9	2077.96	2004.45	2054.24	74.22
1962	2078.9	2031.24	2078.9	2035.14	2063.54	47.66
1963	2077.5	2049.2	2077.5	2058.92	2071.19	28.30
1964	2078	1988.12	2078	1991.37	2052.29	89.88
1965	2078.11	1975.97	2078.11	1975.97	2042.02	102.14
1966	2078.25	2009.95	2078.11	2025.41	2058.47	68.30
1967	2078.1	2013.54	2078.1	2013.54	2058.84	64.56
1968	2078.05	2043.25	2078.05	2043.25	2066.78	34.80
1969	2078.15	1998.7	2078.15	1998.7	2058.14	79.45
1970	2078.68	2026.9	2078.68	2026.9	2063.41	51.78
1971	2078.12	1975.08	2078.12	1975.08	2053.73	103.04
1972	2078.01	1975	2078.01	1975	2053.01	103.01
1973	2078.11	2033.18	2078.11	2044.85	2066.12	44.93
1974	2077.9	2004.17	2077.9	2004.17	2059.04	73.73
1975	2078.1	2009.33	2078.1	2009.33	2059.36	68.77
1976	2078.21	2029.62	2078.21	2030.1	2064.61	48.59
1977	2077.12	2053.2	2076.73	2053.79	2066.28	23.92
1978	2077.5	2025.72	2077.5	2025.96	2059.69	51.78
1979	2077.08	2039.12	2077.08	2043.29	2058.84	37.96
1980	2077.63	2029.42	2077.63	2047.75	2064.83	48.21
1981	2078.05	2051.18	2078.05	2053.05	2069.36	26.87
1982	2077.92	2013.98	2077.92	2018.3	2059.60	63.94
1983	2077.63	2018.65	2077.63	2018.65	2064.03	58.98
1984	2077.36	2037.82	2077.36	2039.95	2063.15	39.54
1985	2077.53	2016.85	2077.53	2021.5	2054.92	60.68
1986	2078.03	2043.41	2078.03	2043.41	2067.22	34.62
1987	2077.54	2046.88	2077.54	2065.11	2068.74	30.66
1988	2077.81	2042.1	2077.81	2048.1	2066.40	35.71
1989	2077.38	2027.59	2077.38	2027.59	2059.96	49.79
1990	2077.73	2046.67	2077.73	2049.79	2068.13	31.06
1991	2077.04	2055.24	2077.04	2058.32	2068.69	21.80
1992	2077.08	2053.04	2077.08	2059.34	2067.42	24.04
1993	2077.29	2025.9	2077.29	2045.8	2061.43	51.39
1994	2077	2051.1	2077	2055.8	2065.96	25.90
1995	2077	2034.6	2077	2042.5	2062.54	42.40
1996	2077	2000	2077	2000	2056.06	77.00
1997	2077	1976	2077	1976	2041.06	101.00
1998	2077.1	2000	2077.1	2000	2056.67	77.10
1999	2076.68	1959.95	2076.68	1959.95	2039.02	116.72
$\bar{x}$	2077.67	2020.74	2077.65	2025.10	2060.37	56.93

ALL YEARS	Abs. Max	Abs. Min	Max Apr-Sep	Min Apr-Sep
	2078.9	1959.95	2078.9	1959.95

Table 16. Vegetation and geomorphic descriptions of the Brownlee reach of the Snake River as derived from general land surveys and photographic records.

Photo Point	General Location	T, R, S	GLO Records (1870-1900)	GLO Records (1901-1936)	Historic Photo: Plant Communities	Historic Photo: Geomorphic Features	Current Photo(1999): Plant Communities	Current Photo (1999): Geomorphic Features
BR-1	Burnt River/R.R. Bridge	T12N, R7W	dense willow, rose, sage (1899)	sagebrush, and no timber (1920)	scattered willow and hackberry (1899)	gradual-sloping banks fines w/sandbars	former riverbanks inundated, exotic annuals in barren zones	moderate slopes fine to fine-cobble
BR-2	Morgan Creek Confluence	T13N, R7W	willow, cherry & hackberry (1899)	—	scattered willow and hackberry (1952)	gradual slopes fine to fine-cobble, sandbars	former riverbanks inundated exotic annuals in barren zones	steep slopes fine-cobble to bedrock
BR-3	Hibbard Ck/Bastian Ranch	T14N, R7W	dense willows, wild roses (1899)	dense willows (1905)	scattered willow below grazed pasture (1950's)	gradual slopes fine to fine cobble substrates	—	—
BR-4	Soda Creek Confluence	T14N, R7W	dense willows, wild roses (1899)	dense willows (1905)	scattered willow and hackberry (1952)	gradual slopes fine to fine cobble substrates	former riverbanks inundated exotic annuals in barren zones	steep slopes fine-cobble to bedrock
BR-5	Powder River Confluence	T16N, R6W	willow, hackberry, no timber (1900)	—	scattered willow and hackberry (1946)	gradual to steep slopes fines, bedrock, sandbars	former riverbanks inundated exotic annuals in barren zones	steep slopes fine-cobble to bedrock
BR-6	Brownlee Dam Site	T17N, R5W	—	—	scattered pine, willow and hackberry (1953)	gradual to steep slopes fines, bedrock, sandbars	former riverbanks inundated exotic annuals in barren zones	steep slopes fine-cobble to bedrock

Notes: T, R, S = Township, Range, and Section, GLO = General Land Office

Table 17. Annual fluctuation data for Oxbow Reservoir.

	Year	Abs. Max	Abs. Min	Max Apr-Sep	Min Apr-Sep	Yearly Mean	Decline (ft)
	1962	1805.18	1798.39	1805.18	1798.39	1802.78	6.79
	1963	1805.02	1799.10	1804.88	1799.70	1802.80	5.92
	1964	1805.12	1794.32	1805.02	1794.32	1802.57	10.80
	1965	1804.9	1774.95	1804.83	1774.95	1801.72	29.95
	1966	1804.89	1795.42	1804.89	1795.42	1802.30	9.47
	1967	1805.18	1791.45	1805.18	1794.4	1802.31	13.73
	1968	1805.15	1794.95	1804.87	1797.8	1802.51	10.20
	1969	1804.95	1796.58	1804.68	1796.58	1802.11	8.37
	1970	1805.02	1798.35	1805.02	1798.35	1802.54	6.67
	1971	1807.88	1795.75	1807.88	1795.75	1802.41	12.13
	1972	1804.91	1798.66	1804.91	1799.63	1802.62	6.25
	1973	1804.85	1798.7	1804.78	1798.7	1803.38	6.15
	1974	1805.14	1798.47	1804.85	1798.47	1802.94	6.67
	1975	1805.02	1791	1804.69	1797.97	1802.95	14.02
	1976	1804.85	1797.57	1804.85	1797.57	1803.23	7.28
	1977	1804.82	1796.3	1804.82	1799.7	1803.55	8.52
	1978	1804.85	1798.9	1804.8	1799.65	1802.42	5.95
	1979	1804.9	1797.6	1804.8	1797.6	1803.00	7.30
	1980	1804.5	1795.25	1804.5	1795.25	1802.01	9.25
Not full yr	1981	1803.69	1795.2			1800.55	8.49
	1982	1804.39	1795.95	1804.39	1796.53	1800.97	8.44
	1983	1804.98	1794.34	1804.67	1796.91	1800.98	10.64
	1984	1804.98	1793.2	1804.45	1793.2	1800.75	11.78
	1985	1804.75	1793	1804.75	1794.98	1800.66	11.75
	1986	1804.8	1794.49	1804.8	1795.42	1801.50	10.31
	1987	1805.19	1794.64	1805.14	1794.89	1801.77	10.55
	1988	1805.1	1794.89	1804.7	1794.89	1801.58	10.21
	1989	1805.05	1794.3	1804.7	1794.4	1801.35	10.75
	1990	1804.7	1795.81	1804.46	1796.11	1801.49	8.89
No values	1991						
	1992	1804.81	1797.95	1804.62	1797.95	1801.99	6.86
	1993	1804.57	1795.4	1804.46	1795.4	1801.68	9.17
	1994	1804.3	1795.7	1804.2	1797.7	1801.46	8.60
	1995	1804.5	1795.2	1804.3	1795.2	1801.38	9.30
	1996	1804.6	1795.6	1804.6	1798.5	1802.15	9.00
	1997	1804.8	1795.9	1804.8	1795.9	1801.47	8.90
	1998	1804.9	1796.5	1804.9	1798.3	1802.45	8.40
	1999	1804.85	1797.80	1804.85	1798.33	1802.30	7.04
	$\bar{x}$	1804.92	1795.34	1804.84	1796.24	1802.07	9.58

ALL YEARS	Abs. Max	Abs. Min	Max Apr-Sep	Min Apr-Sep
	1807.88	1774.95	1807.88	1774.95

Table 18. Annual fluctuation data for Hells Canyon Reservoir.

	Year	Abs. Max	Abs. Min	Max Apr-Sep	Min Apr-Sep	Yearly Mean	Decline (ft)
	1968	1689.04	1673.78	1689.04	1673.9	1684.24	15.26
	1969	1688.2	1676	1688.2	1676	1684.46	12.20
	1970	1688.8	1681.05	1688.8	1681.05	1685.22	7.75
	1971	1687.9	1677.9	1687.9	1677.9	1685.06	10.00
	1972	1687.65	1678.3	1687.65	1679.8	1685.15	9.35
	1973	1687.8	1673.1	1687.6	1679.6	1684.97	14.70
	1974	1687.65	1679.8	1687.5	1679.8	1685.06	7.85
	1975	1687.75	1678.65	1687.75	1681.8	1685.22	9.10
No values	1976						
	1977	1688.05	1677.4	1688.05	1677.4	1685.40	10.65
	1978	1687.7	1675.85	1687.7	1677.4	1683.88	11.85
	1979	1687.95	1675	1687.95	1675.85	1684.40	12.95
	1980	1689.95	1679.55	1687.6	1680.85	1685.32	10.40
	1981	1687.8	1654.7	1687.15	1671.1	1684.85	33.10
	1982	1687.79	1680.22	1687.17	1680.96	1684.65	7.57
	1983	1687.49	1678.62	1687.49	1680.91	1684.67	8.87
	1984	1687.70	1681.21	1687.70	1681.99	1685.21	6.49
	1985	1687.75	1681.60	1687.51	1681.60	1685.48	6.15
	1986	1687.75	1679.55	1687.75	1681.60	1685.67	8.20
	1987	1688.05	1682.77	1688.05	1683.11	1686.33	5.28
	1988	1688.14	1681.65	1688.14	1681.74	1686.32	6.49
	1989	1688.24	1679.84	1688.24	1681.79	1686.48	8.40
	1990	1688.05	1682.77	1687.97	1683.11	1686.42	5.28
	1991	1688.24	1681.16	1688.24	1682.05	1686.44	7.08
	1992	1688.04	1678.13	1688.04	1681.82	1685.76	9.91
	1993	1687.81	1680.90	1687.70	1682.59	1685.73	6.91
	1994	1687.50	1678.40	1687.40	1681.90	1685.55	9.10
	1995	1687.80	1682.30	1687.80	1682.30	1686.05	5.50
	1996	1688.10	1678.60	1688.10	1680.30	1686.03	9.50
	1997	1687.70	1681.70	1687.70	1682.20	1686.01	6.00
	1998	1688.30	1680.10	1688.30	1682.80	1685.41	8.20
	1999	1687.99	1670	1687.99	1670	1685.79	17.99
	$\bar{x}$	1688.02	1678.08	1687.88	1679.85	1685.40	9.94

ALL YEARS	Abs. Max	Abs. Min	Max Apr-Sep	Min Apr-Sep
	1689.95	1654.7	1689.04	1670

Table 19. Vegetation and geomorphic descriptions of the Oxbow/Hells Canyon Reservoirs reach as derived from general land surveys and photographic records.

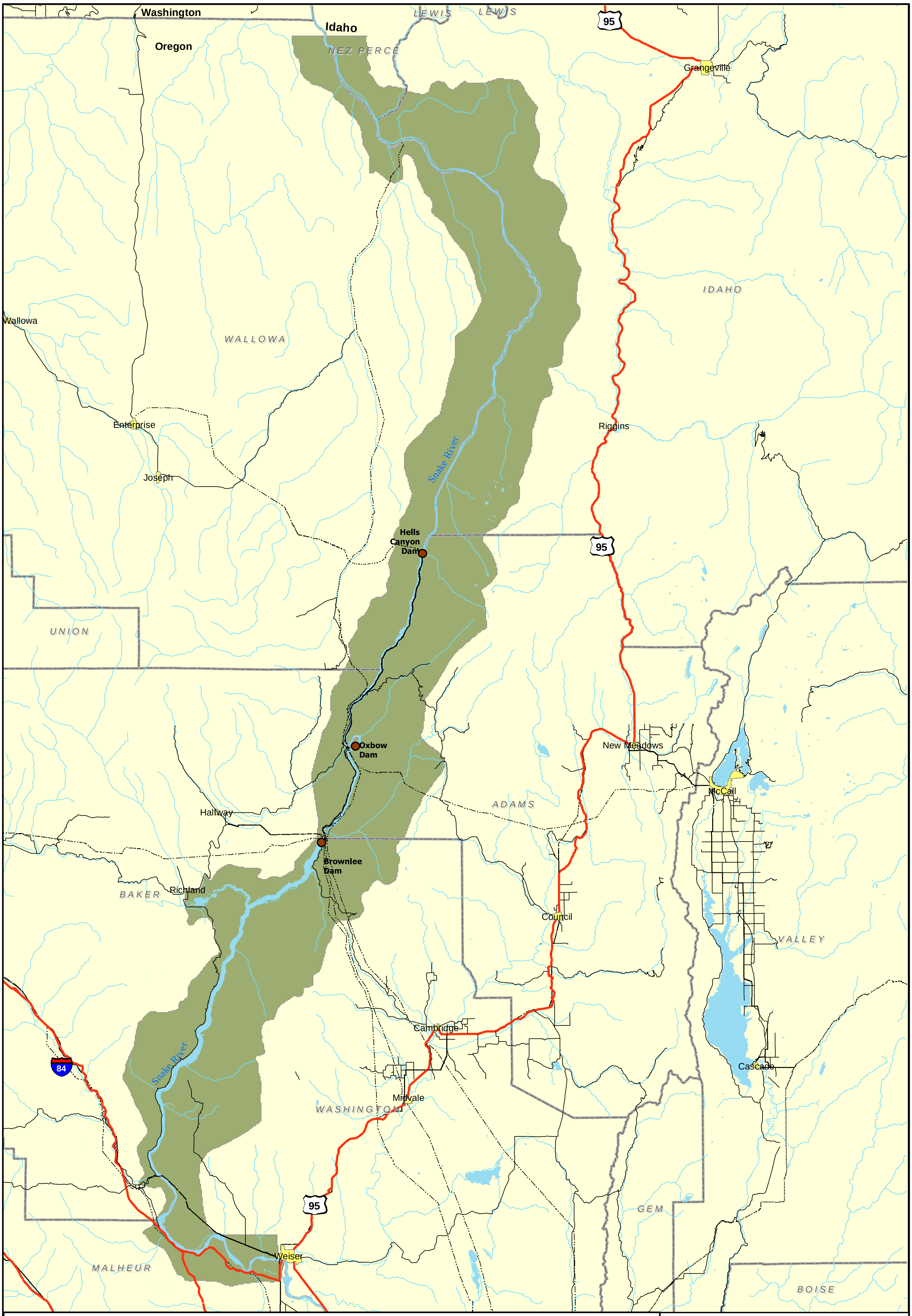
Photo Point	General Location	T, R, S	GLO Records (1870-1900)	GLO Records (1901-1936)	Historic Photo: Plant Communities	Historic Photo: Geomorphic Features	Current Photo(1999): Plant Communities	Current Photo (1999): Geomorphic Features
OX-1	Scorpion Creek/ Oxbow Dam Site	T19N, R4W	N/A	willow w/scattered pine/fir (1910)	scattered pines, willow and hackberry	alluvial fans to steep slopes fines, bedrock, sandbars	inundated riverbanks, scattered shrubs and hackberry	gradual to steep slopes fine to fine-cobble, bedrock
OX-2a/b	The Oxbow-Blue Creek to Scorpion Creek	T19N, R4W	N/A	willow, cottonwood, scattered pine/fir (1910)	scattered pines, shrubs w/ hackberry fringe	alluvial fans to steep slopes fines, bedrock, sandbars	inundated riverbanks, scattered shrubs and hackberry	gradual to steep slopes fine to fine-cobble, bedrock
OX-3a/b	The Oxbow-Pine Creek to Cottonwood Creek	T19N, R4W	N/A	willow, cottonwood, scattered pine/fir (1910)	scattered pines, shrubs w/ hackberry fringe	alluvial fans to steep slopes fines, bedrock, sandbars	inundated riverbanks, scattered shrubs and hackberry	gradual to steep slopes fine to fine-cobble, bedrock
HC-1	Kleinschmidt Grade	T20N, R4W	N/A	willow/scattered pine to no timber (1904)	riparian willow fringe	steep riverbank of fines and cobbles	—	—
HC-2	Ballard Bridge/ Hells Canyon Park	T20N, R4W	N/A	willow/scattered pine to no timber (1904)	scattered willow and hackberry	alluvial fans to steep slopes fines, bedrock, sandbars	inundated riverbanks, with scattered shrubs/hackberry	steep slopes cobble to bedrock
HC-3	McGraw Creek Confluence	T20N, R4W	N/A	willow/scattered pine to no timber (1904)	scattered hackberry, willow and alder	alluvial fans to steep slopes fines, bedrock, sandbars	inundated banks/fans, with scattered shrubs/hackberry	steep slopes cobble to bedrock
HC-4	Spring Creek Confluence	T21N, R4W	N/A	willow/scattered pine (1904/1936)	scattered hackberry, willow and alder	alluvial fans to steep slopes fines, bedrock, sandbars	inundated banks/fans, with scattered shrubs/hackberry	steep slopes cobble to bedrock
HC-5	Kinney Creek Rapids	T21N, R3W	N/A	willow/scattered pine (1904/1936)	pine forested slopes w/ willow/hackberry	alluvial fans to steep slopes fines, bedrock, sandbars	inundated banks/fans, with scattered shrubs/hackberry	steep slopes cobble to bedrock
HC-6	Eagle Bar Landing	T21N, R3W	N/A	willow/scattered pine to no timber (1904)	scattered hackberry and pine	steep slopes cobbles and bedrock	Former riverbanks inundated and/or barren	steep slopes cobble to bedrock

Notes: T, R, S = Township, Range, and Section, GLO = General Land Office

Table 20. Vegetation and geomorphic descriptions of the downstream reach as derived from general land surveys and photographic records.

Photo Point	General Location	T, R, S	GLO Records (1870-1900)	GLO Records (1901-1936)	Historic Photo: Plant Communities	Historic Photo: Geomorphic Features	Current Photo (1999): Plant Communities	Current Photo (1999): Geomorphic Features
SR-1	Deep Ck to Hells Canyon Ck (RM 247)	T22N, R3W	N/A	willow, buckbrush with scattered pine/fir (1935)	scattered pine and hackberry (1951)	steep slopes fines, bedrock, sandbars	scattered pine and barren cobble slopes	steep slopes cobble and bedrock
SR-2	Saddle Creek Confl (RM 236)	T24N, R2W	N/A	willow, maple with scattered pine/fir (1910)	hackberry w/ sparse cover along Saddle Ck	alluvial fan/side-tributary with fine to cobble substrate	hackberry w/ diverse riparian vegetation along Saddle Ck	alluvial fan/side with fine to cobble substrates
SR-3	Johnson Bar (RM 230)	T25N, R2W	N/A	willow, maple with scattered pine/fir (1910)	scattered pine & hackberry	steep slopes with Bonneville-related deposits, fines to bedrock	downslope extension of hackberry w/ more foliage	steep slopes, Bonneville deposits, cobble to bedrock
SR-4	Sheep Creek Rapids (RM 229.5)	T25N, R2W	N/A	willow, maple with scattered pine/fir (1910)	scattered pine & hackberry	rocky rapids with fine sands to cobble substrates	expansion/growth of hackberry canopy	rocky rapids with cobble substrates
SR-5	Sturgeon Rock/Pine Bar (RM 227.5)	T25N, R2W	N/A	willow, maple with scattered pine/fir (1910)	scattered pine with large stand of willow	large sandbar deposition	scattered pine with some hackberry and no willow	highly eroded sandbar
SR-6	Pittsburg Landing (RM 215, OR)	T27N, R1W	N/A	willow, maple with scattered pine/fir (1901-04)	scattered hackberry	steep bedrock to cobble slopes	scattered hackberry	steep bedrock to cobble slopes
SR-7	Lower Pittsburg Landing (RM 214.5, ID)	T27N, R1W	N/A	willow, maple with scattered pine/fir (1901-04)	scattered riparian fringe of hackberry	steep Bonneville depositions with fine-coarse to large cobble	expanded riparian fringe of hackberry	steep Bonneville deposits with cobble banks
SR-8	Getta/High Range Creek (RM 206)	T27N, R1W	N/A	willow, maple with scattered pine/fir (1901-04)	sparse upland vegetation	steep bedrock to cobble slopes	sparse upland vegetation	steep bedrock to cobble slopes
SR-9	Ragtown Bar Area (RM 205)	T27N, R1W	N/A	willow, maple with scattered pine/fir (1901-04)	scattered hackberry	open valley with cobble slopes	scattered hackberry	open valley with cobble slopes
SR-10	Dug Bar: basalt columns (RM 196.5)	T29N, R3W	N/A	cliffs, ravines, basalt ledges, no timber (1906)	scattered hackberry	basalt cliffs/talus slopes	scattered hackberry	basalt cliffs/talus slopes
SR-11	Eureka Bar/Imnaha Landing (RM 191.5)	T29N, R4W	N/A	No timber/no other notes	sparse willow	steep rocky slopes w/ sandbars	expanded willow patch	steep rocky slopes with remnant sandbar
SR-12	Salmon River Mouth (RM 188.5)	T29N, R4W	N/A	No timber/no other notes	sparse upland vegetation	steep rocky slopes	sparse upland vegetation	steep rocky slopes

Notes: T, R, S = Township, Range, and Section, GLO = General Land Office



IDAHO POWER
An IDACORP Company

Hells Canyon Project - FERC No. 1971

Tech. Report E.3.2-44 Figure 1

Hells Canyon Complex
Study Area and Vicinity

Scale = 1:583,519

This page left blank intentionally.

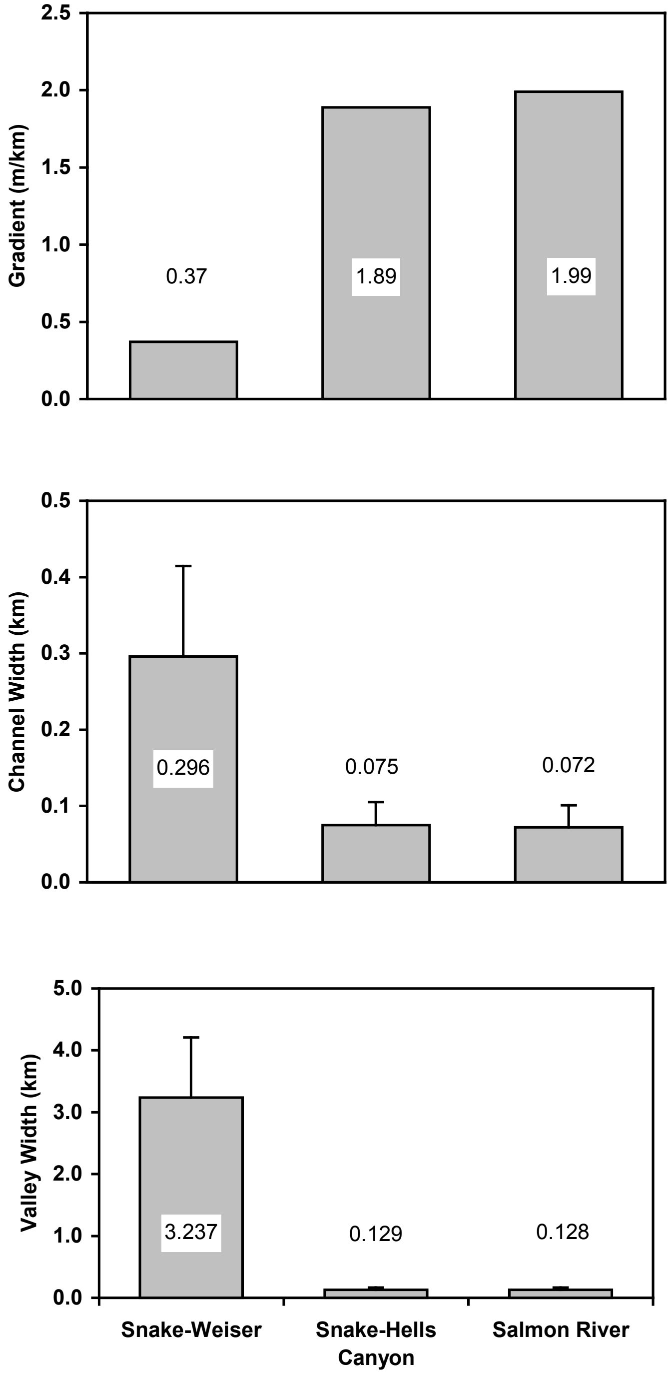


Figure 2. Comparison of channel slope (longitudinal gradient), channel width, and valley width for reaches of the Snake River above (near Weiser) and below (through Hells Canyon) for Hells Canyon Complex of dams and for the Salmon River (near White Bird to the confluence) (mean ± S.D.).

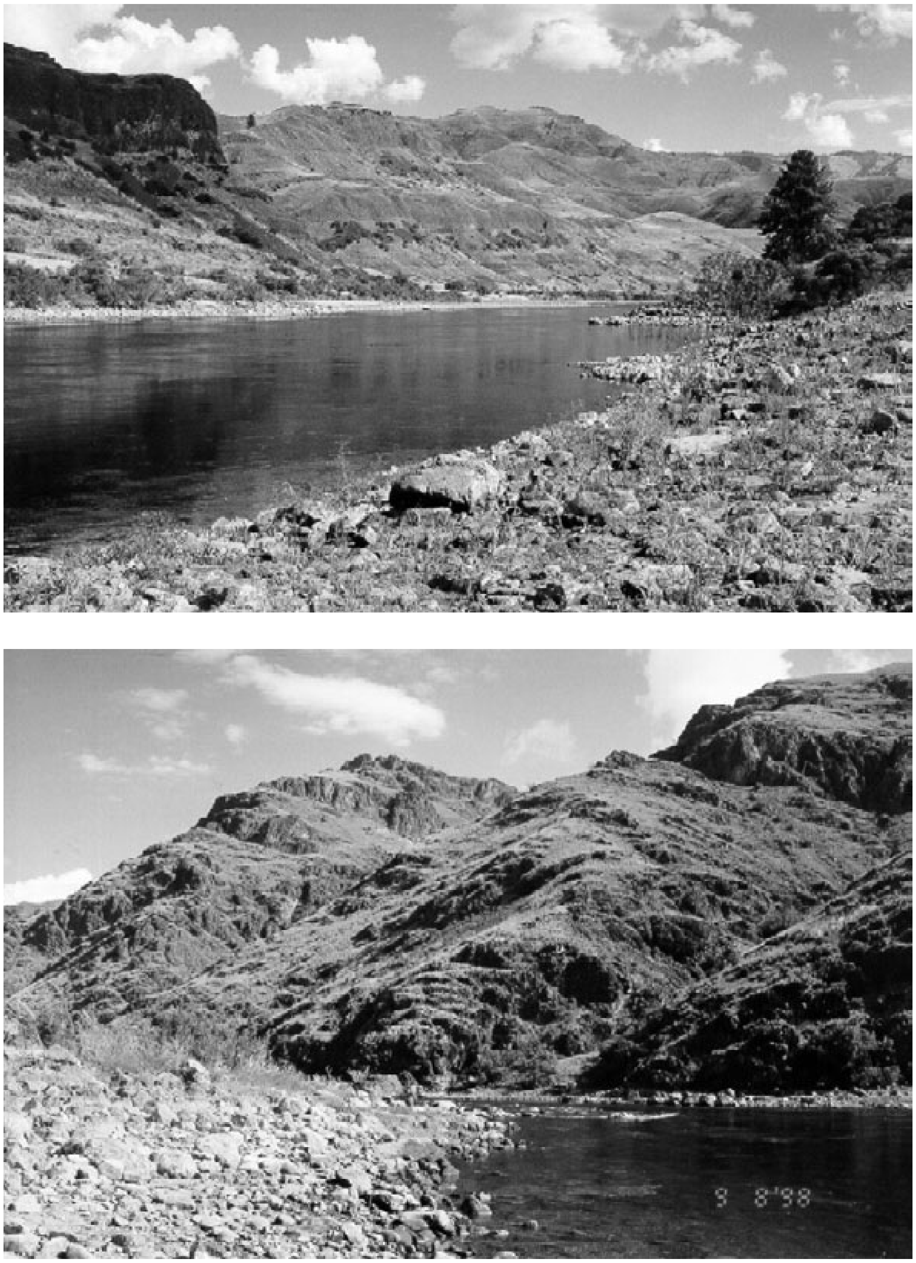


Figure 3a. Photograph comparisons of the Snake and Salmon Rivers—views of the Snake River taken near Copper Bar (top) and Bob Creek (bottom) on September 8, 1998.

Figure 3b. Photograph comparisons of the Snake and Salmon Rivers—views of the Salmon River taken near White House Bar (top) and China Bar (bottom) on September 6 and 5, 1999, respectively.

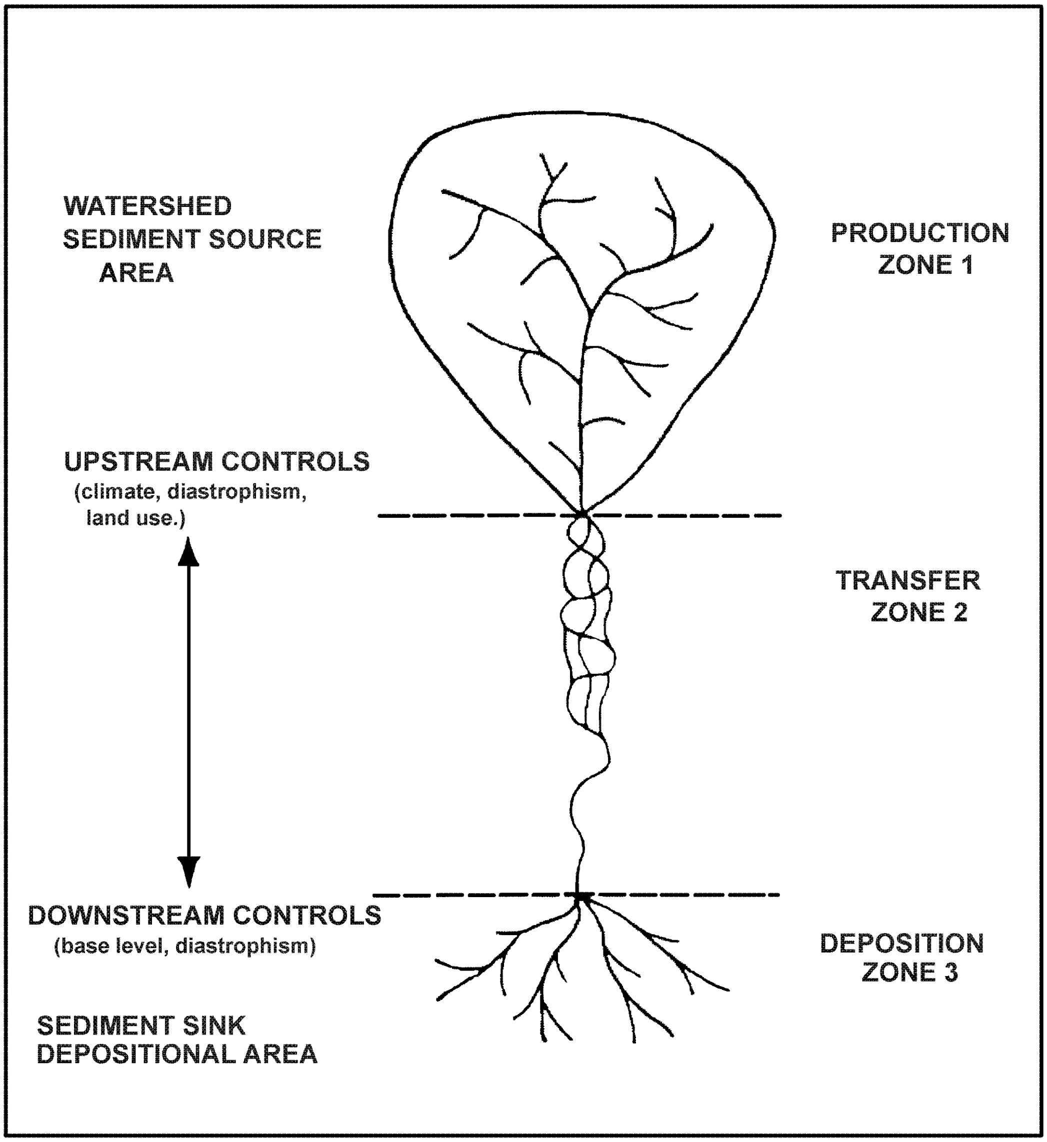


Figure 4. Key geomorphic zones.

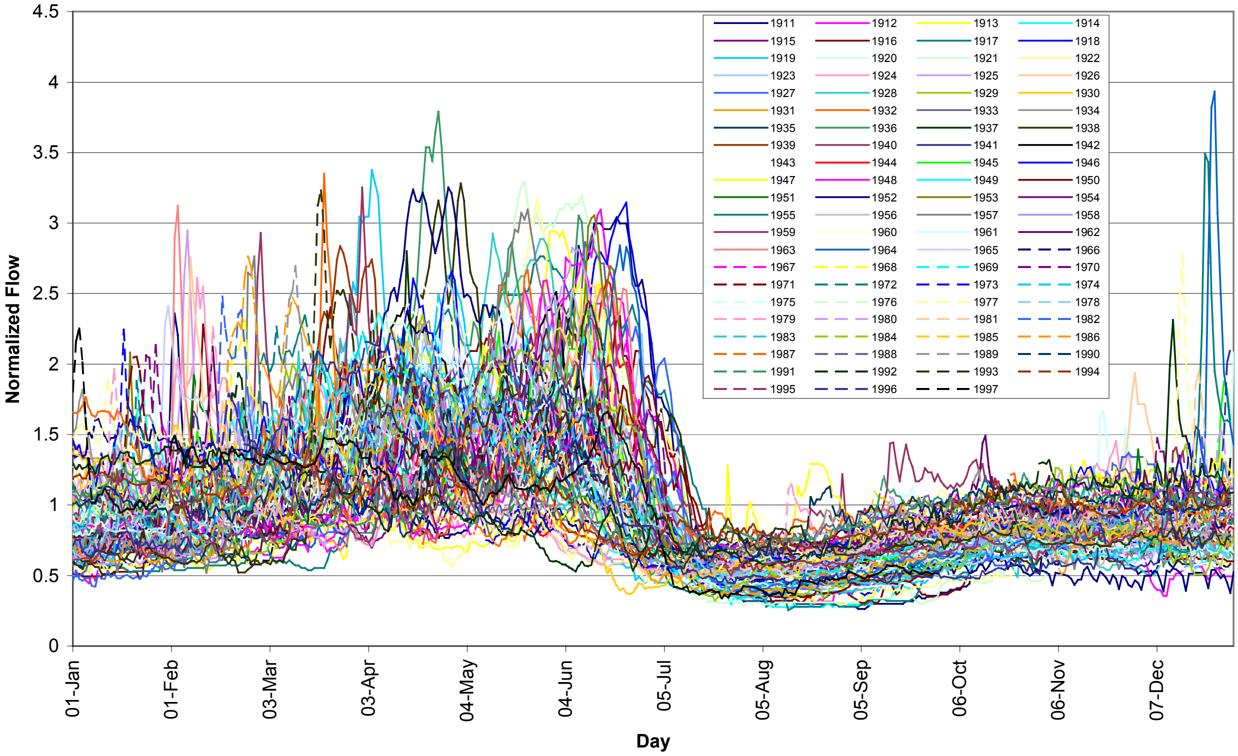


Figure 5. Historical record of annual flow of the Snake River at the Weiser gauge, 1911–1994.

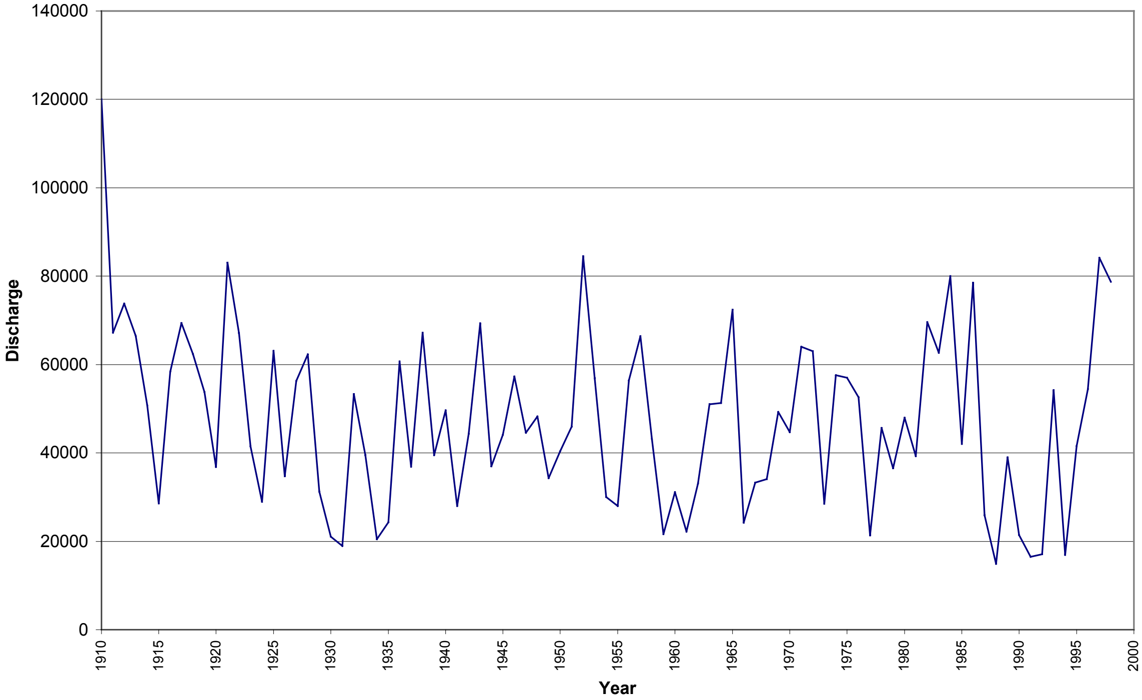


Figure 6. Annual peak flows of the Snake River at the Weiser gauge, 1910–1997.

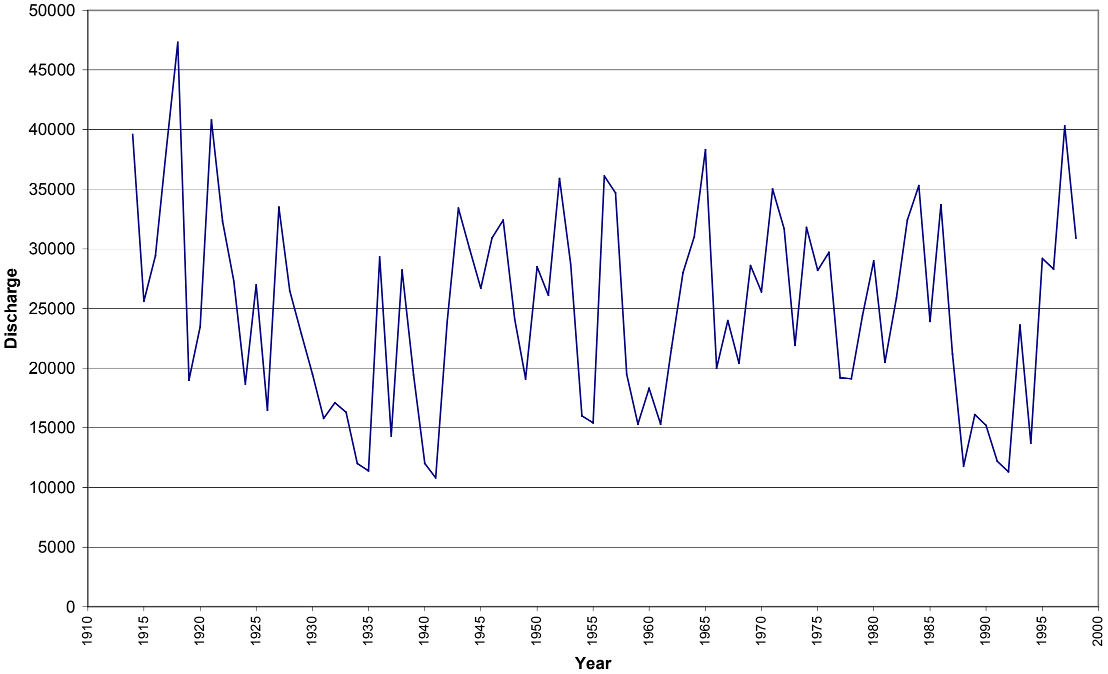


Figure 7. Annual peak flows of the Snake River at the Murphy gauge, 1915–1997.

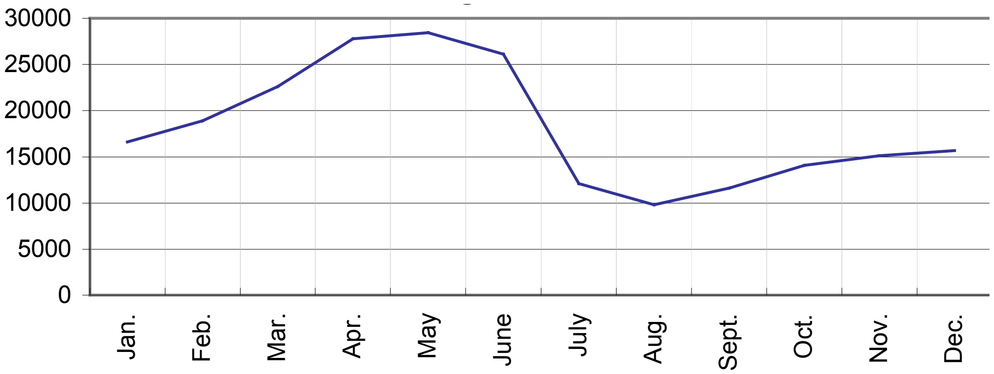


Figure 8. Average monthly flow of the Snake River at the Weiser gauge, 1910−1997.

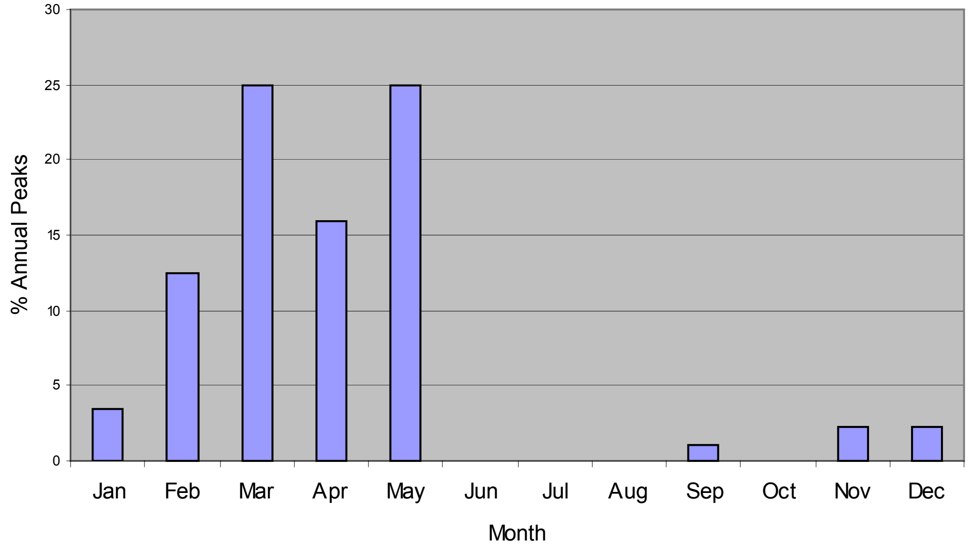


Figure 9. Monthly distribution of annual peak flows in the Snake River, based on historical flows measured at the Weiser gauge, Idaho, 1911–1998.

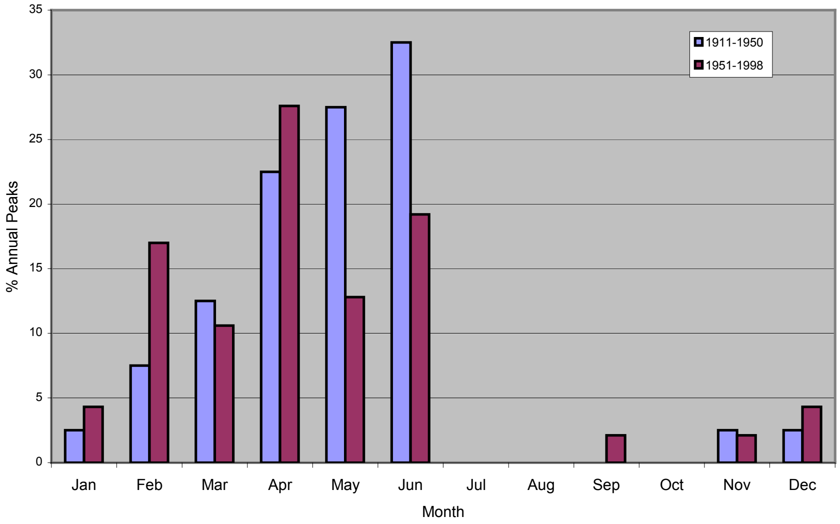


Figure 10. Monthly distribution of annual peak flows in the Snake River, based on historical flows measured at the Weiser gauge, Idaho, during 1911–1950 and 1950–1998.

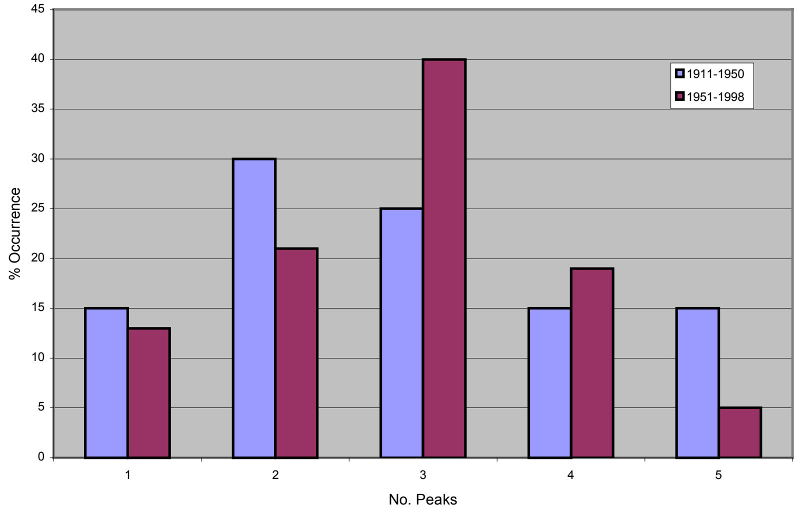


Figure 11. Proportional distribution of the number of annual peak flows in the Snake River, based on historical flows measured at the Weiser gauge, Idaho, during 1911–1950 and 1950–1998.

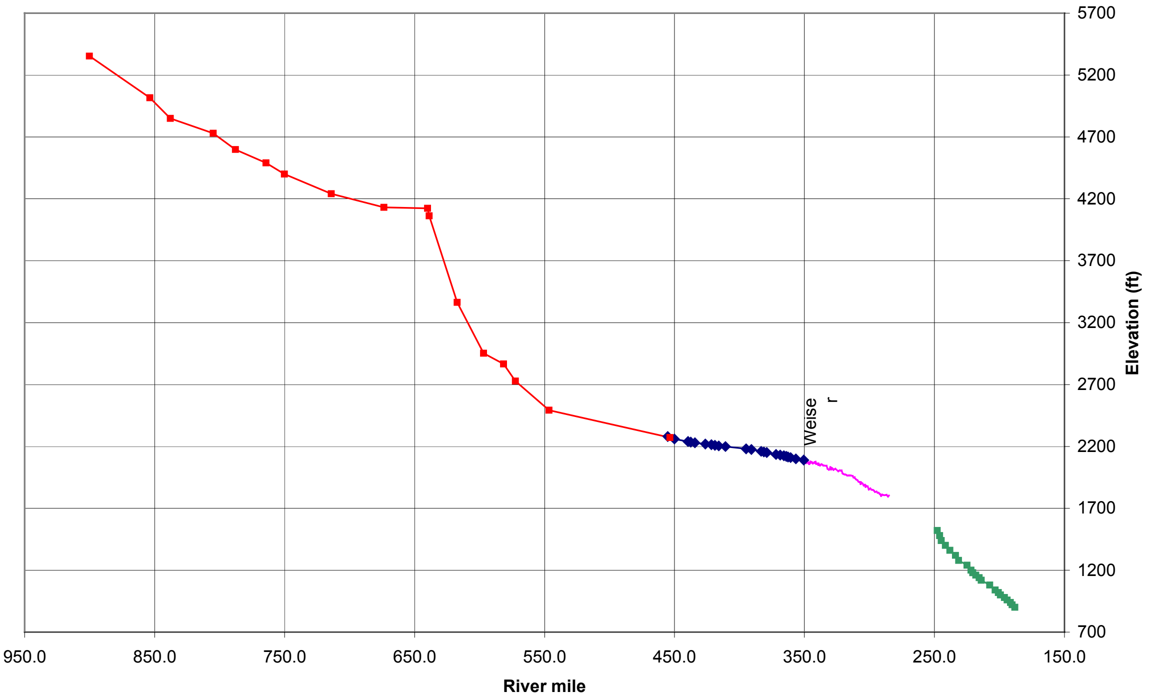
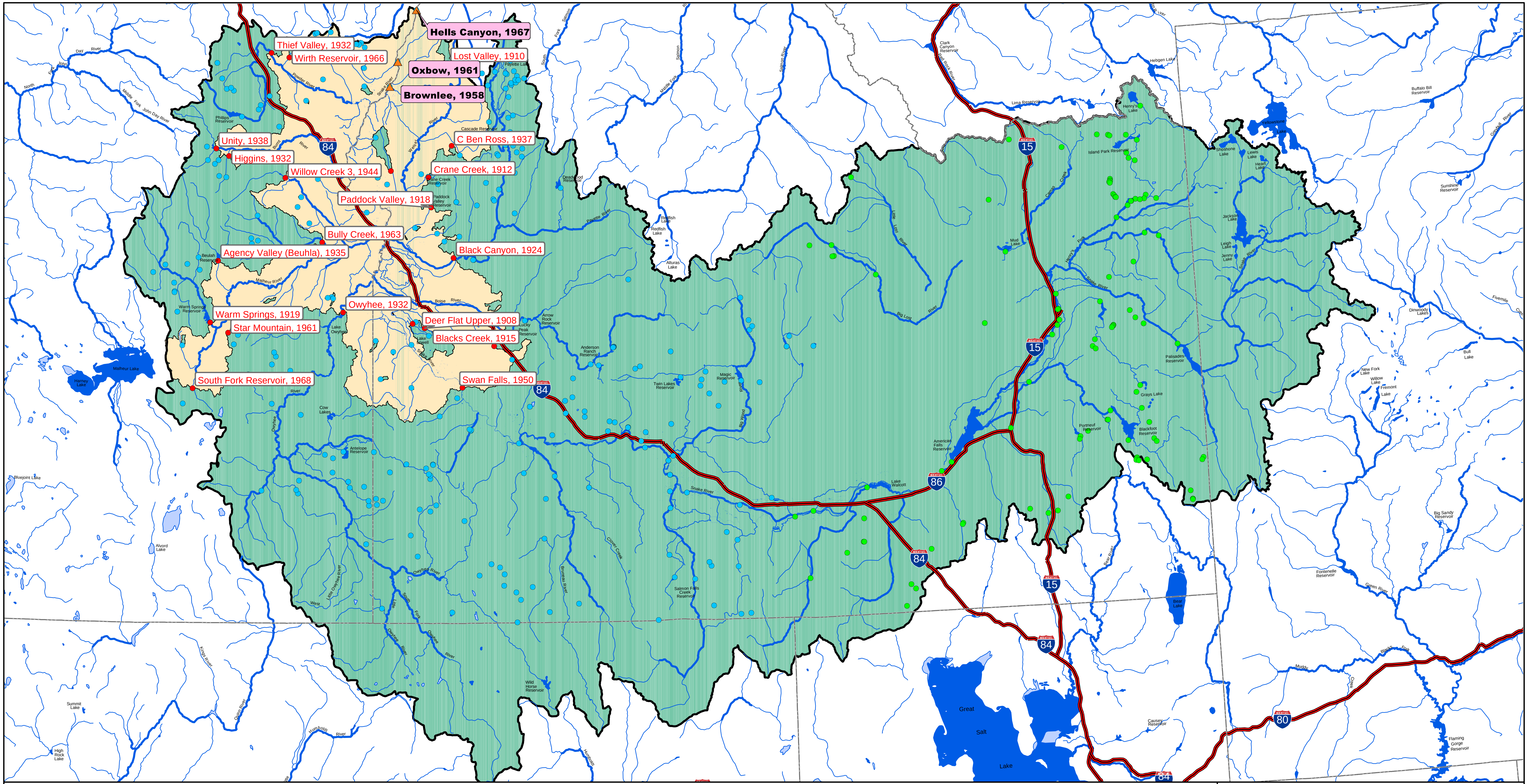


Figure 12. Longitudinal profile of the Snake River upstream and through the study area.

This page left blank intentionally.

Theme: i:\relic\hellscan\aquatic\e3244f13.mxd



Vicinity Map

Features Legend

- Lake, Reservoir
- Dry Lake
- Rivers and Streams
- Interstate Highway
- State Boundary
- ▨ Available Habitat
- 🟩 Unaccessible Habitat
- ● Upper Snake Dams
- ▲ Hells Canyon Complex, Year Built
- ● Upstream Terminus Dams, Year Built
- ● Other Dams (circa 1968)

IDAHO POWER
An IDACORP Company

Tech. Report E.3.2-44 Figure 13

HELLS CANYON HYDROELECTRIC COMPLEX

Upstream basin development affecting sediment loads

0 15 30 60 90 Miles

Scale = 1:2200000

This page left blank intentionally.

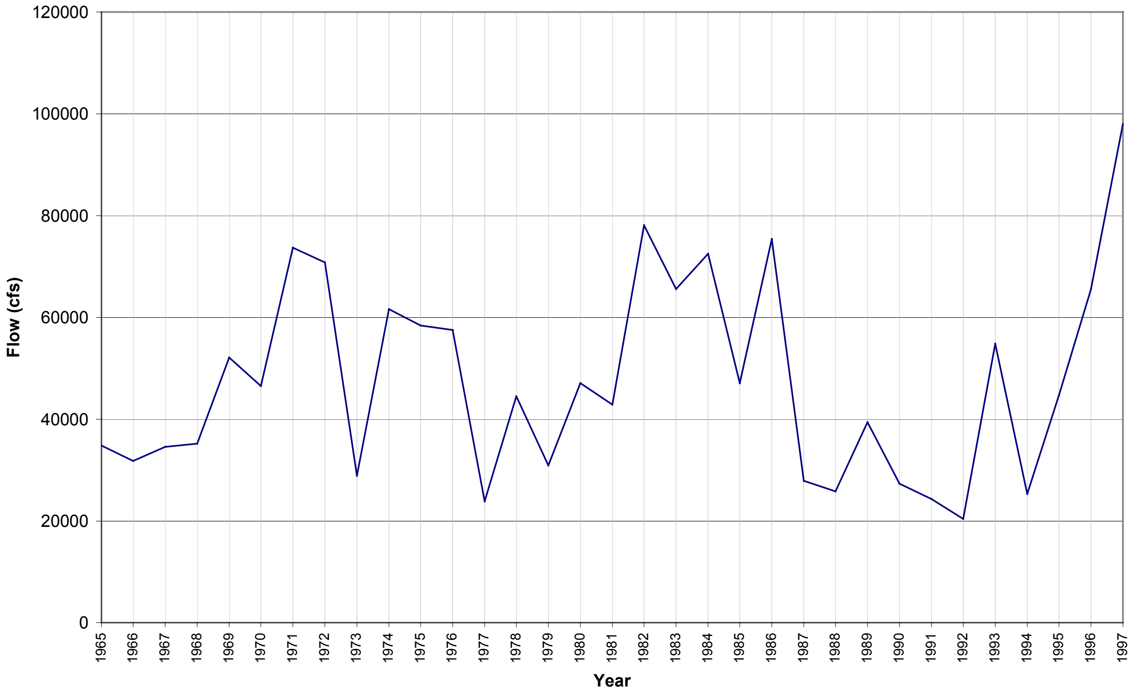


Figure 14. Annual peak flow of the Snake River at the Hells Canyon gauge, 1965−1997.

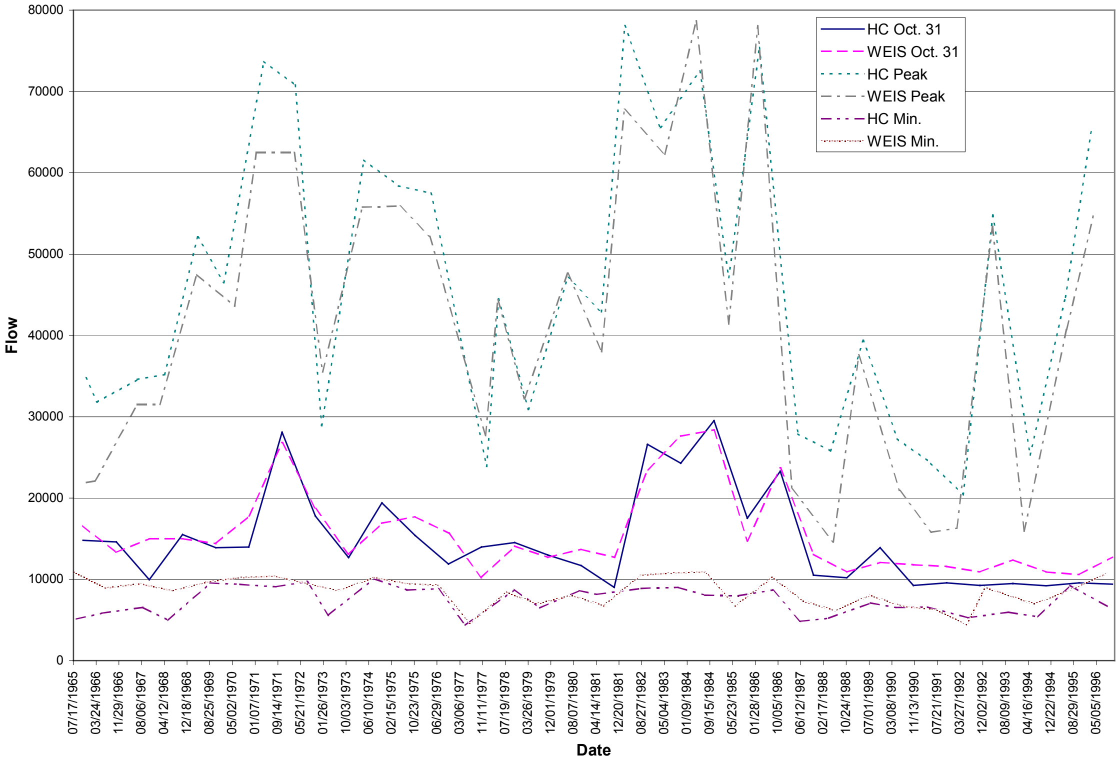
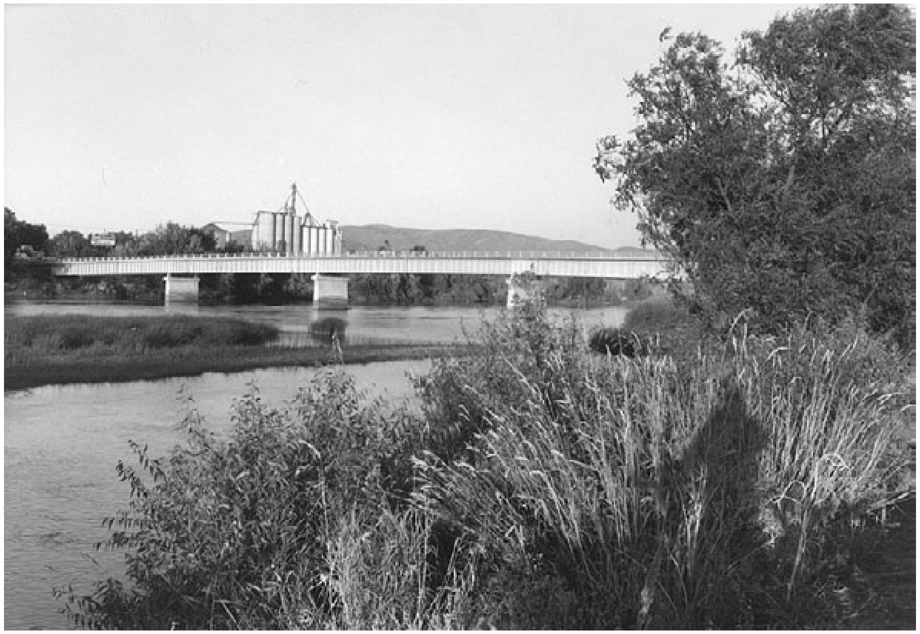


Figure 15. Flow comparison of the Snake River at the Hells Canyon and Weiser gauges.

March 8, 1908. Photograph of hackberry and sandbar willow growing along the edge of the river channel with highly eroded banks. The substrates are fine to fine-cobble (Idaho Historical Society). Higher flows during early March may be obscuring islands within the main channel.



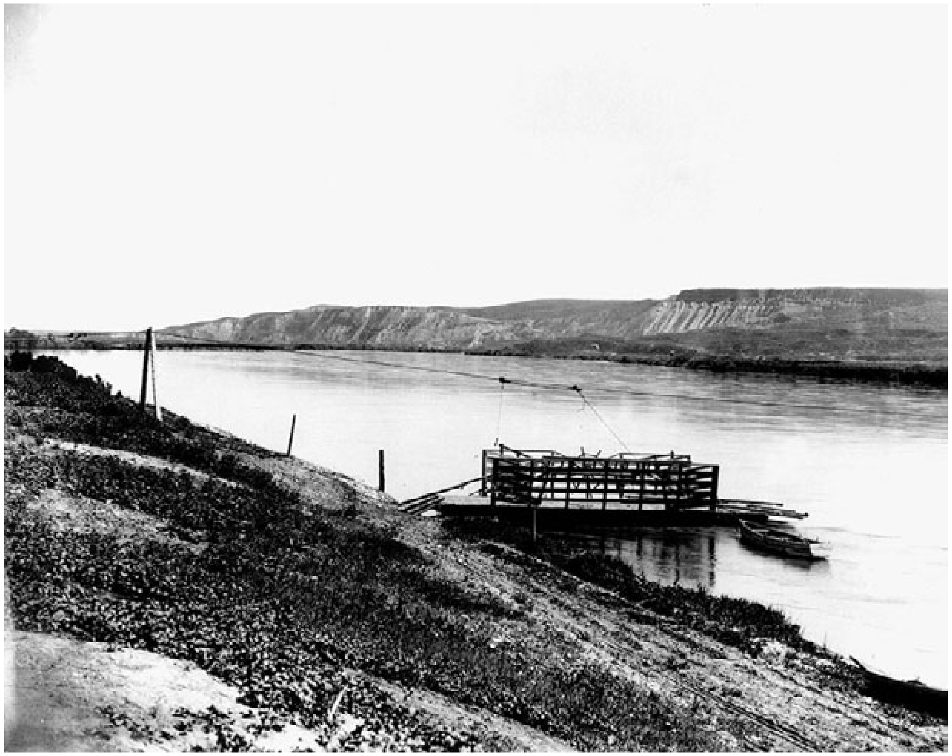
September 1999. Photograph of exotic woody and herbaceous plants along the entire riverbank, with low-lying channel islands visible in the foreground (photograph by J.H. Braatne). Riparian communities are dominated by silver maple (*Acer saccharium*), elm (*Ulmus pumila*), European willow (*Salix Coco* x *rubens* and S*alix alba*), native willows (*Salix exigua*), and poison hemlock (*Conium maculatum*). The substrates are fine to fine-cobble.

Series 1. (WR-1) Weiser Bridge crossing of the Snake River.

August 23, 1955. Aerial view of irrigated crops and pastures on the Weiser Flats floodplain. Only a few areas support woody riparian plants. Patterns of former channel migration (that is, paleo-channels) are visible within cultivated fields on Weiser Flats as variation in surface substrate conditions. The extent of paleo-channels suggests that this area was dominated by dense stands of sandbar willows prior to clearing and cultivation.

May 7, 1997. Aerial view of irrigated fields near Weiser, Idaho. A narrow fringe of dense woody vegetation is visible along the main river channel. The large island in the center of the channel is no longer farmed and has become partially bisected by shallow cross-channels. Channel morphology is comparable with historic photo, although patterns of past channel migration are less evident in recent aerial photos.

Series 1. (WR-1) (Cont.).



1908. Photograph of a sparsely vegetated riparian zone with scattered clumps of hackberry and sandbar willow along the opposite riverbank (Idaho Historical Society). Upland habitats consist of sagebrush steppe vegetation. Gently sloping banks promote access to the ferry, and barren soils are compacted by ferry traffic and dominated by annuals, such as cocklebur (*Xanthium strumarium*). The channel is wide and appears to lack small channel islands.

Series 2. (WR-2) Westlake Island ferry crossing.

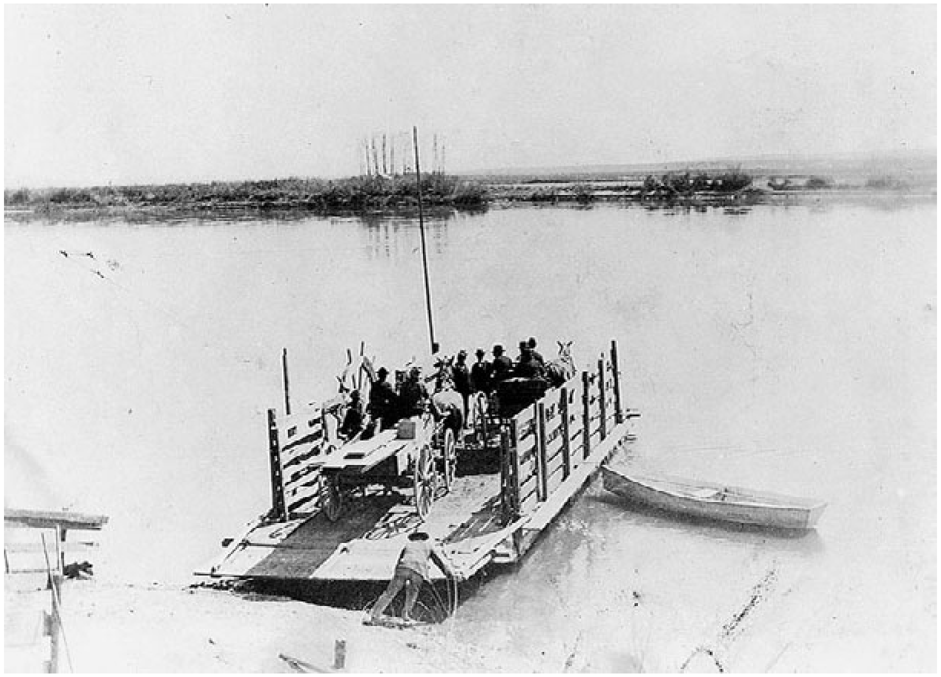
August 1999. View of riparian woody habitats composed of European willow trees, with salt-cedar or tamarisk (*Tamarix* spp.) along the lower bank. Russian olive (*Elaeagnus angustifolia*) with dense areas of reed canarygrass (*Phalaris arundinaceae*) and Eurasian herbs (*Amaranthus* spp., *Portulaca oleracea*) are common in areas of irrigation water seeps along the riverbanks (photographs by R.N. Fuller).

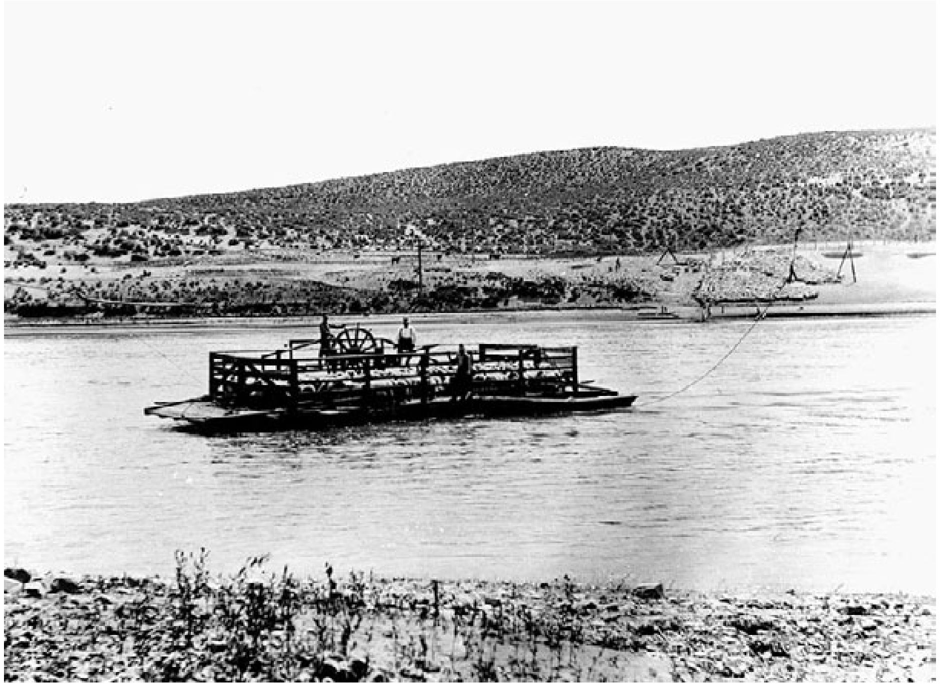
Series 2. (WR-2) (Cont.).

August 23, 1955. Aerial view of Westlake Island with surrounding irrigated fields and upland sagebrush steppe habitats. Riparian woody plants are notably absent, and the island is under cultivation.

May 7, 1997. Aerial view of Westlake Island showing cultivation patterns similar to the 1950s, although a narrow riparian fringe of woody plants is more visible. Channel morphology is similar in both aerial views.

Series 2. (WR-2) (Cont.).



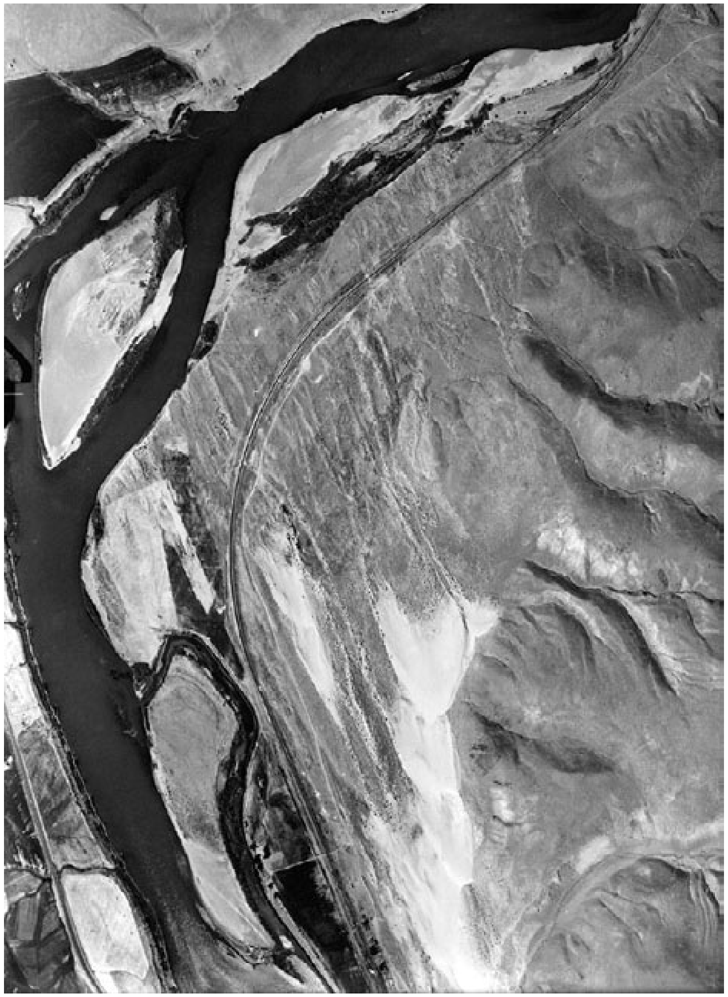


1902. Photograph of ferry traffic crossing toward the banks of Idaho (photograph on left, Weiser Historical Society) and Oregon (photograph on right, Idaho Historical Society). Paths leading to the ferry are sparsely vegetated, although widely scattered sandbar willow and hackberry are visible along the opposite riverbanks. The channel is wide and open, with gently sloping banks of fine substrates. Channel islands and bars are not visible in these photographs.

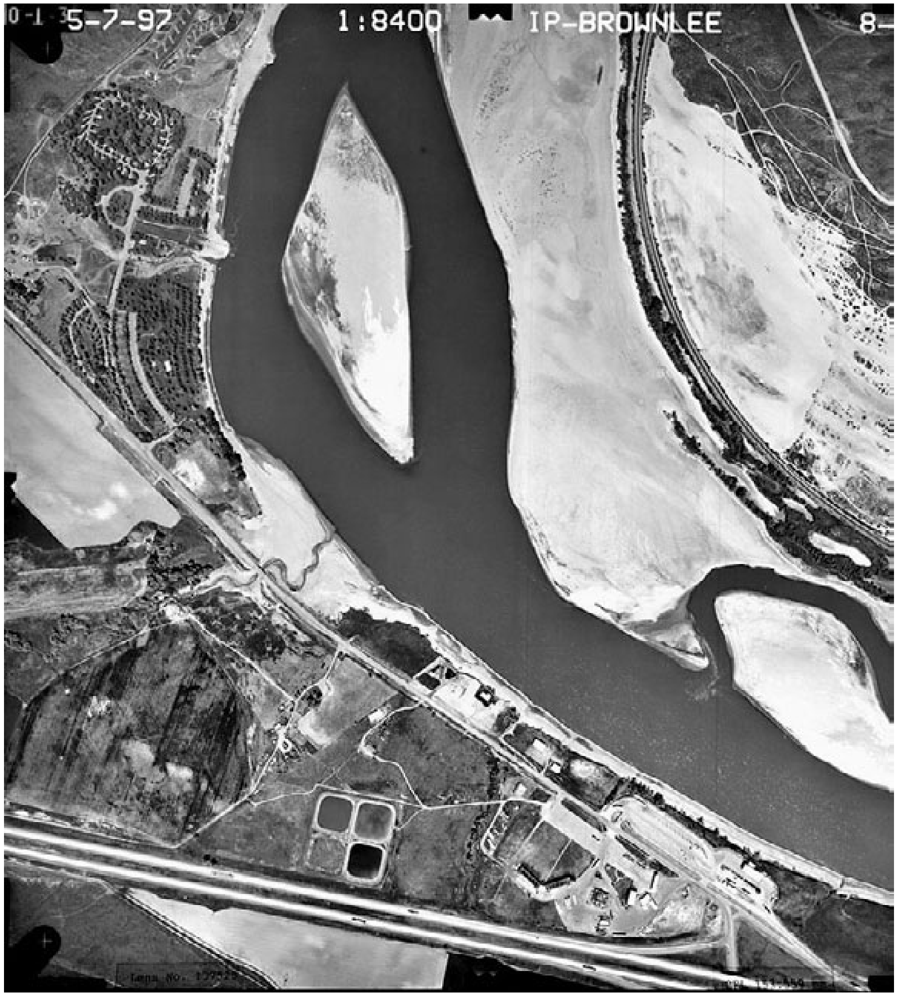
Series 3. (WR-3) Farewell Bend/Olds Ferry crossing.

September 1999. Photograph of dense, wide swards of cocklebur along the riverbanks that are periodically inundated or exposed by fluctuating water levels in Brownlee Reservoir. The shoreline consists of fine-cobble to cobble substrates (photograph by J.H. Braatne).

Series 3. (WR-3) (Cont.).



August 23, 1955. Aerial view of Farewell Bend.



May 7, 1997. Aerial view of Farewell Bend. In both aerial photos, water levels are comparable, and channel morphology appears similar. However, large barren zones associated with fluctuating water levels are visible in the post-dam aerial view.

Series 3. (WR-3) (Cont.).

1899. View of a sparse riparian zone of sandbar willow and herbaceous plants (Idaho Historical Society: Rodenbaugh collection). The abundance of fine substrates, particularly along the opposite bank, is related to the alluvial deposits typically found near the confluence of two rivers.

September 1999. View of barren reservoir shorelines dominated by exotic annuals, such as cocklebur, purslane (*Portulaca oleracea*), and pigweed (*Amaranthus albus*) (photograph by J.H. Braatne). The lack of woody vegetation is related to fluctuating reservoir water levels. Shoreline substrates consist of fine-cobble to cobble substrates.

Series 4. (BR-1) Burnt River/railroad bridge.

August 23, 1955. Aerial view of the confluence of the Burnt and Snake Rivers. Upland sagebrush steppe vegetation dominates the landscape, with woody plants limited to a scattered fringe of hackberry. Islands and sandbars are common geomorphic features.

May 7, 1997. Aerial view of the confluence of the Burnt River with the upper Brownlee Reservoir corridor. Extensive barren zones are visible along reservoir shorelines. Upland sagebrush steppe vegetation extends down the slope to the reservoir high-water mark. Former islands and sandbars are inundated in the recent aerial photograph.

Series 4. (BR-1) (Cont.).

1952. Photograph of the alluvial fan associated with the confluence of Morgan Creek with the Snake River (photograph by P. Basche). A narrow fringe of sandbar willow with scattered hackberry grows along the riverbank. Steep upland habitats extend downslope to an open river valley with scattered sandbar deposits and channel islands.

August 1999. Photograph of the reservoir corridor near Morgan Creek (photograph by R.N. Fuller). Steep upland habitats of sagebrush and bitterbrush drop abruptly to barren reservoir shorelines; substrates consist of cobble and bedrock. The former alluvial fan, low-lying river terraces, and channel islands have been inundated by the reservoir.

Series 5. (BR-2) Morgan Creek confluence with the Snake River/Brownlee corridor.

Pre-dam aerial photograph is not available at this time.

May 7, 1997. Aerial view of the Morgan Creek confluence with Brownlee Reservoir. Extensive barren zones can be seen along the reservoir shorelines, with an abrupt transition to upland habitats.

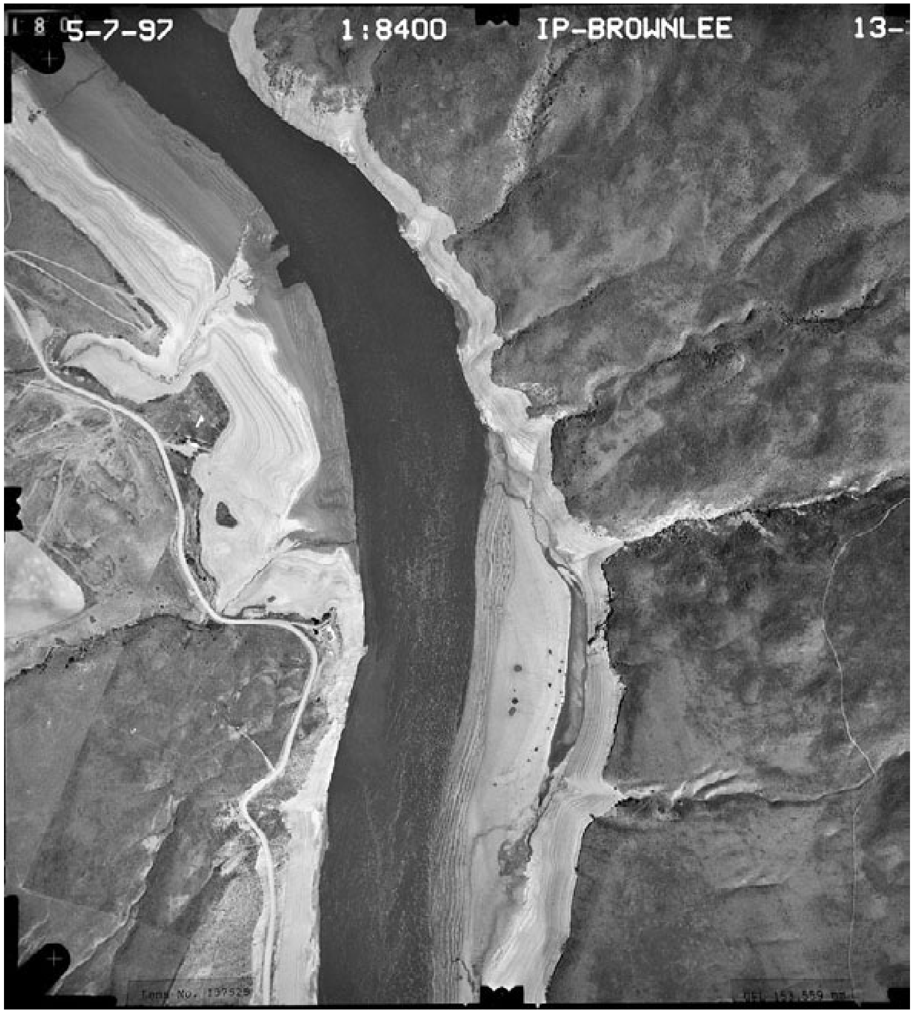
Series 5. (BR-2) (Cont.).

195?. Photograph of Mary Basche with a view of the Idaho riverbank in the background (photograph by W. Forsea). A sparse, narrow fringe of sandbar willows is visible along the lower riverbank on the Idaho side of the Snake River. The bench above the riverbank appears to be cultivated, perhaps as irrigated alfalfa or grains.

No recent oblique photograph for this area is available at this time.

Series 6. (BR-3) Hibbard Creek confluence with the Snake River/Brownlee corridor.

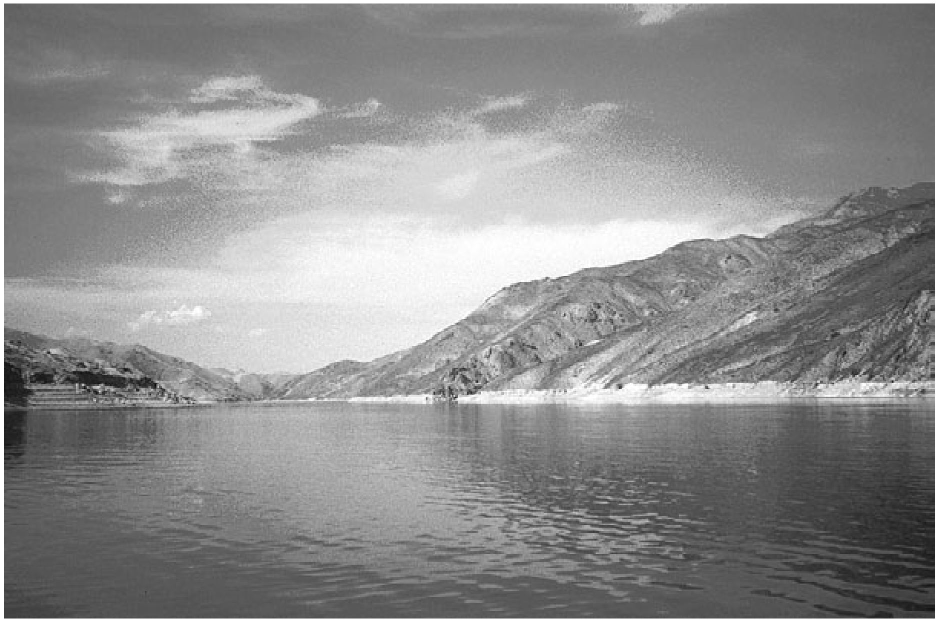
No pre-dam aerial photograph is available at this time.



May 7, 1997. Aerial view of the confluence of Hibbard Creek with Brownlee Reservoir. Extensive barren zones can be seen along the reservoir shorelines, with an abrupt transition to upland habitats.

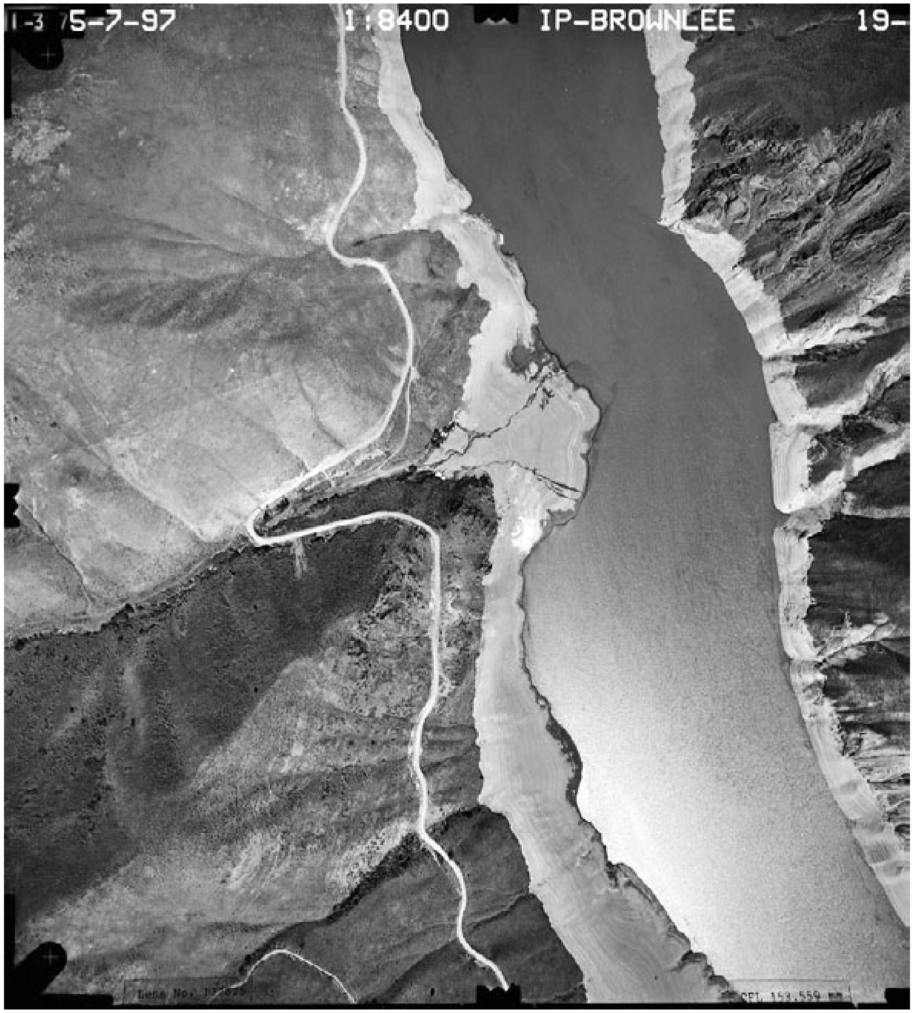
Series 6. (BR-3) (Cont.).

1952. Photograph of a sparse fringe of sandbar willows adjacent to overgrazed, pastured river terrace/alluvial fan near the Soda Creek confluence (photograph by P. Basche).



August 1999. View of the reservoir corridor near Soda Creek (photograph by M.L. Polzin). The river terrace/alluvial fan and valley bottoms have been inundated by the reservoir. Steep upland habitats of sagebrush steppe vegetation now drop abruptly to barren reservoir shorelines.

Series 7. (BR-4) Soda Creek confluence with the Snake River/Brownlee corridor.



No pre-dam aerial photograph is available at this time.

May 7, 1997. Aerial view of the confluence of Soda Creek with Brownlee Reservoir, showing extensive barren shorelines, with an abrupt transition from upland to barren shoreline habitats.

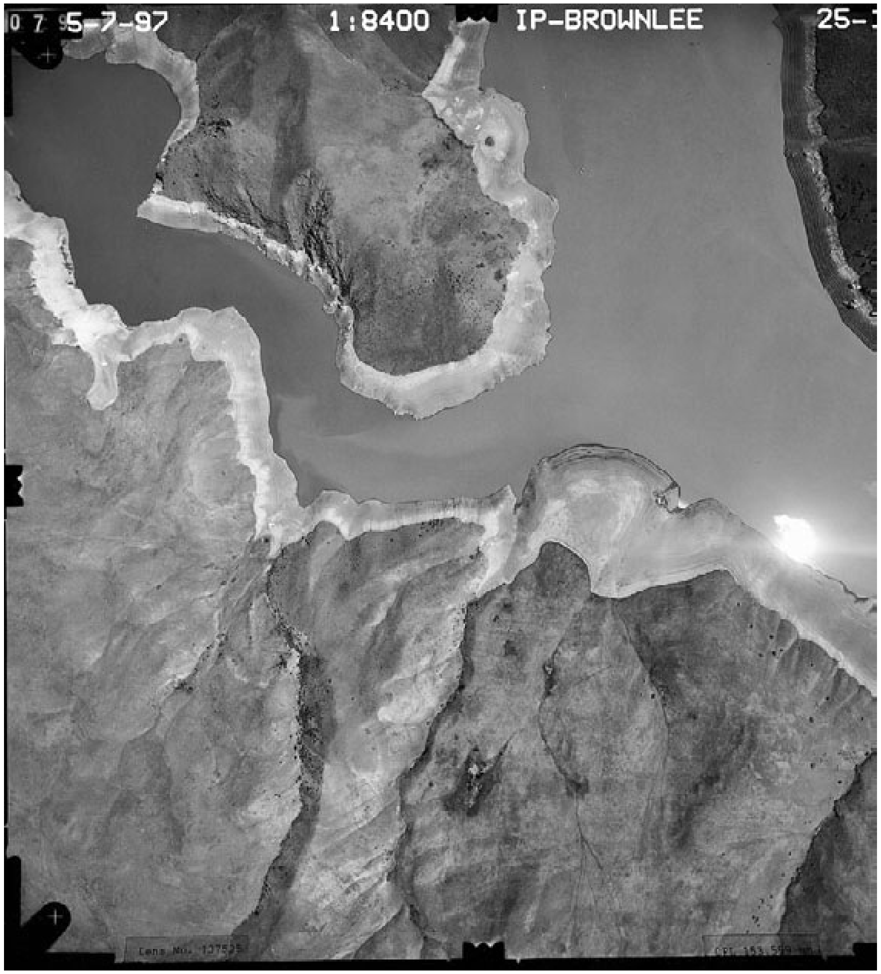
Series 7. (BR-4) (Cont.).

1946. Winter photograph of the Powder River confluence with the Snake River (photograph by P. Basche). Scattered hackberry and sandbar willows are visible along the riverbanks. Fine sands are abundant in this confluence zone, and most of the visible sandbar is barren. Adjacent upland slopes range from moderate to steep.

August 1999. View of the confluence of the Powder River with the Brownlee Reservoir corridor (photograph by M.L. Polzin). The former confluence has been permanently inundated. Upland sagebrush steppe habitats extend down steep slopes to barren reservoir shorelines.

Series 8. (BR-5) Powder River confluence with the Snake River/Brownlee corridor.

No pre-dam aerial photograph is available at this time.



May 7, 1997. Aerial view of the confluence of the Powder River with Brownlee Reservoir. This aerial view shows extensive barren shorelines, with an abrupt transition from uplands to barren shoreline habitats and cobble and bedrock substrates.

Series 8. (BR-5) (Cont.).

August 1953. Photograph of the right abutment for Brownlee Dam (photograph by F.R. McCormick). An open, scattered stand of pines are growing on a low river terrace/alluvial fan, with sandbar willow along portions of the river's edge. The slopes are moderate to steep, and substrates range from fines to cobble and bedrock. Sunflower is visible in the foreground, suggesting recent disturbance of portions of the site.

September 1999. Photograph of the right abutment of Brownlee Dam (photograph by J.H. Braatne). Steep upland habitats of sagebrush steppe communities drop abruptly to barren reservoir shorelines. Substrates range from cobble to bedrock.

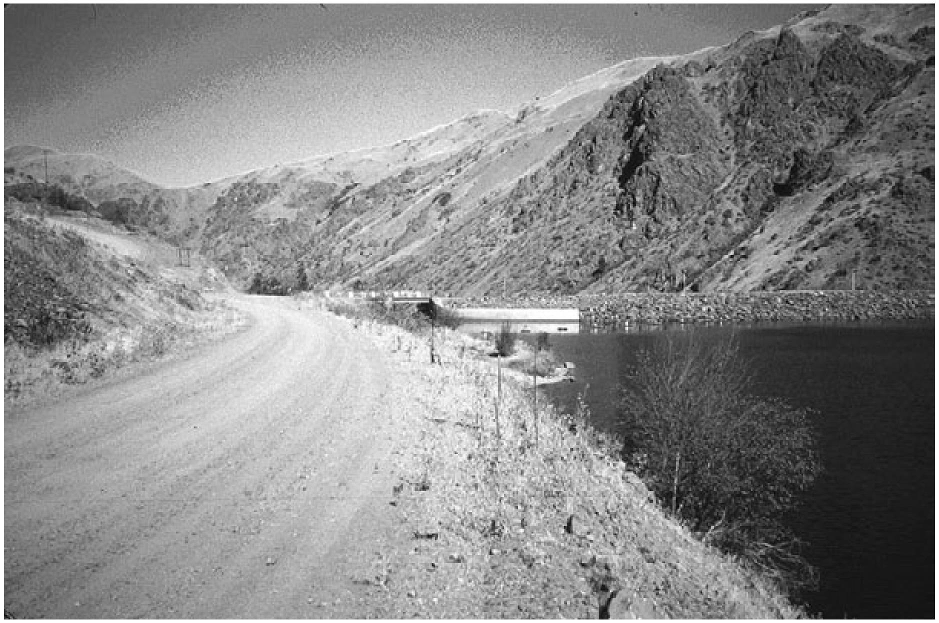
Series 9. (BR-6) Brownlee Dam site.

August 22, 1955. Aerial view of the Snake River corridor near the Brownlee Dam site. Low river terraces/alluvial fans, sandbars, and islands are common throughout this corridor. A scattered fringe of hackberry and sandbar willow is discernable along the riverbanks. Islands do not appear to support riparian vegetation, and one larger island has several conifers.

May 7, 1997. Aerial view of Brownlee Dam/Reservoir. The former alluvial fan, river terraces, sandbars, and islands were inundated by the reservoir. Steep upland sagebrush habitats extend downslope to steep, barren shoreline habitats. The substrates are cobble and bedrock.

Series 9. (BR-6) (Cont.).

August 1953. Photograph of the Oxbow Dam site and alluvial fan of Scorpion Creek (photograph by F.R. McCormick). Sandbar willow (far bank) and hackberry (near shore) are scattered along the river's edge, with upland habitats of pine and sagebrush steppe vegetation. The riverbanks are composed of fine to fine-cobble substrates. The late summer river surface level is several feet below the normal spring high-water level, which is marked by the location of the hackberry in the foreground and the willow/edge of cobble on the far bank.



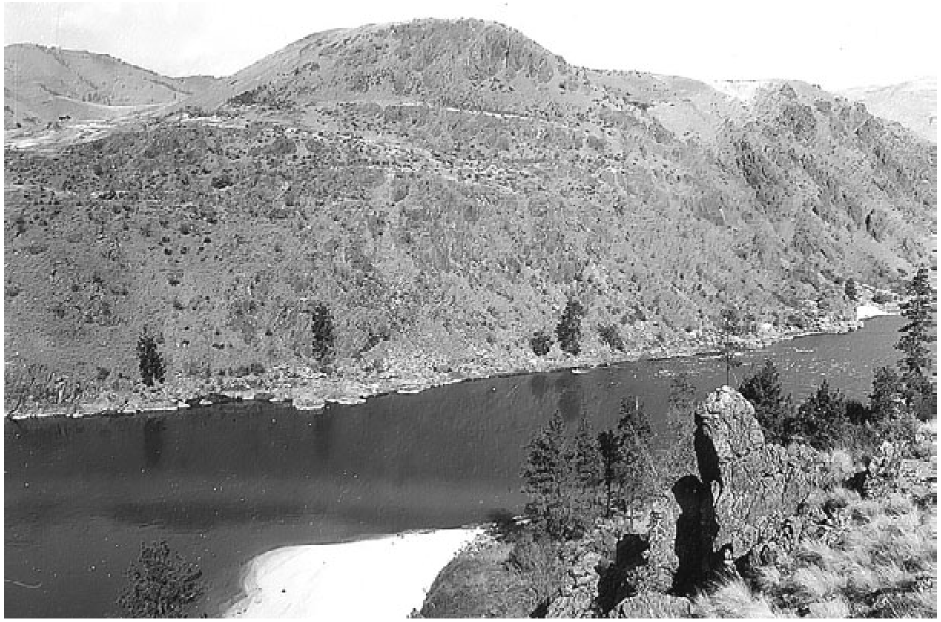
September 1999. Photograph of Oxbow Dam (photograph by J.H. Braatne). Upland habitats extend down steep slopes to the water surface, with former river terraces, sandbars, and islands inundated by the reservoir.

Series 10. (OX-1) Upriver of Scorpion Creek and Oxbow Dam site.

August 1953. Photograph of broad low terraces and barren sandbars with scattered stands of pine and hackberry. The terraces support pines and upland shrubs. The riverbanks are composed of fine to cobble and bedrock substrates (photograph by F.R. McCormick.

September 1999. Photograph of the dam site showing the inundation of low terraces and sandbars. A few hackberry bushes are widely scattered along the reservoir shoreline (photograph by J.H. Braatne). Upland habitats extend downslope to the water surface of the reservoir. Shoreline substrates consist of cobble and bedrock.

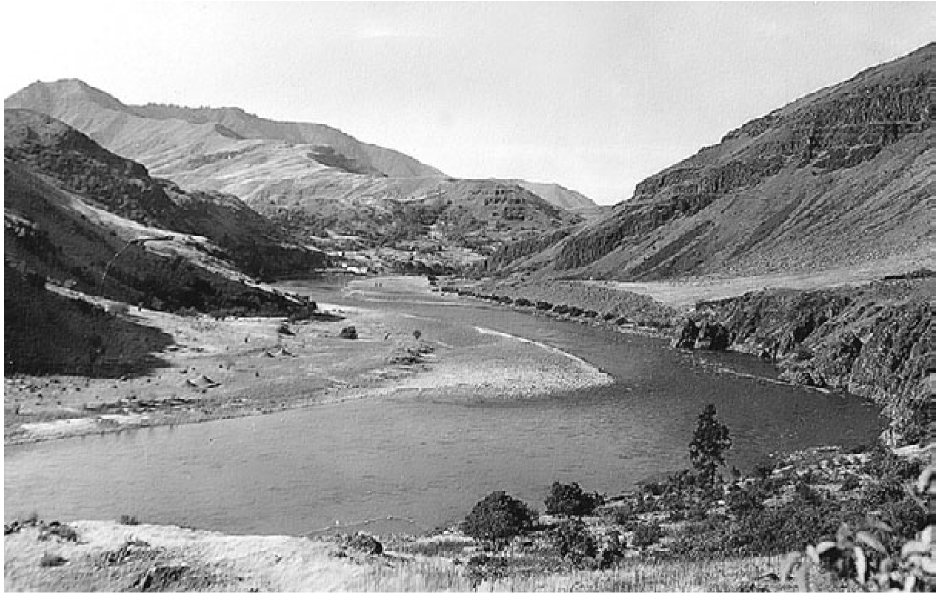
Series 11. (OX-2a) Above Scorpion Creek and Oxbow Dam looking upriver.



August 1953. Photograph of steep rocky slopes and a large sandbar with scattered pine and hackberry growing along the river. No willow is apparent (photograph by F.R. McCormick).

September 1999. Photograph of steep rocky slopes and the dewatered channel directly below the spillway of the dam. A few scattered hackberry and pine are located at the downstream end of the photograph and appear to predate the dam (photograph by J.H. Braatne). The channel bed lacks fine substrates and appears to be heavily armored.

Series 12. (OX-2b) Above Scorpion Creek and Oxbow Dam looking downriver.



August 1953. Photograph showing the river flowing through the lower half of the oxbow (photograph by F.R. McCormick). Upland habitats of sagebrush steppe vegetation with scattered pines, hawthorn (*Crataegus douglasii*), and a riparian fringe of hackberry are present. On higher portions of the alluvial fan at left, the vegetation appears to be heavily grazed. Riverbanks are composed of fine to fine-cobble and bedrock.

September 1999. Photograph showing partial inundation of the oxbow by Hells Canyon Reservoir (photograph by J.H. Braatne). Upland and riparian habitats appear similar to pre-dam conditions, alternating cycles of inundation and drawdown have armored the channel bed; shoreline consists of cobble and bedrock.

Series 13. (OX-3a) Looking downriver from the tip of the oxbow.

August 1953. Photograph of the river flowing through the lower half of the oxbow (photograph by F.R. McCormick). Upland habitats of sagebrush steppe with a fragmented fringe of hackberry are present along the river. The broad river terraces are composed of fine to fine-cobble and bedrock, and a browse line is evident on tall shrubs (hackberry and possibly serviceberry).

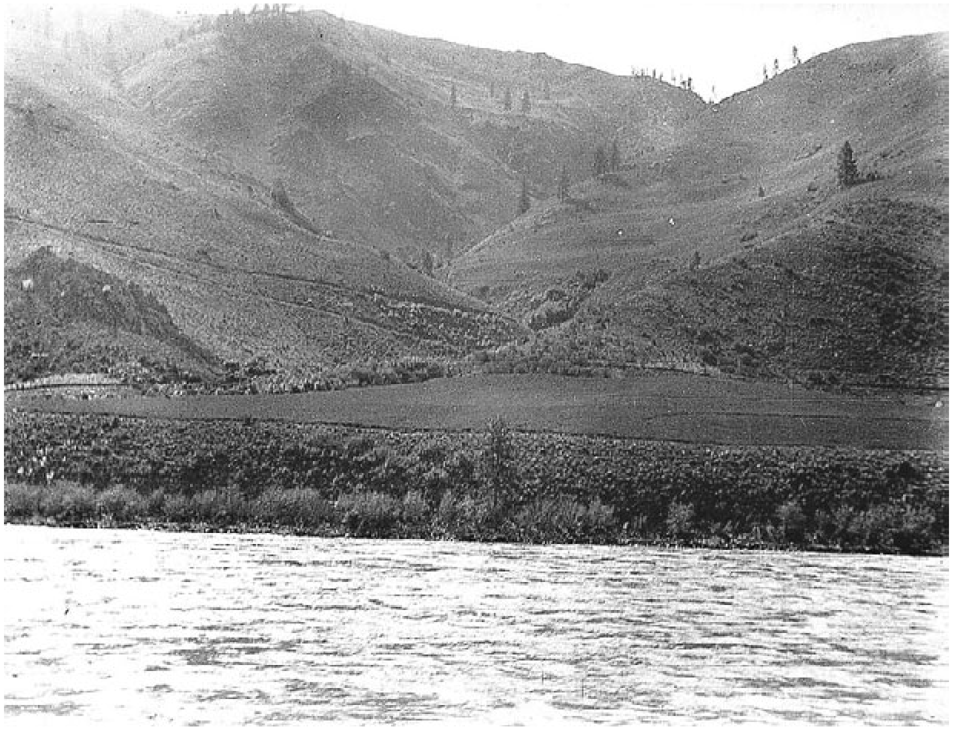
August 1999. Photograph of the inundation of river terraces near Hells Canyon Reservoir (photograph by J.H. Braatne). Upland and riparian habitats appear similar to pre-dam conditions, although the areal extent of hackberry, thornberry, and serviceberry (*Amelanchier alnifolia*) have increased significantly. The road on the upper right side of the 1999 photograph was not present in 1953.

Series 14. (OX-3b) Looking upriver toward the tip of the oxbow.

August 22, 1955. Aerial view of the oxbow. As the river flows through the oxbow, sandbars, islands, and low-elevation river terraces are common. Riparian habitats consist of a scattered fringe of hackberry and sandbar willow. Islands and sandbars appear to be barren.

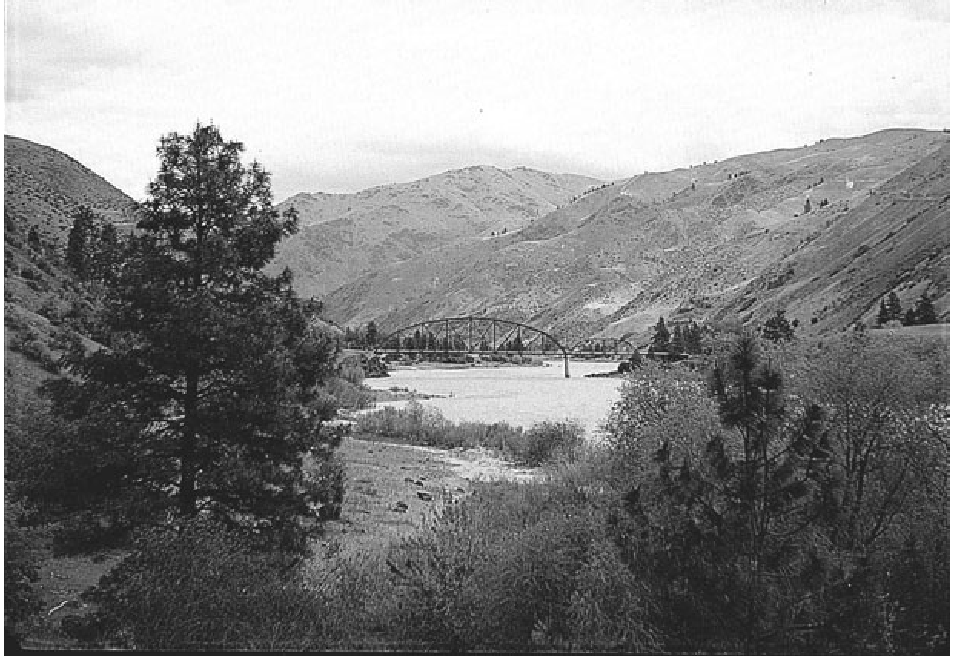
August 9, 1997. Aerial views of the oxbow. Sandbars, islands, and river terraces have been inundated by reservoir operations. Riparian habitats are limited to a fragmented fringe of hackberry.

Series 15. (OX-1 to 3) Aerial views of the oxbow.



1950 (?). Photograph of the riverbank below Kleinschmidt Grade, near the present location of Hells Canyon Park (photograph by Eugene Antz). A narrow, continuous band of sandbar willow is growing along the lower riverbank, with sagebrush steppe vegetation on the upper riverbank and surrounding canyon slopes. A cultivated field (alfalfa, grasses, or grains) is on the adjacent river terrace.

Series 16. (HC-1) Below Kleinschmidt Grade.



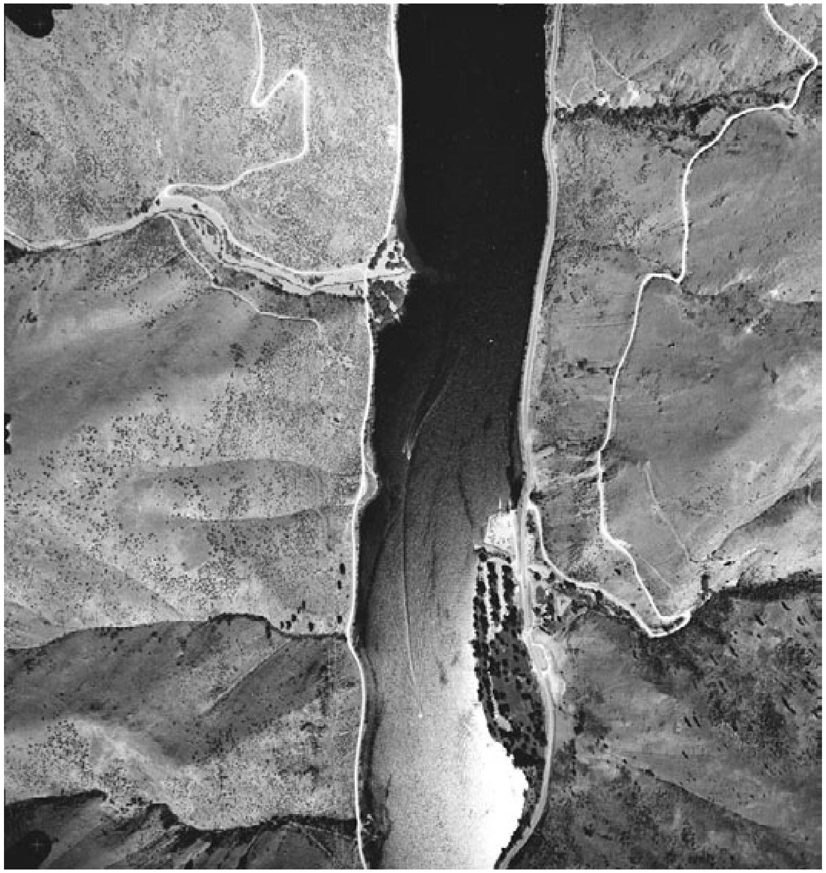
August 1953. Photograph of large stands of sandbar willow with scattered pine and hackberry below Ballard Bridge (photograph by F.R. McCormick).

Series 17. (HC-2) Ballard Bridge/Hells Canyon Park.

September 1999. Views of the reservoir corridor below Hells Canyon Park (photographs by J.H. Braatne). Former river terraces and riparian habitats have been inundated, with shrub communities composed of hackberry, Himalayan blackberry (*Rubus discolor*), serviceberry, and false indigo along reservoir shorelines. Large trees in the background are associated with Hells Canyon Park and private residences.

Series 17. (HC-2) (Cont.).

May 8, 1959. Aerial view of Kleinschmidt Grade and the Ballard Bridge crossing of the Snake River. Islands, sandbars, and terraces associated with alluvial fans of side tributaries are common throughout this reach. Islands generally do not appear to support riparian vegetation. Only a fragmented fringe of hackberry is visible along the river channel.



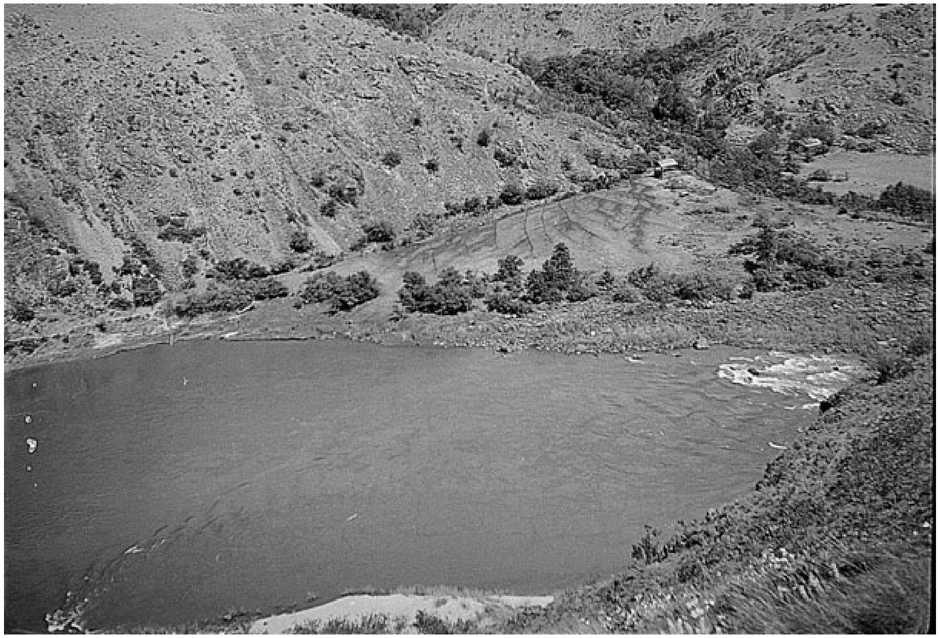
August 9, 1997. Aerial view of Hells Canyon Park and associated reservoir corridor. Islands, sandbars, and alluvial fans have been inundated. Upland habitats end abruptly, with scattered patches of hackberry visible at the reservoir shoreline.

Series 18. (HC-1 to 2) Aerial views of the Hells Canyon corridor associated with Kleinschmidt Grade/Hells Canyon Park.

August 1953. Photograph of the lower reach and alluvial fan of McGraw Creek (photograph by F.R. McCormick). White alder dominates the lower reach, with scattered hackberry and sandbar willow on the alluvial fan adjacent to the Snake River. The riverbank is composed of fines to fine-cobble and bedrock.

September 1999. Photograph of the confluence of McGraw Creek with the Hells Canyon Reservoir corridor showing inundation of the alluvial fan (photograph by J.H. Braatne). A flood-related debris flow during winter 1997 scoured McGraw Creek, removing all riparian vegetation along the lower reach of this creek. Shoreline substrates consist of cobble and bedrock.

Series 19. (HC-3) McGraw Creek confluence with the Snake River/Hells Canyon Reservoir.

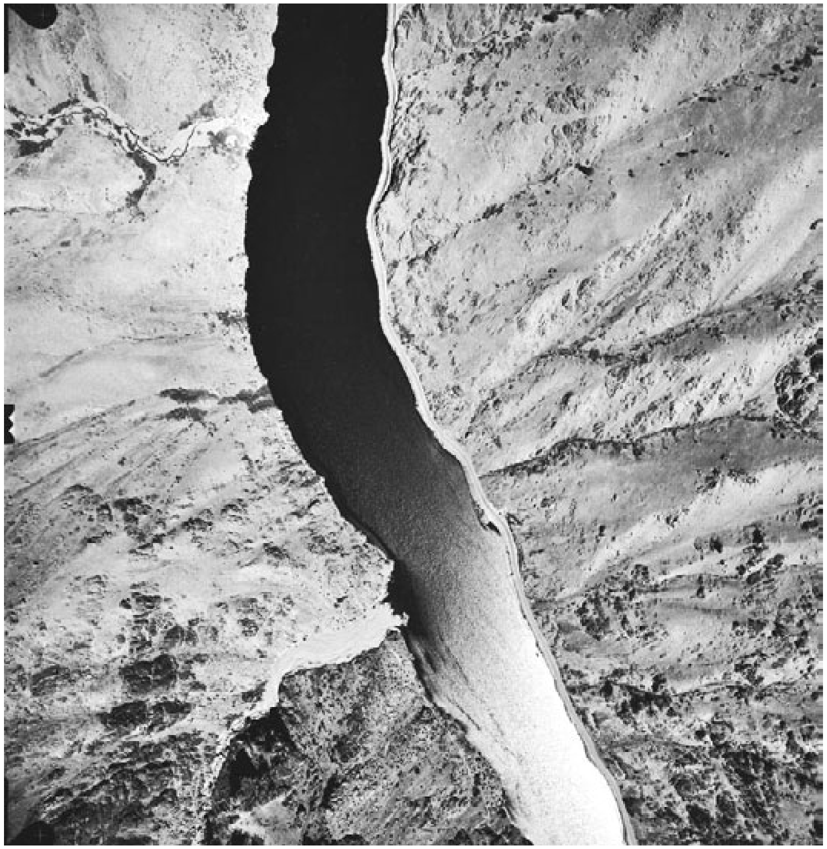


August 1953. Photograph of the lower reach and alluvial fan of Spring Creek (photograph by F.R. McCormick). White alder dominates the lower reach, with scattered hackberry and sandbar willow on the alluvial fan adjacent to the Snake River. The riverbank consists of fines to fine-cobble and bedrock.

September 1999. Photograph of the confluence of Spring Creek with the Hells Canyon Reservoir corridor showing inundation of the alluvial fan (photograph by J.H. Braatne). In contrast to McGraw Creek and other small tributaries, some white alder and pine along Spring Creek appear to have survived the 1997 debris flow. The shoreline consists of cobble and bedrock substrates and limited vegetation.

Series 20. (HC-4) Spring Creek confluence with the Snake River/Hells Canyon Reservoir.

August 22, 1955. Aerial view of the Snake River corridor near McGraw and Spring Creeks. This corridor is noted for steep canyon walls with scattered sandbars and alluvial fans. The riparian zone is limited to scattered fragments of hackberry. Riparian stands of white alder along Spring Creek are much more extensive than those along McGraw Creek.



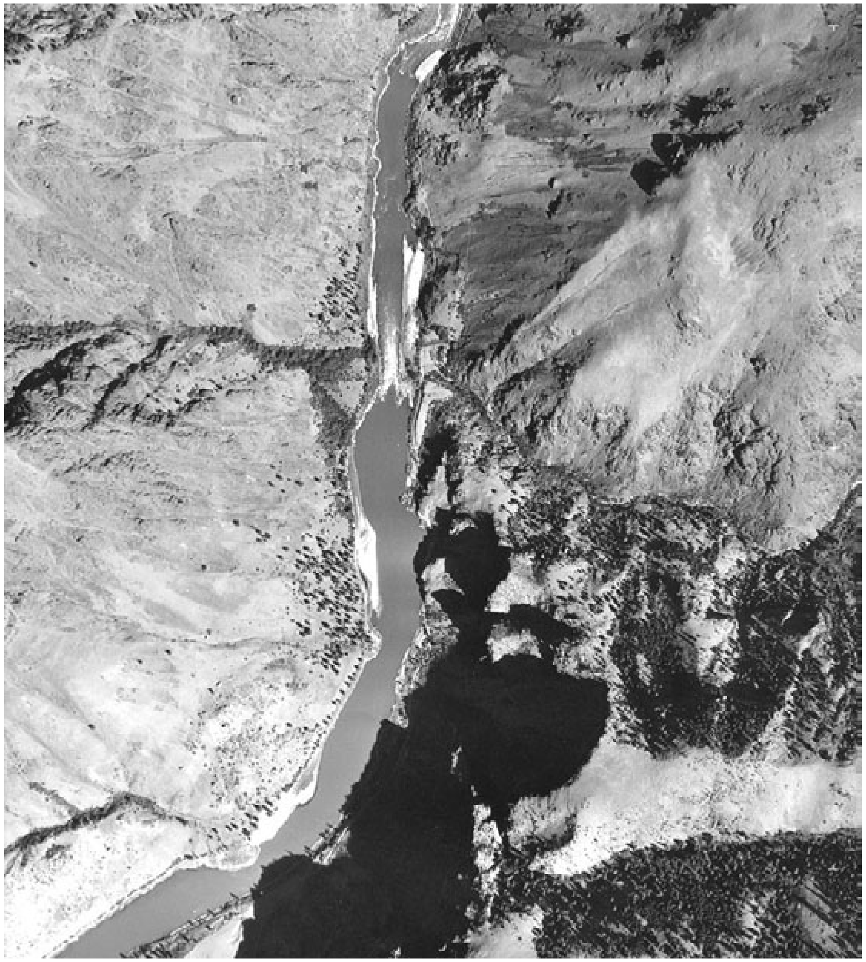
August 9, 1997. Aerial view of the confluence of Spring and McGraw Creeks with the Hells Canyon Reservoir corridor. The reservoir inundated sandbars and alluvial fans associated with these side tributaries, along with other fluvial and channel features. The areal extent of storm-related debris flows can be seen along the lower reaches of Spring and McGraw Creeks. Higher coverage of riparian habitats along Spring Creek appears to be related to higher summer base flows than McGraw Creek experiences.

Series 21. (HC-3 to 4) Aerial views of the confluence of McGraw and Spring Creeks with the Snake River.

1953. Photograph of Kinney Creek Rapids showing a diverse mosaic of riparian and upland habitats (photograph by P. Basche). White alder dominates the lower reaches of Lynch Creek (Oregon) and the alluvial fan of Kinney Creek (Idaho), with a fragmented fringe of hackberry and sandbar willow growing along the river. An extensive stand of pine can be seen along the Oregon side of the river that gradually transitions upslope to sagebrush steppe communities on the steeper canyon slopes. Riverbanks are composed of fine, to cobble and bedrock substrates. Separation bars and channel-margin sandbars are visible below the rapids.

1999. Photograph of the confluence of Kinney Creek with the reservoir corridor showing inundation of the riparian habitats associated with alluvial fans, riverbanks, and sandbars (photograph by J.H. Braatne). The stand of pines has been inundated, with Himalayan blackberry being the dominant shrub growing along the shoreline. The steep shorelines consist of bedrock and cobble substrates.

Series 22. (HC-5) Kinney Creek Rapids.



August 22, 1955. Aerial view of the Snake River corridor near Kinney Creek. Alluvial fans and sandbars, along with scattered hackberry and pine, are common throughout this reach.

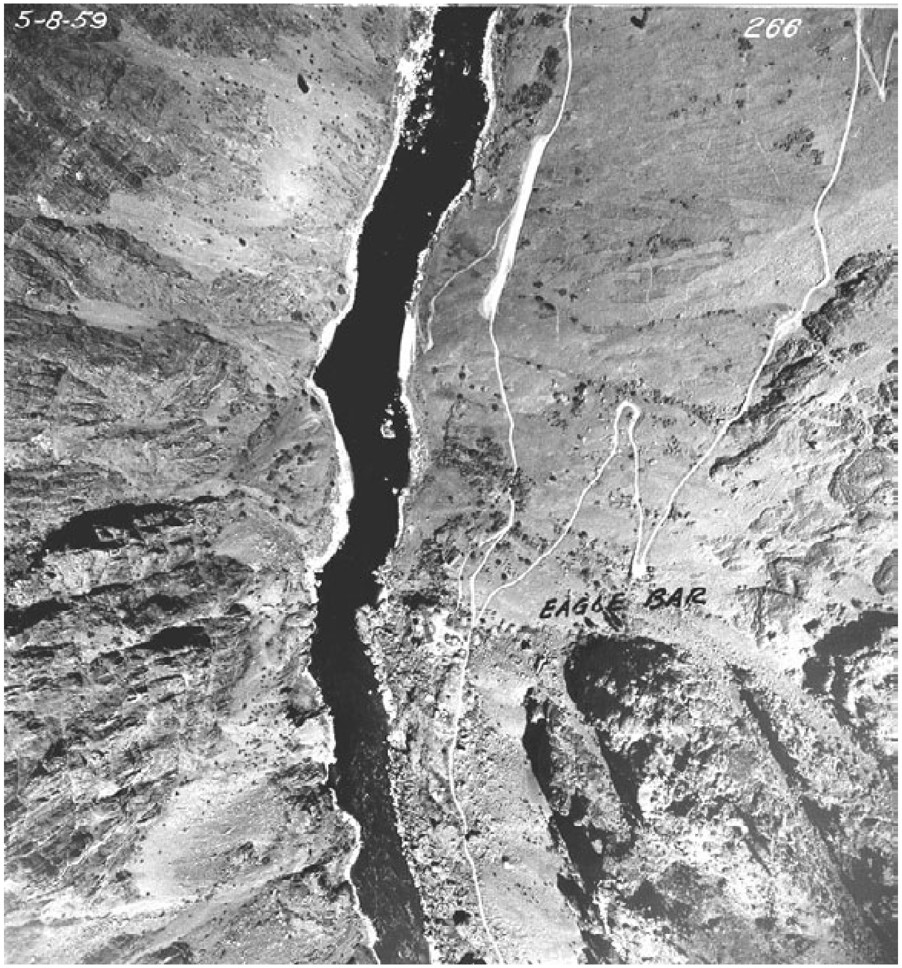
August 9, 1997. Aerial view of the reservoir corridor near Kinney Creek showing inundation of alluvial features and scattered stands of pine and hackberry. Himalayan blackberry dominates the shrubs growing along the reservoir shoreline.

Series 22. (HC-5) (Cont.).

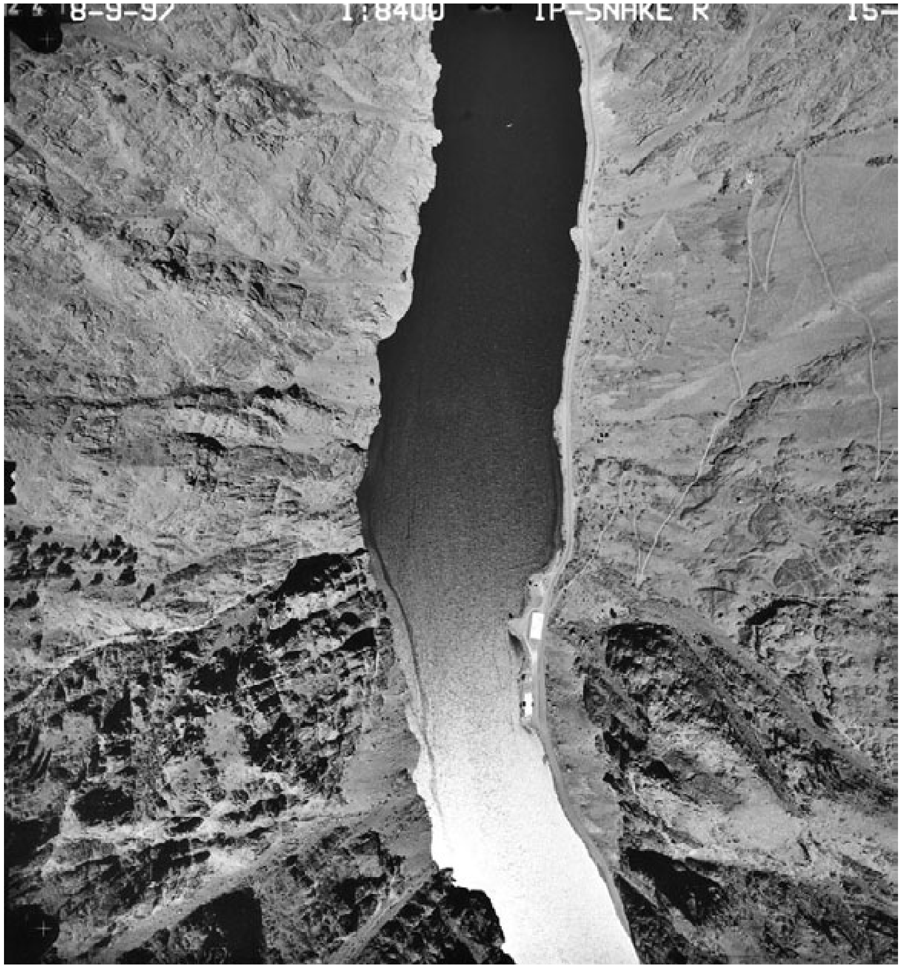
August 1953. Photograph of the Snake River corridor near Eagle Bar Landing (photograph by F.R. McCormick). Steep canyon walls extend downslope to sparsely vegetated riverbanks of bedrock and cobble.

September 1999. Photograph showing inundation of low-elevation bedrock formations. Sparsely vegetated slopes appear similar to pre-dam conditions (photograph by J.H. Braatne).

Series 23. (HC-6) Eagle Bar Landing.

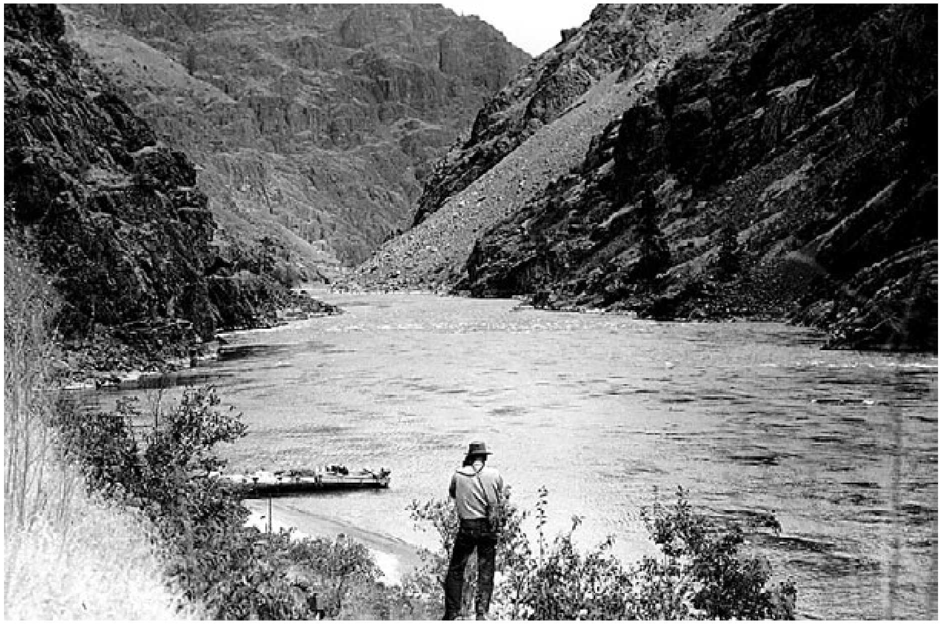


May 8, 1959. Aerial view of Eagle Bar. Steep canyon walls and riverbanks are sparsely vegetated. Sandbars are limited throughout this reach.



August 9, 1997. Aerial view of the steep canyon walls associated with the reservoir corridor near Eagle Bar. Steep upland habitats extend downward to reservoir shorelines.

Series 23. (HC-6) (Cont.).

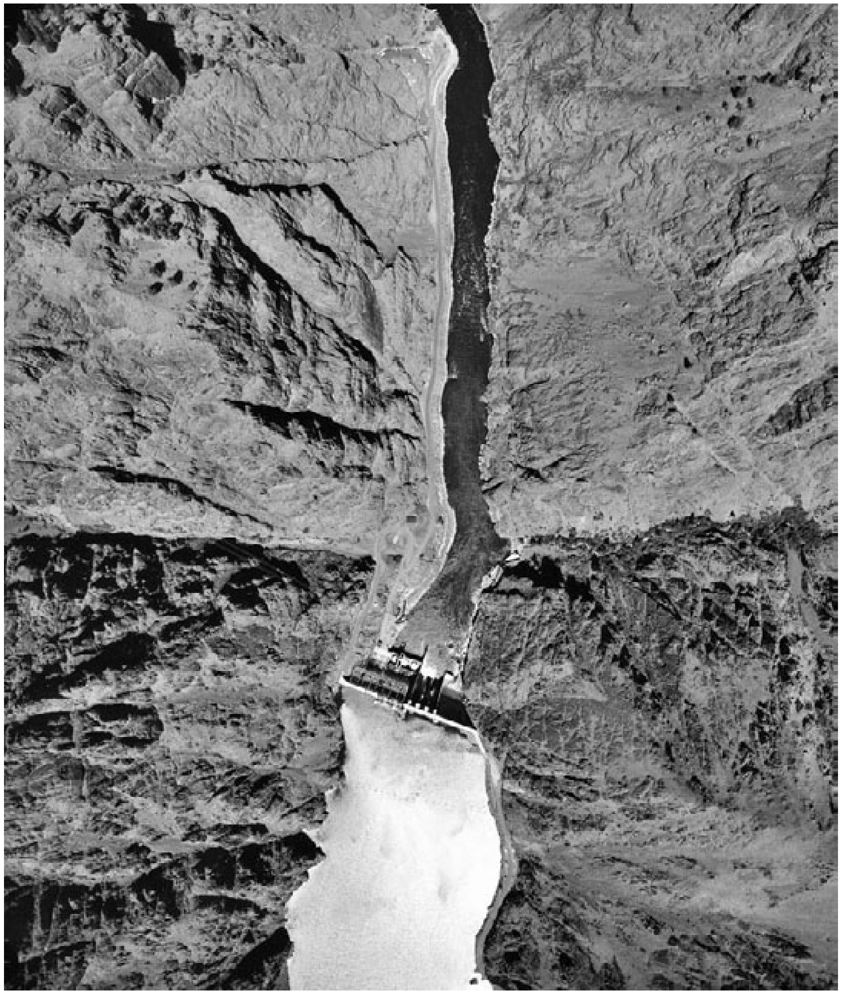


1951. Photograph of the Snake River corridor between Deep and Hells Canyon Creeks (photograph by P. Basche). This reach has steep canyon walls with bedrock and talus slopes. The riparian zone is limited, though some hackberry and serviceberry are growing above a small side-channel bar with pines scattered along the base of talus slopes.

September 1999. Photograph of the Snake River corridor between Deep and Hells Canyon Creeks (photograph by J.H. Braatne). This reach is now directly below Hells Canyon Dam. The banks on the Oregon side of the river have been heavily armored with revetments, whereas the Idaho side of the river does not differ from pre-dam conditions and features a riverbank composed of cobbles, boulder, and bedrock.

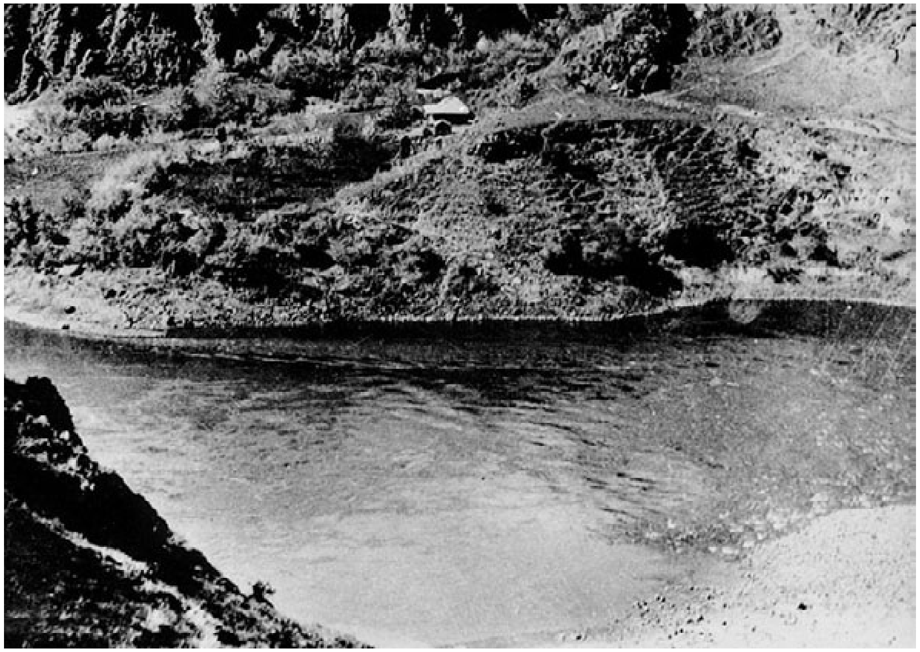
Series 24. (SR-1) Deep Creek to Hells Canyon Creek.

August 22, 1955. Aerial view of the deep confined canyon between Deep and Hells Canyon Creeks. Steep, rocky canyon walls and talus slopes limit sediment deposition and riparian habitats along this reach.



August 9, 1997. Aerial view of the corridor between Deep and Hells Canyon Creeks. Channel morphology and shoreline conditions appear similar to those in the earlier aerial photograph. Steep canyon walls promote sediment transport through the reach.

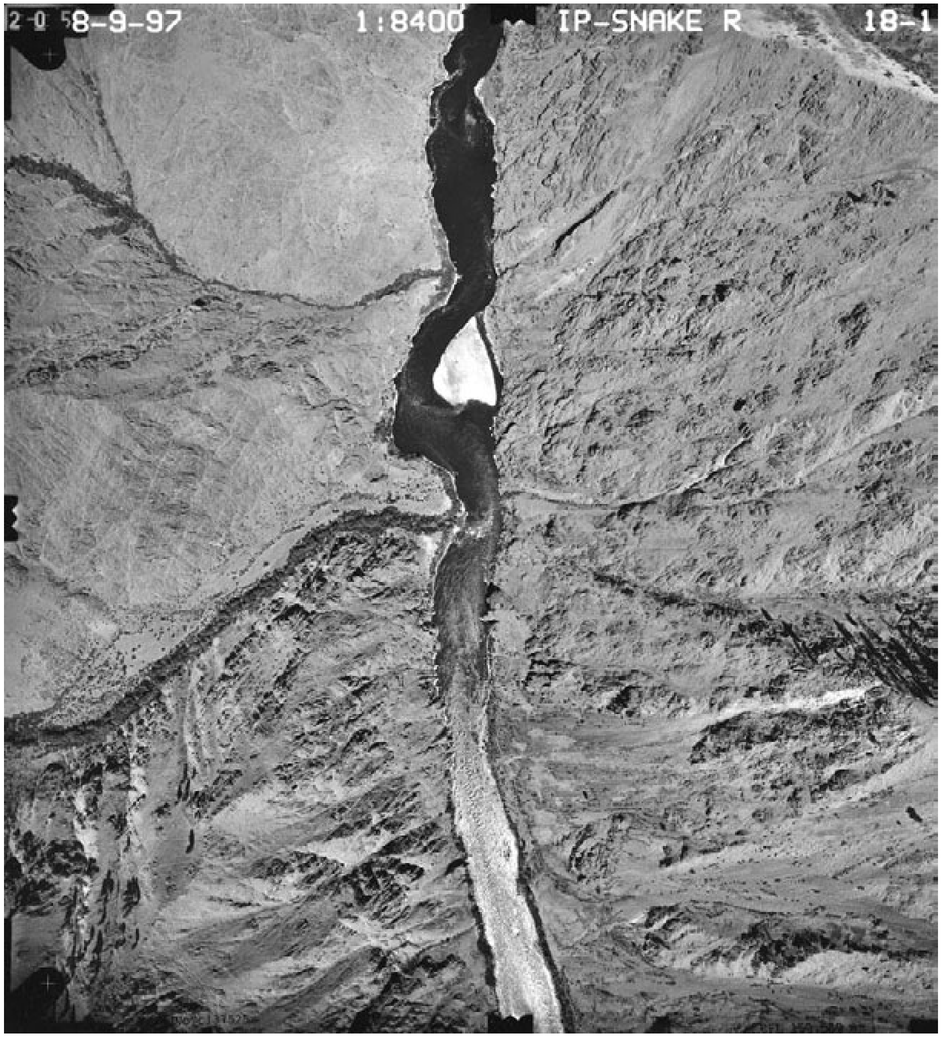
Series 24. (SR-1) (Cont.).



1934. Photograph of the lower reach and alluvial fan of Saddle Creek (Edith Wilson, HCNRA photograph collections). The lower reach and alluvial fan have been largely cleared of white alder and other woody vegetation. Some scattered hackberry and willow remain on portions of the alluvial fan. The riverbank consists of cobble and bedrock..

September 1999. Photograph of the alluvial fan of Saddle Creek showing a diverse, dense stand of riparian woody vegetation (photograph by C.L. Blair). Riparian vegetation is dominated by white alder, with hackberry and other shrubs growing along the margins of the alluvial fan. The riverbank consists of cobble and bedrock.

Series 25. (SR-2) Confluence of Saddle Creek with the Snake River.



No pre-dam aerial photograph of this reach is available at this time.

August 9, 1997. Aerial view of the confluence of Saddle Creek with the Snake River.

Series 25. (SR-2) (Cont.).

December 1953. Photograph of Johnson Bar showing a widely scattered riparian fringe of hackberry and channel-margin sandbars (photograph by F.R. McCormick). The broad, sloping terraces adjacent to the river are deposits related to the Bonneville Flood (14,500 years ago). Riverbanks consist of fines to cobble and bedrock.

September 1999. Photograph of Johnson Bar showing a continuous riparian fringe of hackberry (photograph by J.H. Braatne). The relative growth rate of hackberry during the last 50 years can be seen by comparing the size of individual trees growing along the river's edge and on top of the adjacent terraces. (In this comparison, also note that the earlier photograph was taken during winter). Fine sands have eroded from the channel-margin sandbars, and riverbanks consist of fine-cobble to bedrock. A close-up photograph shows the general pattern of downslope expansion by hackberry root suckers. This downslope expansion may be related to the lack of extreme scouring flows (for example, the 120,000-cfs peak flow at the Weiser gauge in 1910) associated with the filling and operation of the American Falls Reservoir (1927) and other water developments upriver from the HCC.

Series 26. (SR-3) Upriver overview of Johnson Bar.

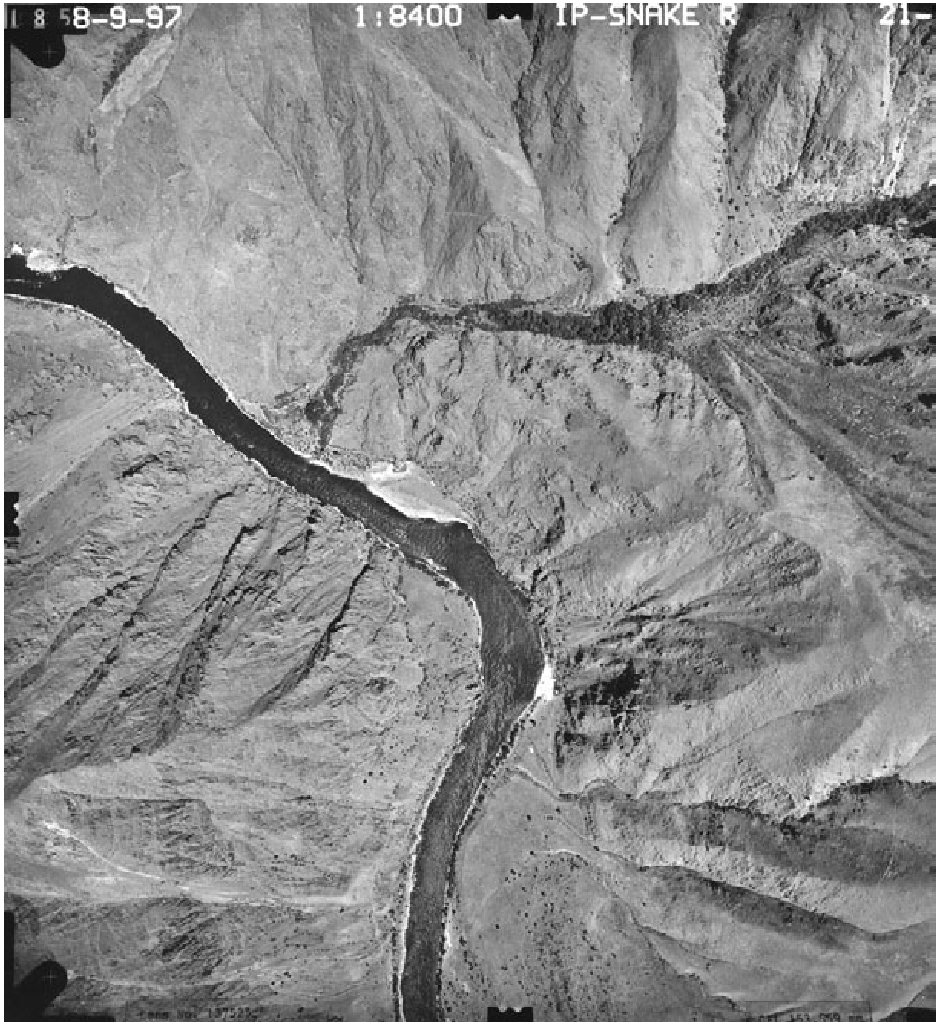
September 1999. A close-up photograph of Johnson Bar showing the general pattern of downslope expansion by hackberry root suckers. This downslope expansion may be related to the lack of extreme scouring flows (for example, the 120,000-cfs peak flow at the Weiser gauge in 1910) associated with the filling and operation of the American Falls Reservoir (1927) and other water developments upriver from the HCC.

Series 26. (SR-3) (Cont.).

December 1953. Photograph of Sheep Creek Rapids showing scattered pines and hackberry, with fine sand to coarse gravel along the channel margin (photograph by F.R. McCormick). Some form of agricultural activity (hay or pasture) is evident along the lower terrace (alluvial fan and Bonneville Flood deposits). The alluvial fan of Sheep Creek (see background) also lacks woody riparian vegetation.

September 1999. Photograph of Sheep Creek Rapids showing an increase in the growth and canopy development of hackberry (photograph by J.H. Braatne). Compare the height and size of hackberry relative to the small pine tree in the foreground of the 1953 photograph; this pine tree is almost completely obscured by hackberry in the 1999 photograph. Regrowth of white alder and associated shrubs can also be seen along the alluvial fan of Sheep Creek. Fine sands have eroded from the channel-margin sandbars. The riverbanks consist of fine-cobble to bedrock.

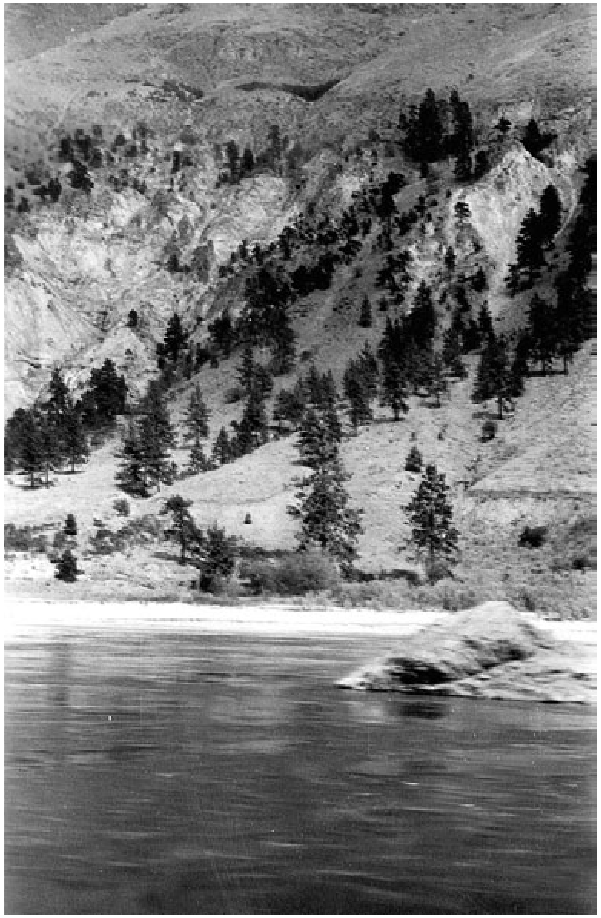
Series 27. (SR-4) Downriver overview of Sheep Creek Rapids.



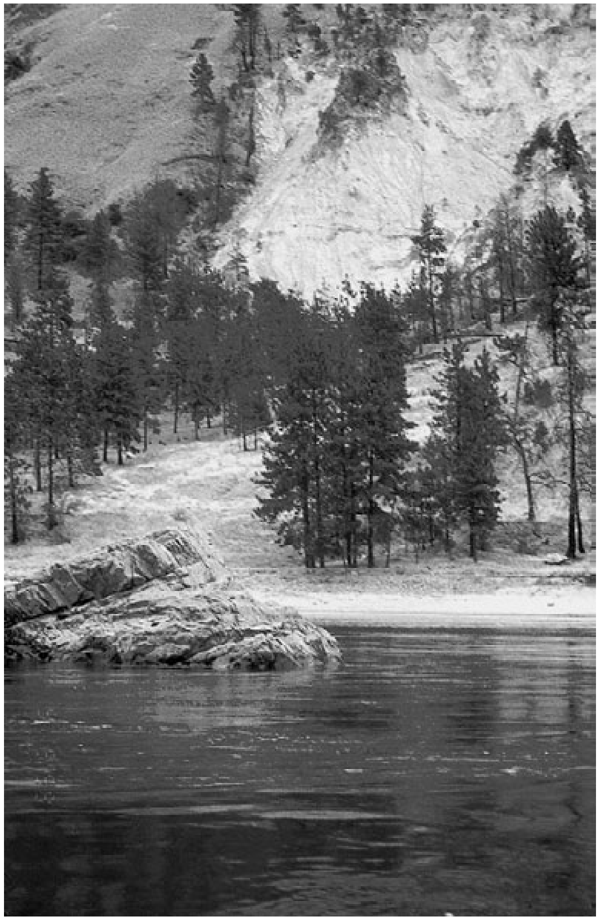
No pre-dam aerial photograph is available at this time.

August 9, 1997. Aerial view of the confluence of the Salmon River with the Snake River.

Series 28. (SR-3 to 4) Aerial views of Johnson Bar and Sheep Creek Rapids.



1930s to 1940s. Photograph of Sturgeon Rock and Alum/Pine Bar (Pickett, WSU Special Collections). The large sandbar supports a stand of sandbar willow, with some hackberry upslope from the bar. The riverbank consists of fine sands. Scattered pines and sagebrush steppe vegetation are growing on the lower canyon walls.



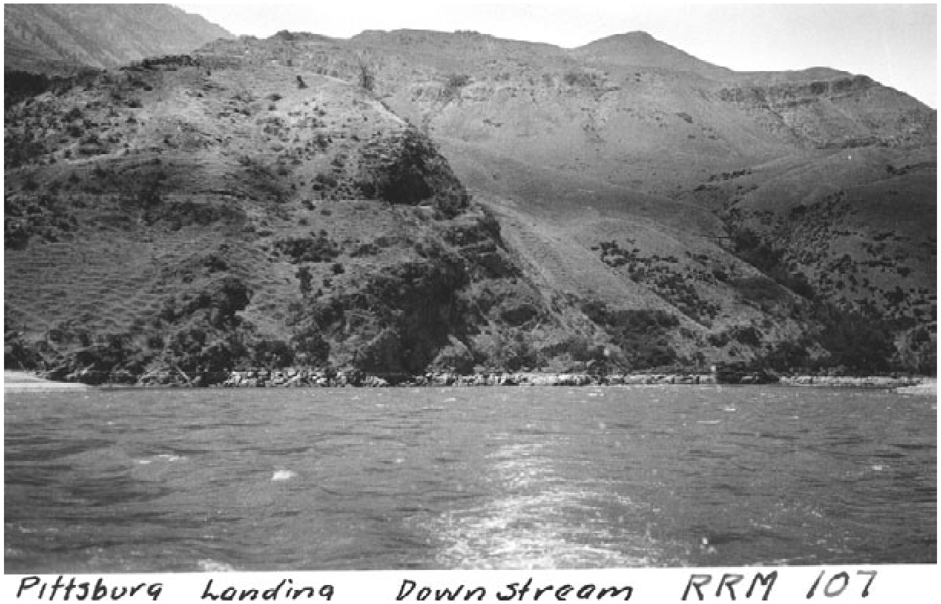
September 1999. Photograph of Sturgeon Rock and Alum/Pine Bar showing sandbar erosion and the loss of sandbar willow and hackberry. The riverbank consists of fine sands (photograph by J.H. Braatne). A recent fire appears to have burned through some of the pines growing along the canyon walls.

Series 29. (SR-5) Sturgeon Rock and Alum/Pine Bar.

No pre-dam aerial photograph is available at this time.

August 9, 1997. Aerial view of the Alum/Pine Bar corridor.

Series 29. (SR-5) (Cont.).



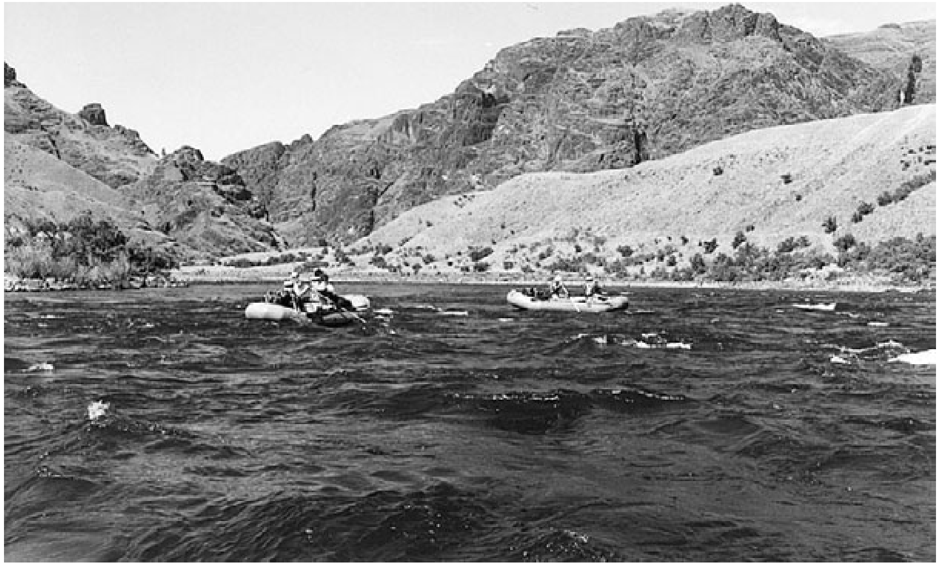
1928 to 1929. Photograph of the riverbank opposite from Pittsburg Landing (Van Aardsel, WSU Special Collections). Steep upland slopes of sagebrush steppe vegetation drop abruptly to the edge of the river. Scattered hackberry is growing along the steep rocky banks and draws. Bright high-water marks are visible on the rocks adjacent to the river. The riverbanks consist of cobble and bedrock.

Note: R.R.M. is Railroad River Mile, as measured by Van Aardsel. It has no consistent relationship with river miles.

1999. Photograph of the riverbank opposite from Pittsburg Landing (photograph by J.H. Braatne). No apparent changes are visible in vegetation or shoreline conditions. The high-water mark appears at a similar river stage. A moderate increase in shrub coverage is associated with seeps and draws; much of this expansion by shrubs is related to the colonization and growth of Himalayan blackberry.

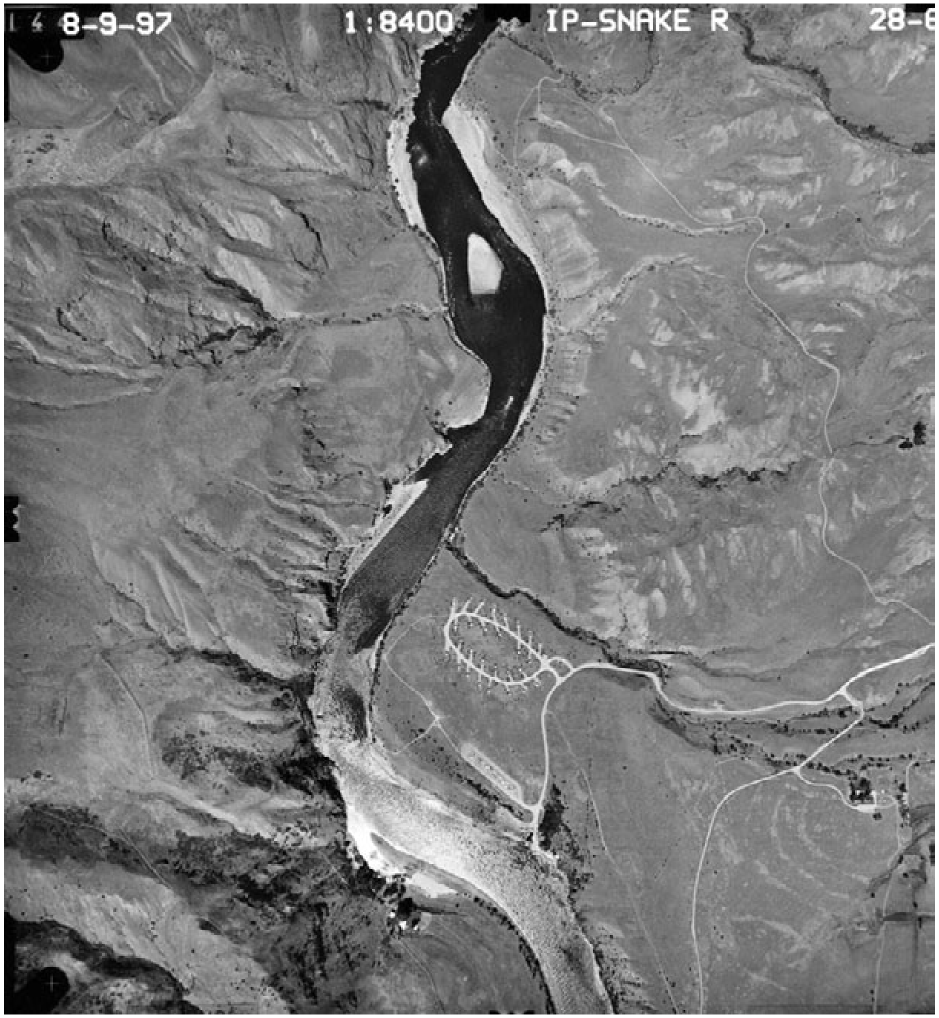
Series 30. (SR-6) Downriver view of the Snake River at Pittsburg Landing.

December 1953. Photograph of the riverbank adjacent to lower Pittsburg Landing (photograph by F.R. McCormick). The riparian zone is limited to a few hackberry growing at the toe slope of Bonneville Flood depositions (14,500 years ago). Riverbanks consist of cobble substrates



September 1999. Photograph of the riverbank adjacent to lower Pittsburg Landing (photograph by J.H. Braatne). The riparian fringe of hackberry has expanded significantly, and a healthy stand of sandbar willow can be seen growing along the Oregon side of the river. Riverbanks are composed of cobble substrates.

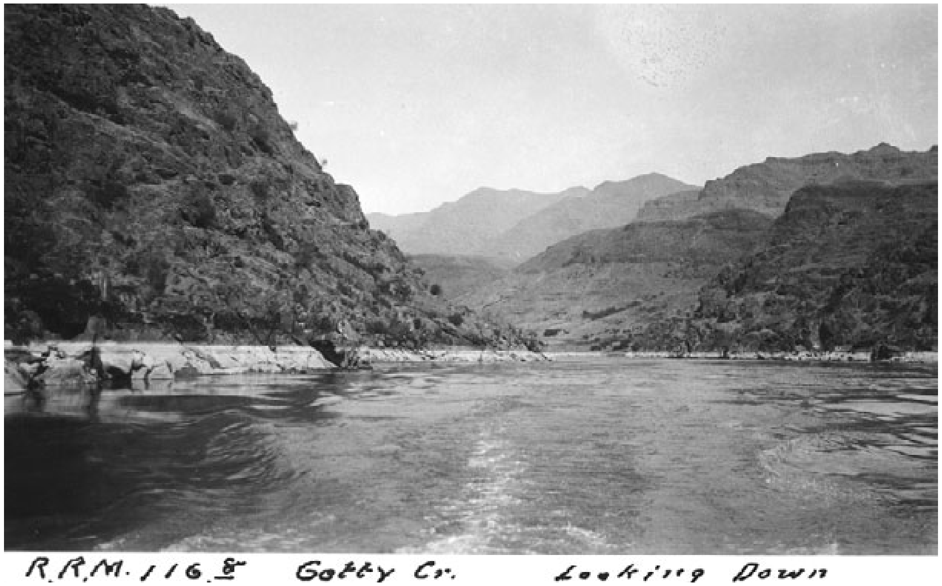
Series 31. (SR-7) Downriver view of the Snake River at lower Pittsburg Landing.



No pre-dam aerial photograph is available at this time.

August 9, 1997. Aerial view of lower Pittsburg Landing.

Series 32. (SR-6 to 7) Aerial views of the Snake River at Pittsburg Landing.



1928 to 1929. Photograph looking downriver toward High Range and Getta Creeks (Van Aardsel, WSU Special Collections). The steep, rocky riverbanks and canyon walls support only a few upland shrubs and grasses. Seasonal high-water marks can be seen along the lower riverbanks.

September 1999. Photograph of the Snake River looking downriver toward High Range and Getta Creeks (photograph by J.H. Braatne). No significant differences in vegetation or shoreline conditions are apparent from the historic photograph. The high-water marks appear at a similar river stage.

Series 33. (SR-8) Downriver view of High Range and Getta Creeks.

No pre-dam aerial photograph is available at this time.

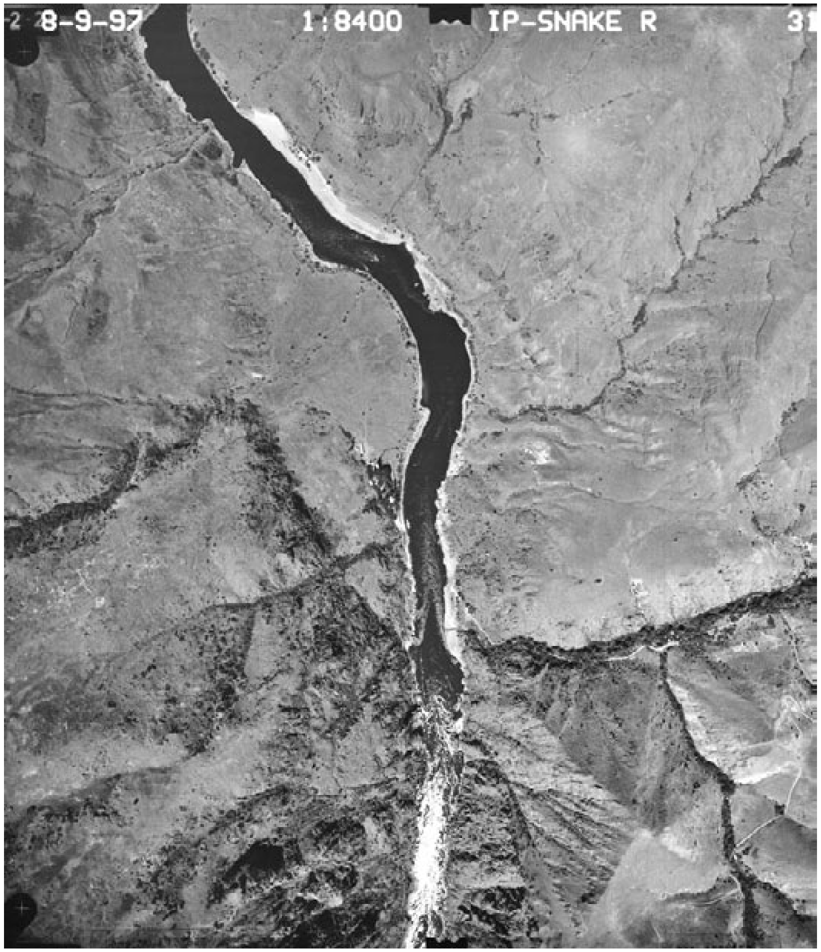
August 9, 1997. Aerial photograph of the Snake River corridor between High Range and Getta Creeks.

Series 33. (SR-8) (Cont.).

1928 to 1929. Photograph looking downriver toward Ragtown Bar showing an open valley with very sparse riparian vegetation (Van Aardsel, WSU Special Collections). Only a few scattered hackberry are visible along the upper riverbanks. Substrates consist of fine-cobble to bedrock.

September 1999. Photograph looking downriver toward Ragtown Bar (photograph by J.H. Braatne). There are no significant differences in vegetation or shoreline conditions. Riverbanks consist of cobble and bedrock. Hackberry appears to have grown somewhat larger during the last 70 years.

Series 34. (SR-9) Ragtown Bar area.



No pre-dam aerial photograph is available at this time.

August 9, 1997. Aerial photograph of the Ragtown Bar corridor.

Series 34. (SR-9) (Cont.).

1928 to 1929. Photograph of the basalt columns and talus slopes on the banks opposite from Dug Bar (Van Aardsel, WSU Special Collections). Only a few scattered hackberry and upland shrubs and grasses are growing along the lower talus slopes. Riverbanks consist of cobble substrate.

September 1999. Photograph of the Dug Bar basalt columns (photograph by J.H. Braatne). Vegetation and shoreline conditions are comparable to those in the earlier photograph. Riverbanks consist of cobble substrate.

Series 35. (SR-10) Basalt columns at Dug Bar.

August 3, 1955. Aerial view of Dug Bar. The reach just upriver from Dug Bar is highly constrained by steep canyon walls. The canyon opens as the river flows by Dug Bar, a broad terrace derived from Bonneville Flood deposits (14,500 years ago). Channel-margin sandbars appear common along the Dug Bar corridor. Woody riparian vegetation is limited to a few scattered hackberry.

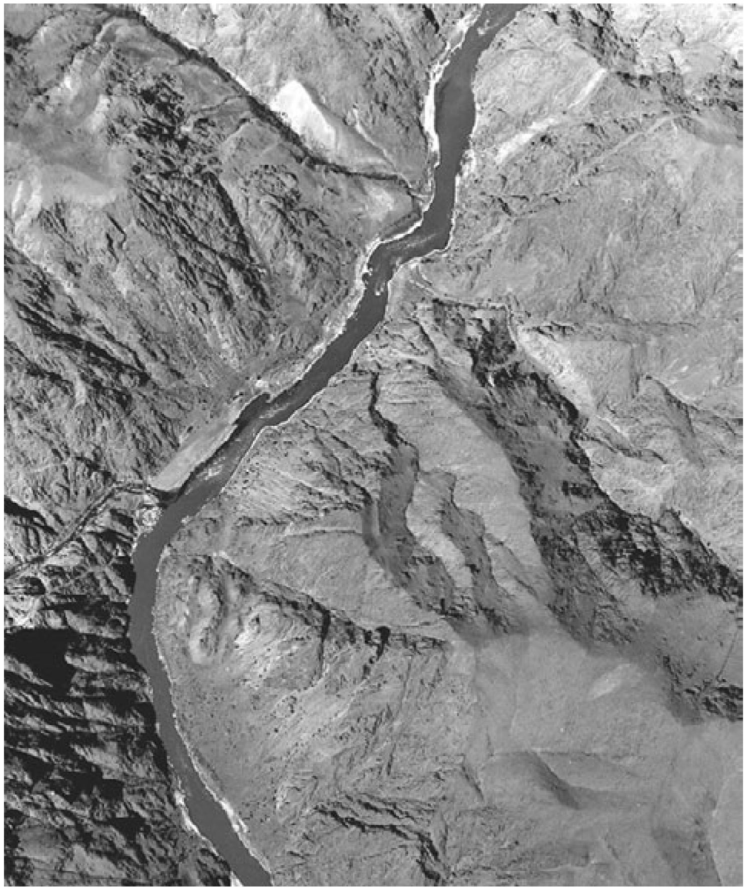
August 9, 1997. Aerial view of Dug Bar. Channel morphology is similar, yet it now lacks channel-margin sandbars. The margins of the river channel thus appear to be less jagged and more smooth. The areal extent of hackberry has increased slightly along the reach.

Series 35. (SR-10) (Cont.).

19??. Photograph of the Imnaha steamboat docked at Eureka Bar showing sparsely vegetated rocky slopes and sandbars in protected channel margins. The riverbanks consist of fine sands to bedrock (Nez Perce Historical Society, John Miller Collections).

September 1999. Photograph of rafting party landed at Eureka Bar (photograph by J.H. Braatne). Canyon walls support only a limited amount of plant cover. A healthy stand of sandbar willow is growing along the upper margin of Eureka Bar. Riverbanks consist of fine sands to bedrock.

Series 36. (SR-11) Eureka Bar/Imnaha Landing.



August 3, 1955. Aerial view of the corridor between Imnaha and Eureka Bars. The channel is highly confined by steep canyon walls, although small channel-margin sandbars are common. Hackberry and other woody riparian vegetation are scarce.

August 9, 1997. Aerial view of corridor between Imnaha and Eureka Bars. Channel morphology is similar though the areal extent of channel-margin sandbars (for example, Eureka Bar) has decreased. The edges of the river channel thus appear to be less jagged and more smooth. Areal extent of hackberry and other woody vegetation remains extremely limited.

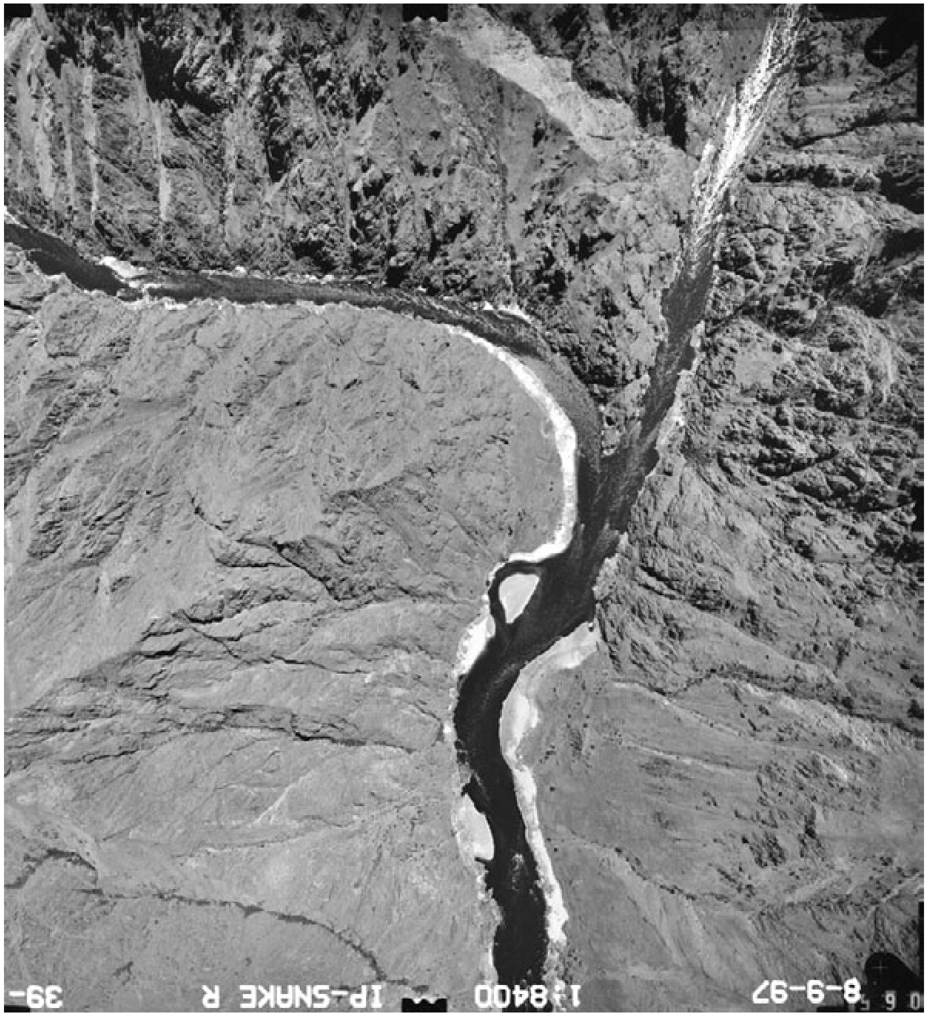
Series 36. (SR-11) (Cont.).

1928 to 1929. Photograph of the corridor just upriver from the confluence of the Snake and Salmon Rivers (Van Aardsel, WSU Special Collections). This reach has very steep canyon walls and lacks riparian vegetation. The riverbanks consist of bedrock and boulders. High-water marks are readily visible along the riverbank.

September 1999. Photograph of the corridor just upriver from the confluence of the Snake and Salmon Rivers (photograph by J.H. Braatne). There are no apparent differences in vegetation or shoreline conditions from the earlier photograph. Riverbanks consist of boulders and bedrock. High-water marks appear at a similar river stage.

Series 37. (SR-12) Upriver of the confluence of the Snake and Salmon Rivers.

No pre-dam aerial photograph is available at this time.



August 9, 1997. Aerial view of corridor upriver from the confluence of the Snake and Salmon Rivers.

Series 37. (SR-12) (Cont.).

Appendix 1

Snake River Hells Canyon Study Area, Idaho General Land Office Records

This page left blank intentionally.

The Greater Hells Canyon Area Project

Explanation of General Land Office Records
Brief Historical Context of Settlement, Land Use
Madeline Buckendorf, The Arrowrock Group
November 12, 1999

AN EXPLANATION OF THE GENERAL LAND OFFICE RECORDS

Between 1860 and 1915, The General Land Office (precursor of the Bureau of Land Management) completed the initial cadastral surveys across Idaho. These surveyors were establishing the township system in advance of transferring lands into private ownership through various federal land claims acts (Homestead Act, Timber and Stone Act, Timber Claims, Desert Land Entry, etc.). During their travels, surveyors took notes on the following items: types of soil, general topography, existence of timber, types of plant undergrowth, locations of roads and creeks, extant homesteads and mines. The surveyors' notes and early maps include a wealth of information for those trying to discern both the physical and cultural landscapes of the time these surveys were conducted.

Idaho General Land Office (hereafter GLO) surveys were started first at Initial Point near Kuna in the 1860s. Surveys were conducted first in the areas where there was the most demand for them, and then were carried on as money was available to conduct them at the time. Thus, the Olds Ferry area is where the first townships were established in the study area, because they were settled earlier than other parts of the greater Snake River-Hells Canyon country and were easily accessible. Inaccessible areas in the wilderness were not usually done first because of money shortages, lack of demand, or lack of proper equipment to survey the remote sites. For example, some sections of a township may have been partially surveyed in 1870 until money ran out or the next sections were too difficult to survey. The rest of the township may not have been surveyed until 1907, when there was more money, demand, new equipment, or cooperative funding available from the Forest Service or the BLM. The earliest surveyors wrote down more details about plants and trees than did later surveyors (after 1900).

Only the state offices of the BLM, at least in Oregon and Idaho, hold the GLO survey records on microfiche. The records are arranged according to township and range, so researchers must have this information before they can access the records. A card is provided with a small map of the township, range, and sections. The sections are outlined in different colors according to survey date and storage volume. The sections also have page numbers indicating where in the volume notes the sections are located. Some townships may have had as many as seven different surveys done at seven different times; these are not resurveys of the same area. The researcher is given microfiche of the volumes related to the earliest surveys done and the sections desired. The researcher must then locate the surveyors' notes and read them to find the needed information. Photocopies of these notes cost $1.10. (Note: I have a laptop computer and just take notes on the appropriate sections, quoting them verbatim when it seems necessary.)

GREATER SNAKE RIVER-HELLS CANYON AREA
HISTORICAL CONTEXT OF SETTLEMENT

Post Exploration and Fur Trade--Beginnings of Permanent Settlement

Native peoples, explorers, and fur traders established the major transportation routes through Idaho to the Pacific Northwest. By the 1840s, Oregon Trail emigrants used Wilson Price Hunt's old trade route along the Powder River to the coast. In 1862, Tim Goodale established an alternate trail near Brownlee and Pine Creek, and the Brownlee Ferry was constructed to assist emigrants crossing the Snake River. In 1863, Rueben Olds built a ferry at Farewell Bend, bringing Oregon Trail through the Weiser Valley.

Permanent nonnative settlement of the greater Hells Canyon area came from three directions: northeast from Missouri, as Oregon Tail emigrants stopped and stayed along inviting rivers and valleys instead of continuing to the coast; from the West, as a "backwash" of Oregon Trail travelers returned to less settled (and rainy) lands; and from the Southwest, as California gold miners followed new strikes in Florence, Pierce, Baker City, and later the Boise Basin. In 1862 Levi Allen brought gold seekers from eastern Washington to the Snake and Salmon Rivers, through the future site of Pittsburg Landing. Their discovery of copper at White Monument brought floods of fortune hunters into the Seven Devils Mountains. Small ranches, stage stations, stores, hotels, and farms developed as disillusioned miners sought their livelihood from travelers and freighters passing through the area.

The majority of early settlers were Anglo-Americans of European descent, emigrating from southern and midwestern "border states" during the Civil War, such as Missouri and Kansas. After the war, former soldiers and young entrepreneurs went West to try their hand at mining; they came from Ohio, Illinois, Kentucky, Arkansas, Indiana, western New York, and western Pennsylvania. Chinese immigrants followed white miners to rework claims in the Hells Canyon area, but few stayed permanently. As ranching developed in the 1880s and 1890s, many Basque immigrants found work in the Snake River country as sheepherders. Small enclaves of other ethnic groups, such as Greeks, Italians, Rumanians, Japanese, and Mexicans came to the area working on the railroad between the 1880s and the 1920s. Only a few stayed permanently, working first as hired ranch hands or working on jobs in towns, eventually acquiring small farms or ranches.

A Sampler of Earliest Area Settlers, Settlement Dates and Their Places of Origin (if mentioned):

Payette and Weiser, along the Payette and Weiser Rivers near its Confluence with the Snake River--

David Bivens, 1862--born in Missouri, lived in Kansas, came on the Oregon trail in 1861. Went to mining camps near Union, Oregon. Came back to Boise Basin in 1862. Started a stage station near site of present-day Payette on the Payette River. Took up ranching in the late 1860's; brought large herd of cattle and dryland alfalfa seed from Mexico in 1870s.

Typical of many Payette and Weiser early settlers.

Olds Ferry--In 1863, Rueben Olds started a ferry and purchased a trading post near Farewell Bend. William and Nancy Logan came back from Oregon and started a road house at Olds Ferry in 1863.

Brownlee Creek--Jim Summers, early 1860s--born in Kentucky, prospected in California in the 1850s, then went to southern Oregon, then to Canyon City, Oregon, then to Pine Creek near Richland, Oregon in the 1860s. Prospected at Brownlee Creek; also helped locate Ruthburg and Heath veins in the 1870s. Summers buried on Cuddy Mountain's west slope.

Eureka Bar--M. E. Barton and Martin Hibbs, 1899--had one of the first claims at Eureka Bar, started a ranch nearby in 1899.

Pittsburg Landing--Settlers arrived in late 1870s. Previously an Indian winter camp. Mike Thomason established a ferry there after 1870s. Albert Kurry had interest in the operation. Kurry and George Woods early settlers on Idaho side of landing. In 1920s their lands became part of Circle C Ranch (Albert Campbell).

Mineral--Fahy Bros., 1886--ran ferry nearby called Sunnyside Ferry.

Bernard Creek, (T23N, R2W, Sec. 2, NW1/4), Jack Hastings, 1908--placer mined tributaries; series of sluices and dams.

Salt Creek, (T1N R50E, S254, NW 1/4), Frank Somer, 1870s--first placer mined at mouth of Salt Creek; diverted water from creek. Later mined what became known as Somars Creek. One of the first stockmen in Hells Canyon--homesteaded and squatted in the area.

Dug Bar, 1880, Thomas J. Douglas--mined there and raised cattle. Killed in 1883.

Kirkwood Creek, David Kirk, 1880s--later owned by Len B. Jordan.

Temperance Creek Ranch, Warnock brothers, 1882--brothers mined and ranched there.

Tulley Creek, J. H. Dobbin, 1890--Dobbin had ranch along creek, raised sheep for 50 years.

Cow Creek and Lightning Creek, Lower Imnaha Valley, 1878--two ranches started there that year. Later owned by J. W. McClaran, cattle rancher, in 1919.

Big Bar, John Eckles (Eccles) and Archibald Ritchie, 1888--also a traditional winter campsite for Native Americans. Eckles settled at Big Bar in 1888; homesteaded it. Raised hay, grain, fruit, garden. Water taken from Eckles Gulch. Small herd of cattle and horses.

Forest ranger Arthur V. Robertson noted in his 1909 report that "No timber on this land except for 3 or 4 scrubby bull pine trees down near the river bank." Ritchie born in Scotland, worked in New York City, was a Union soldier, went to Virginia. Headed to the Rocky Mountains in 1867; since 1887 placer mined and raised small garden near Eckles ranch. Later both of them operated Eckles ranch.

SNAKE RIVER-GREATER HELLS CANYON STUDY AREA
BUREAU OF LAND MANAGEMENT, IDAHO
GENERAL LAND OFFICE RECORDS, SURVEYORS' NOTES
MADELINE BUCKENDORF, THE ARROWROCK GROUP
NOV. 3, 1999

[Note: The Surveyors' notes are organized by township and range, moving downstream from Weiser to Hells Canyon Dam, T22N, R3W. Only the Idaho side of the river has been researched. The section numbers underlined are ones Jeff Braatne specifically requested for the photographs.]

T11N, R5W--Allen M. Thompson, 1870, Vol. 74:
Sec. 31 & 32, pp. 61-62--General Description of Township: "...rich bottomland chiefly situated in the Snake River and Weiser bottoms....Well adapted for grazing."

T11N R5W--Ernest S. Hesse, 1907, Vol. 224:
Wild Cat Island, Sec. 32, pp. 997-999--dense undergrowth of willows; No timber.
P. 999--General Description—"Wild Cat Island is well adapted for cultivation."

T11N, R6W--Allen M. Thompson, 1870, Vol. 9:
Sec. 19 &20, p. 130--General Description of Township and Range—"...soil covered with fine bunch grass."

T11N, R7W--Dorius F. Baker, 1883:
Sec. 27, p. 180—"Dense undergrowth of willows."
Sec. 26, p. 181--dense undergrowth of willows.

T12N, R7W--Oliver and Klippel 1899, Vol. 169:
Sec. 18, p. 469—"dense undergrowth of willows and wild roses."
SW corner of Sec. 33, p. 433—"No timber."
Sec. 33, 28, & 29, pp. 463-466—"Dense undergrowth of willows, wild roses, and sagebrush."
Sec. 20, p. 467—"dense undergrowth of willows, wild roses, and sagebrush."

T12N, R7W--Frank D. Maxwell, 1910-1920, Vol. 328:
Sec. 18, p. 330--sage undergrowth on Snake River, northwest edge of Sec. 18.
Sec. 32, p. 332—"No timber."

T12N, R8W--Oliver & Klippel, 1899, Vol. 169:
Section 12—"no timber...mountainous land."

T12N, R8W--Frank D. Maxwell, 1920, Vol. 328:
Sec. 12—"Timber-none...Undergrowth-sage."
Sec. 13—"Timber-none...Undergrowth-sage and willows."

T13N, R7W--Oliver & Klippel, 1899, Vol. 169:
Sec.'s 5, 6, & part of Sec. 8 along riverbank; pp. 554-555—"dense undergrowth of sagebrush and chaparral [greasewood?], willow and wild cherry."

Sec. 7 along Snake River, p. 562—“No timber except for a few scattered [unidentified] trees...dense undergrowth of willow, wild roses, sagebrush, chaparral, and hackberry.”
Sec.’s 17 & 18, pp. 560-561—“no timber except for a few scattered hackberry trees...Dense undergrowth of willow, wild cherry, wild roses, sagebrush, chaparral, and hackberry.”
Sec.’s 19 & 20, p. 559--mentions a few small trees.
Sec.’s 29, 30; NW tip of Sec. 32, pp. 557-558—“a few small hackberry trees...dense undergrowth of willow, wild cherry, and hackberry.”
Sec. 31, p. 551—“dense undergrowth.”

Idaho BLM, GLO Records, P. 2:

T14N, R7W--Oliver & Klippel, 1899, Vol. 169:
The riverbank touched the middle of Sec. 15’s west side, p. 589—“dense undergrowth of willow and wild roses.” No timber except “small willow trees.”
East edge of Sec. 11, NW tip of Sec. 12, pp. 590-591--dense willows and wild roses.
Sec. 1, p. 592, along riverbank: willows, wild roses, dense underbrush.
P. 594—settlers in Sec.’s 1,11, 12, 13, & 36; “extensive improvements made by each settler.”
P. 593, General Description—“The land along the river is nearly all taken by settlers and a greater portion is in cultivation.”

T14N, R7W, Darwin H. Utter and Marcellus, 1905, Vol. 224:
Sec. 33, p. 836—“dense undergrowth, willow.”
Sec 28, p. 837--dense undergrowth, willow.
Sec 27, p. 839--no timber.
Sec. 26 &23, p. 840-841--dense undergrowth, willows.
Pp. General Description—“There are 2 settler is in the fraction township along the Snake River who raise their crops from the small creeks and streams.” Mining tunnels in Sec.’s 23, 26--looking for gypsum, “which was never found in paying quantity.”

T15N, R7W--Oliver & Klippel, 1899, Vol. 169:
Sec. 36, se corner, p. 374--mountainous land, no timber.

T15N, R7W--J. H. Robb, 1900, Vol. 179:
East edge of Sec. 36, p. 416--mountainous banks, dense undergrowth.
Sec. 25, p. 418--mountainous banks, dense undergrowth.
P. 419--General Description of Township—“covered with abundant growth of grass.”
Along Snake River in Sec. 36—“some level land claimed by settlers.”

T15N, R6W--J. H. Robb, 1900, Vol. 179:
Sec. 30, p. 514--mountainous banks; cabin and a placer mine; dense undergrowth.
Sec. 19, p. 515--undergrowth of willow, cherry, and hackberry.
Sec.’s 17&18, pp. 517-518--undergr. of willow, cherry, hackberry, and wild roses.
Sec. 12--mountainous, dense undergrowth of cherry and aspen.
Sec. 19, p. 515--undergr. of willow, cherry, hackberry, and wild roses.
Sec. 8, p. 519--no timber; mountainous land.
Sec. 5, pp. 520-521--land covered with dense undergrowth.

Sec. 4, p. 522--land covered with dense undergrowth.
General Description--southeast portion of Township covered with lumber, about 3 square miles in area. Along creeks and Snake River banks--level land, some of it settled. Entire township covered with abundant growth of grass--excellent grazing for stock. Settlers in Sec's 3,5, 30.

T16N, R6W--J. H. Robb, 1900, Vol. 179:
Sec. 33, p. 573--no timber; fence and house located there.
Sect. 28, p. 574--575--dense undergrowth of willows, cherry, and hackberry.
Sec. 21, 15, and 22, pp. 576-577--mountainous; no timber.
Sec. 16, 10, 11, pp. 577-581--no timber.
Sec. 2, p. 581--undergrowth of willow and "thorn."
Sec. 1, pp. 582-583--dense undergrowth; house located at Cottonwood Creek; "no timber except a few small trees"; dense undergrowth of willow and thorn.

Idaho BLM, GLO Records, p. 3:
T16N, R6W--J. H. Robb, 1900, Vol. 179, continued:
P. 583, General Description-- Sec. 13 and 14—"Along the Snake River and its tributary creeks are narrow strips of rich soil which produces excellent crops raised without irrigation." Township covered with "abundant grass."
Sec. 28--Placer mining occurring there.

T16N, R5W--J. H. Robb, 1900, Vol. 179:
Sec. 35 & 36, p. 592--scattered timber, pine and fir; undergrowth of willow, balm [note: term sometimes used for certain types of firs or poplars], buckbrush, pine, and fir.

[T17N, R5W--Not yet researched.]

T18 N, R5W, A. L. Rinearson, 1902, vol. 202:
Sec. 36, p. 771-773--dense undergrowth; no timber.
P. 774, General Description--In Sec. 36 is one settler who has made substantial improvements. "Nearly all kinds of vegetables and fruit are grown in this section."

T18N, R4W, Godfrey Sperling, 1909, Vol. 256:
Sec.'s 31, p. 319--no timber; undergrowth of service berries and willows.
Sec.'s 30 & 19, pp. 319-321--Timber--pine and cottonwood; undergrowth--buckbrush, sarvis (sic) [Service] berries, willows.
Sec. 20, p. 321--timber--pine and balm; undergrowth--willows and buckbrush.
Sec.'s 17 & 18, p. 322--timber--pine; undergrowth sage and buckbrush.
Sec. 8, p. 322--timber--pine and balm; undergrowth--willow, service berries, buckbrush.
Fraction of Sec. 9, p. 323--timber--pine and balm ; undergrowth--willow and buckbrush.
Sec. pp. 323-324--timber--pine and cottonwood; undergrowth--buckbrush.
P. 326, General Description--Wild Horse River runs through Township; a number of settlers own well-improved farms and are cultivating the bottomlands along the Wild Horse River; also raising stock (winter range in adjoining mountains).

T18N, R5W, A. L. Rinearson, 1902, Vol. 202:
Sec. 36, p. 771-773--dense undergrowth; no timber.

P. 774--General Description--In Sec. 36, one settler who has made substantial improvements. "Nearly all kinds of vegetables and fruit are grown in this section."

T19N, R4W, Godfrey Sperling, 1910, Vol. 256:
Sec. 33, p. 228--Salt Creek bar--dense undergrowth
P. 229--North 21 3/4 degrees West--heavy timber and dense undergrowth. Timber--pine fir, and cottonwood. Undergrowth--buckbrush, ninebark, quaking aspen and willows.
Sec. 29, pp. 230-231--dense timber and undergrowth; steep and stony banks. Placer cuts North 1/2 degrees East. Timber--pine, fir, cottonwood. Undergrowth--buckbrush, ninebark, and willows.
Sec. 20, pp. 231-231--Oxbow Hydro dam site. Timber--cottonwood, hackberry, pine, and fir; undergrowth--buckbrush, willow, Syringa, and rose.
Sec. 21, p. 232-233--Timber--pine, fir, cottonwood along the Snake River. Undergr.--willow and buckbrush.
Sec.'s 16 and 21, p. 232-233-- Timber--fir and cottonwood in NE section; West-buckbrush and willow.
Sec.'s 16 & 17, pp. 235-236--undergrowth--buckbrush and willow; no timber.
Sec. 20, p. 236--Timber--cottonwood; undergrowth--willow.
Sec. 17, p. 237--Timber--pine and fir along the river; undergr.--willow, buckbrush, and ninebark.

Idaho BLM, GLO Records, p. 4:

T19N, R4W, 1910, Vol. 256, Cont'd:
Sec. 8, p. 238--No timber. Undergrowth--buckbrush, willows, and ninebark.
Sec. 5, pp. 238-239--River King Mine, Paymaster Mine, Sunnyside mining claim. Timber--pine, fir, cottonwood along river; undergrowth--buckbrush, willow, aspen, ninebark, and rose.
P. 240--General Description: part of Wild Horse River drainage. Southern portion of township—"heavy growth of bunch grass...A few settlers irrigate the lowland and cultivate the bars adjoining the Snake River." Township north of Indian Creek—"slopes are more gentle; springs abound...some of the higher benches cultivated by irrigation and dry farming. There are a few bodies of pine and fir timber." Lots of mining in northern section of township.

T20N, R4W, David B. Wickersham, 1904, Vol. 217:
Sec. 11, p. 397-398--no timber, mountainous.
Sec. 14, p. 398--no timber; undergrowth--willow; mountainous.
Sec.'s 22 & 23, p. 399--timber--pine; undergrowth--willow.
Sec. 27 & 23, p. 399 & 403--ferry across river there; house and barn located there. Scattering of timber--pine; undergrowth--willow.
Sec. 28, p. 405--no timber; undergrowth willow.
P. 406, General Description--Very little timber in the township; several settlers.

T20N, R4W, W. H. Good, 1936, Vol. 362:
Sec.'s 2 & 1, pp. 194-197--scattered pine; scattered buckbrush.
Sec. 36, pp. 285-286--Timber--pine; undergrowth--fir, willow, cherry, and buckbrush.

[T20N, R3W--no sections along the banks of the Snake River during the pre-dam era.]

T21N, R4W--not yet researched--is the citation on Jeff Braatne's list correct? This township seems to be out of the study area?]

T21N, R3W, David Wickersham, 1904, Vol. 217:
Sec. 31, p. 429--scattered timber and undergrowth. Timber--pine; undergr.--hawthorn and juniper.
Sec. 30, p. 427--timber--pine; undergrowth-juniper.
P. 427--General Description--Sec.'s 30 & 31--agricultural land; two settlers.

T21N, R3W, W. H. Good, 1936, Vol. 362:
Sec.'s 19, 20, & 17; p. 181--Timber--a few scattering pine; dense willow.
Sec.'s 8, 5, 4 & 14, pp. 182-183--well defined bank. Scattered undergrowth--willow; a few scattered pines. Road tunnel in Sec. 8.
P. 183, General Description--Fir timber dominates; some yellow pine in south part of township. "There is a fair stand of grass over the entire area...Undergrowth consists of willow, aspen, ash, Syringa, mountain laurel, and maple." "<u>Considerable mining development work done in Sec.'s 1 &2, where the Peacock and South Peacock mining properties are located</u>."

T22N, R3W, W. H. Good & F. Roach, 1935, Vol. 362:
Sec. 33, pp. 318-319--Timber--scattered pine & fir; undergrowth--willow, sage, and buckbrush.
Sec.'s 21 & 28, p. 319--Timber--scatted pine & fir; undergrowth--willow and buckbrush.

Idaho BLM, GLO Records, p. 5:

T22N, R3W, W. H. Good & F. Roach, 1935, Vol. 362, cont'd:
<u>Sec.'s 16, 15, & 10, p. 320--Timber--scatted pine & fir; undergrowth--willow and buckbrush.</u>
Sec. 3, p. 321--scattering of pine and firs; undergrowth of willow and sage.
Sec. 2, p. 321--scattering of pine and firs; undergrowth of buckbrush and willow.

Appendix 2

Bibliography

This page left blank intentionally.

Bibliography

Anderson J. E., and K. E. Holte. 1981. Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in southeastern Idaho. Journal of Range Management 34:25-29.

Arrowrock Group. 1995. Idaho Power Company Hells Canyon oral history report. Idaho Power, Boise, ID.

Asherin, D. A., and J. J. Claar. 1976. Inventory of riparian habitats and associated wildlife along the Columbia and Snake Rivers. College of For., Wildl., Range Sci., University of Idaho, Moscow, ID. 556 p.

Auble, G. T., M. .L Scott, J. M. Friedman, J. Back, V. J. Lee. 1997. Constraints on establishment of plains cottonwood in an urban riparian preserve. Wetlands 17:138-148.

Bailey, R. G. 1943. Hell’s Canyon: A story of the deepest canyon on the North American continent, together with historical sketches of Idaho. Lewiston, ID.

Ball, J., R. D. Bauer, K. Vermeer, and M. J. Rabenberg. 1989. Northwest riverine and Pacific coast. Pages 429–449 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech Univ. Press, Lubbock, TX.

Barnes, W. J. 1997. Vegetation dynamics on the floodplain of the lower Chippewa River in Wisconsin. J. Tor. Bot. Soc. 124:189-197.

Baskin, C. C, J. M. Baskin. 1998. Seeds: ecology, biogeography and evolution of dormancy and germination. Academic Press, New York, NY.

Beck, J. M., C. R. Peterson, M. Gerber, and N. J. S. Turley. 2000. Species occurrence and distribution of amphibians and reptiles in Hells Canyon. In: Technical appendices for Hells Canyon Hydroelectric Project. Idaho Power, Boise, ID. Technical Report E.3.2-36.

Bildstein, K. L., G. T. Bancroft, P. J. Dugan, D. H. Gordon, R. M. Erwin, E. Nol, L. X. Payne, and S. E. Senner. 1991. Approaches to the conservation of coastal wetlands in the western hemisphere. Wilson Bulletin 103:218-254.

Bonneville Power Administration. 1984. Hells Canyon environmental investigation. CH2M HILL for Bonneville Power Administration, Boise, ID.

Bradley, C., and D. Smith. 1984. Meandering channel response to altered flow regime: Milk River, Alberta and Montana. Wat Res 20:1913-1920.

Bradley, C., and D. Smith. 1986. Plains cottonwood recruitment and survival on a prairie meandering river floodplain, Milk River, southern Alberta and northern Montana. Can J Bot 64:1433-1442.

Brooks, P. J., K. Urban, E. Yates, and C. G. Johnson Jr. 1991. Sensitive plants of the Malheur, Ochoco, Umatilla, and the Wallowa-Whitman National Forest. U.S. Forest Service. PNW-R6 WAW TP 04-92.

Brunsfeld, S. J., and F. D. Johnson. 1985. Field guide to the willows of East-Central Idaho. Forest, Wildlife and Range Experiment Station, University of Idaho. Bulletin 39, Moscow, ID.

Buckendorf, M. K., B. P. Bauer, E. Jacox, B. Tydeman. 1995. Historical literature survey of the Hells Canyon area from Farewell Bend to the mouth of the Salmon River. The Arrowrock Group Inc., Boise, ID. Available from Idaho Power Company.

[BLM] Bureau of Land Management. 1986. Draft Baker resource management plan environmental impact statement. Baker Resource Area, Vale District, U.S. Dept. Int., Baker, OR. 120 p.

Bush, J. H., and W. P. Seward. 1992. Geologic field guide to the Columbia River Basalt, northern Idaho and southeastern Washing. Information Circuluar 49. Idaho Geological Survey, University of Idaho, Moscow. 35 p.

Carrey, J., C. Conley, and A. Barton. 1979. Snake River of Hells Canyon. Backeddy Books, Cambridge, ID.

Chapman, W. M. 1940. Report of a field trip to the Snake River drainage in Idaho and Eastern Oregon. Washington Department of Fisheries, Olympia, WA.

Chatters, J. C., and K. C. Reid. 1999-2000. Unpublished progress reports on the archaeological inventory of Hells Canyon. Prepared for Idaho Power Company, Boise, ID.

Christensen, A. (Rocky Mountain Elk Foundation, Missoula, MT). 2001. Delineation and assessment of big game winter range associated with the Hells Canyon Hydroelectric Complex: mule deer, elk, mountain goats, and rocky mountain bighorn sheep. In: Technical appendices for Hells Canyon Complex Hydroelectric Project. Idaho Power, Boise, ID. Technical Report E.3.2-31.

Church, M. 1995. Geomorphic response to river flow regulation: case studies and time-scales. Regulated Rivers: Research and Management 11:3-22.

Clark, R. 1995. River of the west: a chronicle of the Columbia. Picador Press, New York, NY.

Cordes, L. D., F. M. R. Hughes, and M. Getty. 1997. Factors affecting the regeneration and distribution of riparian woodlands along a northern prairie river: the Red Deer River, Alberta, Canada. J. Biogeog. 24:675-695.

Croft, L. K., W. R. Owen, and J. S. Shelly. 1997. Interior Columbia Basin ecosystem management project: analysis of vascular plants. U.S. Forest Service, Portland, OR. 122 p.

Crouch, G. L. 1982. Wildlife on ungrazed and grazed bottomlands on the South Platte River, Northeastern Colorado. Pages 188-197 *in* Wildlife-livestock relationships symposium. Forest Wildlife and Range Experiment Station, Moscow, ID.

Daubenmire, R. 1970. Steppe vegetation of Washington. Washington Agricultural Experiment Station Technical Bulletin 62. 131 p.

——————. 1978. Plant geography—with special reference to North America. Academic Press, New York, NY. 338 p.

DeBolt, A. 1992. The ecology of *Celtis reticulata* Torr. (netleaf hackberry) in Idaho. Oregon State University, Corvallis, OR. 166 p.

Densley, L. C. 1987. Saints, sinners and Snake River secrets. Courier Printers, Baker, OR.

Dixon, M. D., and W. C. Johnson. 1999. Riparian vegetation along the Middle Snake River, Idaho: zonation, geographical trends, and historical changes. Great Basin Naturalist 59:18-34.

Dyer, M. I. 1979. Consumers. Pages 73-86 *in* R. T. Coupland, editor. Grassland ecosystems of the world: analysis of grasslands and their uses. Cambridge University Press, Cambridge, England.

Dynesius, M., C. Nilsson. 1994. Fragmentation and flow regulation of river systems in the northern third of the world. Science 266:753-762.

Eagle Cap Inc. 1999. Preliminary results of invasive, noxious and threatened plant inventories of the Hells Canyon Study Corridor. A preliminary report prepared for the Idaho Power Company.

Edelmann, F. B. (Editor). 2001. Wintering mule deer ecology in the reservoir reach of the Hells Canyon Hydroelectric Complex. In: Technical appendices for Hells Canyon Complex Hydroelectric Project. Idaho Power, Boise, ID. Technical Report E.3.2-32.

Evans, G. R. 1967. Ecology of *Aristida longiseta* in north central Idaho. University of Idaho, Moscow, ID. 69 p.

Federal Power Commission. 1959. Project 1971, Federal Power Commission hearings, December 10, 1959: Testimony of Mr. Murray and Mr. Day. Idaho Power Company files.

Feldhamer, G. A. 1979. Vegetative and edaphic factors affecting abundance and distribution of small mammals in southeast Oregon. Great Basin Naturalist 39:207-218.

Fitzgerald, J. F. 1982. Geology and basalt stratigraphy of the Weiser Embayment, west-central Idaho. Pages 137-141 *in* B. Bonnichsen and R. M. Breckenridge, editors. Cenozoic geology of Idaho. Idaho Bureau of Mines and Geology, University of Idaho, Moscow, ID.

Franklin, J. F., and C. T. Dyrness. 1988. Natural vegetation of Oregon and Washington. Oregon State University Press, Corvallis, OR. 452 p.

Friedman, J. M., W. R. Osterkamp, M. L. Scott, and G. T. Auble. 1998. Downstream effects of dams on channel geometry and bottomland vegetation: regional pattern patterns in the Great Plains. Wetlands 18:619-633.

Galbraith, W. A., and W. E. Anderson. 1971. Grazing history of the Northwest. Journal of Range Management 24:6-12.

Gano, K. A., and W. H. Rickard. 1982. Small mammals of a bitterbrush-cheatgrass community. Northwest Scientist 56:1-7.

Garrison, G. A., and A. J. Bjugstad, et al. 1977. Vegetation and environmental features of forest and range ecosystems. U. S. Forest Service Ag Handbook 475. 68 p.

General Land Office Records. 1890-1905; 1901-1936. U.S. General Land Office (currently U.S. Bureau of Land Management), Washington, D.C.

Gildemeister, J. 1992. Bull trout, talking grouse and buffalo bones: Oral histories of northeast Oregon fish and wildlife. Oregon Department of Fish and Wildlife, LaGrande, OR.

Grams, P., and J. Schmidt. 1991. Degradation of alluvial sand bars along the Snake River below Hells Canyon Dam, Hells Canyon National Recreation Area, Idaho. Middlebury College, Middlebury, VT.

Grayson, D. K. 1977. Paleoclimatic implications of the Dirty Shame Rockshelter mammalian fauna. Tebiwa Misc Pap Mus Nat Hist 9; Idaho State University, Pocatello, ID.

Green, T. J. 1988. White man comes to Snake River. Idaho State Historical Society, Boise, ID.

Gustafson, C. E. 1972. Faunal remains from the Marmes Rockshelter and related archaeological sites in the Columbia Basin. Washington State University, Pullman, WA.

Hall, F. C. 1973. Plant communities of the Blue Mountains in eastern Oregon and southeastern Washington. U.S. Forest Service. PNW, R6 Area Guide 3-1.

Harris, K. W. 1972. Topping out. A. H. Logan. Idaho State Historical Society, Boise, ID.

Hironaka, M., M. A. Fosberg, and A. H. Winward. 1983. Sagebrush-grass habitat types of southern Idaho. Forest Wildl. and Range Exp. Sta. Bulletin 35. Coll. For. Wildl. and Range Sci, University of Idaho, Moscow, ID.

Holechek, J. L., R. D. Piper, and C. H. Herbel. 1989. Range management: principles and practices. Prentice-Hall, Englewood Cliffs, NJ.

Holmstead, G. 2001. Vegetation of the Snake River corridor in Hells Canyon—Weiser, Idaho, to the Salmon River. In: Technical appendices for Hells Canyon Hydroelectric Project. Idaho Power, Boise. Technical Report E.3.3-1.

Hudson's Bay Record Society. 1979. Ogden's Snake Country Journals, 1824-1826. Publications of the Hudson's Bay Record Society, London. Kraus reprint. Nendeln, Liechtenstein.

Huschle, G. 1975. Analysis of the vegetation along the middle and lower Snake River. University of Idaho, Moscow, ID. 268 p.

Hutchings, S. S., and G. Stewart. 1953. Increasing forage yields and sheep production on intermountain winter ranges. USDA Forest Service. Circ. No. 925. 63 pp.

[IDFG] Idaho Department of Fish and Game. 1951. Idaho game population census and range study. A Pittman-Robertson Study. Project 85-R. June 1949 to June 1951.

Idaho Natural Heritage Program. 1988. Plant association classification. May 1, 1988. Idaho Department of Fish and Game, Boise, ID. 28 p.

[IPC] Idaho Power Company. 1997. Formal consultation package for relicensing: Hells Canyon Project (FERC No. 1971). 3 volumes. Environmental Affairs Department, IPC, Boise, ID.

Imbert, J. B., and J. A. Stanford. 1996. An ecological study of a regulated prairie stream in western Montana. Regulated Rivers 12:597-615.

Invader Database System. 2000. Online database for invasive and noxious species of Idaho, Oregon, Montana, Washington and Oregon. http://invader.dbs.umt.edu. Maintained by Dr. Peter Rice, Department of Biological Sciences, University of Montana, Missoula, MT.

Johnson, C. G., and S. A. Simon. 1987. Plant associations of the Wallowa-Snake province, Wallowa-Whitman National Forest. U.S Forest Service. PNR. R-6 ECOL-TP-225A-86. 272 p.

Johnson , W. C. 1990*a*. Statistical analysis of the causes of vegetation change in the Platte River, Nebraska, during the past half-century, and addendum responding to agency comments, Appendix III, Vegetation and channel change, joint response, May 5, 1990. Prepared for Nebraska Public Power District and Central Nebraska Public Power and Irrigation District.

———. 1990*b*. Demographic analysis of cottonwood and willow reproduction and survival in Platte River channels, and addendum responding to agency comments, Appendix III, Vegetation and channel change, joint response, May 5, 1990. Prepared for Nebraska Public Power District and Central Nebraska Public Power and Irrigation District.

———. 1994. Woodland expansion in the Platte River, Nebraska: patterns and causes. Ecological Monographs 64:45-84.

——————. 1996*a*. Effects of the 1995 Platte River flood on vegetation and channel area equilibrium. Prepared for Nebraska Public Power District and Central Nebraska Public Power and Irrigation District.

——————. 1996*b*. Monitoring of tree reproduction and survival in the Platte River 1994-95. Final report to Nebraska Public Power District and Central Nebraska Public Power and Irrigation District.

——————. 1996*c*. Channel equilibrium in the Platte River. Memo prepared for Nebraska Public Power District and Central Nebraska Public Power and Irrigation District.

——————. 1997. Equilibrium response of riparian vegetation to flow regulation in the Platte River, Nebraska. Regulated Rivers: Research & Management 13: 403-415.

——————. 1998. Adjustment of riparian vegetation to river regulation in the Great Plains, USA. Wetlands 18:608-618.

Jones, M. 1989. History of early livestock grazing in the area of the Payette National Forest. U.S. Forest Service, Payette National Forest, McCall, ID.

Jordan, G. 1954. My home below Hells Canyon. Crowell, New York, NY.

Kauffman, J. B, and W.C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications: a review. Journal of Range Management 37:430-438.

Kochert, M. N. 1989. Responses of raptors to livestock grazing in the western United States. Pages 194-203 *in* Proceedings of the Western Raptor Management Symposium Workshop. National Wildlife Federation, Washington, D.C.

Lane, E. W. 1955. Design of stable channels. Transactions ASCE, Volume 120, Paper No. 2776.

Larson, F. 1940. The role of the bison in maintaining the short grass plains. Ecology 21:113-121.

Mack, R. N, and J. N. Thompson. 1982. Evolution in steppe with few large, hooved mammals. American Naturalist 119:757-773.

Mahoney, J. M., and S. B. Rood. 1993*a*. The potential effects of an operating plan for the Oldman River Dam on riparian cottonwood forests. Alberta Public Works, Supply and Services. Oldman River Dam Mitigation Program Downstream Vegetation Project Report Volume II.

——————. 1993*b*. A model for assessing the effects of altered river flows on the recruitment of riparian cottonwoods. Pages 228-232 *in* B. Tellman, H. J. Cortner, M. G. Wallace, L. F. DeBano, and R. H. Hamre, editors. Riparian management: common threads and shared interests. USDA Forest Service General Technical Report RM-226, Albuequerque, NM.

—————. 1997. Streamflow requirements for cottonwood seedling recruitment—a quantitative model. Wetlands (*in press*).

—————. 1998. Streamflow requirements for cottonwood seedling recruitment—an integrative model. Wetlands 18:634-45.

Malheur County Historical Society. 1988. Malheur Country History. 2 volumes. Taylor Publishing, Dallas, TX.

Martin, A. C., H. S. Zim, and A. C. Nelson. 1951. American wildlife and plants, a guide to wildlife food habits. New Dover Publications, New York, NY. 500 p.

McGee, J. M. 1982. Small mammal populations in an unburned and early fire successional sagebrush community. Journal of Range Management 35:177-180.

McKay, S. J. 1996. The impact of river regulation on establishment processes of riparian black cottonwood. University of Washington, Seattle, WA.

Merigliano, M. F. J. 1994. A natural history of the South Fork Snake River, eastern Idaho, emphasizing geomorphology, hydrology, and vegetation. University of Montana, Missoula, MT.

—————. 1996. Ecology and management of the South Fork Snake River cottonwood forest. Idaho State Office, Bureau of Land Management, Boise, ID. BLM Technical Bulletin 96-9.

Milchunas, D. G, O. E Sala, W. K. Lauenroth. 1988. A generalized model of the effects of grazing by large herbivores on grassland community structure. American Naturalist 132:87-106.

Miller, R. F., J. M. Seufert, and M. R. Haferkamp. 1986. The ecology and management of bluebunch wheatgrass (*Agropyron spicatum*): a review. Oregon State University Ag. Exp. Sta. Bulletin 669, Corvallis, OR. 39 p.

Miller, T. B. 1976. Ecology of riparian communities dominated by white alder in western Idaho. University of Idaho, Moscow, ID. 154 p.

Miller, T. B., and F. D. Johnson. 1976. Ecology of riparian communities dominated by white alder in western Idaho. Pages 111-123 *in* Proceedings of Terrestrial and Aquatic Vegetation. Eastern Washington State College, Cheney, WA.

Montgomery, G. L. 1996. RCA III riparian areas, reservoirs of diversity, working paper no. 13. NRCS, USDA, Northern Plains Regional Office, Lincoln, NE.

Moseley, R., and C. Groves. 1992. Rare, threatened and endangered plants and animals of Idaho. Idaho Conservation Data Center, Nongame and Endangered Wildlife Program, Idaho Dept. of Fish and Game, Boise, ID. 38 p.

Moseley, R. K, and M. Mancuso. 1992. Summary of 1992 field surveys for threatened, endangered and sensitive plants in the HCNRA. Idaho Department of Fish and Game, Boise, ID.

[NPS] National Park Service. 1980. Final Wild and Scenic River study report and environmental statement. Snake River: Idaho, Washington, and Oregon. U.S. Department of the Interior.

Nilsson, C., R. Jansson, and U. Zinko. 1997. Long-term responses of river-margin vegetation to water-level regulation. Science 276:798-800.

Noble, D. 1993. A historic reconstruction of Yampa River riparian forest communities. Duke University, Durham, NC.

[NWEA] Northwest Environmental Advocates. 1992. Columbia River—troubled waters. Map. Northwest Environmental Advocates, Portland, OR.

O’Brien, J., and P. Currier. 1987. Channel morphology, channel maintenance, and riparian vegetation changes in the Big Bend Reach of the Platte River in Nebraska. Prepared for the Platte River Habitat Maintenance Whooping Crane Trust, Grand Island, NE.

O’Connor, J. 1993. Hydrology, hydraulics, and geomorphology of the Bonneville Flood. Geological Society of America, Boulder, CO. Special Paper 274.

Ogle, K., and V. DuMond. 1997. Historical vegetation on national forest lands in the intermountain region. USDA, Forest Service, Intermountain Region, Ogden, UT.

Oliphant, J. O. 1946. The eastward movement of cattle from the Oregon country. Agri. Hist. 20:14-43.

[OSGC] Oregon State Game Commission. 1948. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1950. Annual Report. Oregon Department of Fish and Wildlife. Portland, OR.

__________. 1951. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1952. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1953. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1954. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1955. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1956. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1957. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1958. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1959. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1960. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1961. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1962. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

__________. 1963. Annual Report. Oregon Department of Fish and Wildlife, Portland, OR.

Osterkamp, W. 1997. Expert witness testimony of Waite Osterkamp before the district court of the fifth judicial district of the State of Idaho, in and for the county of Twin Falls. U.S. Department of Justice, Environment and Natural Resources Division, Denver, CO.

Ott, J. S. 1997. Clearing the country: a history of the Hudson's Bay Company's fur desert policy. University of Montana, Missoula, MT. 127 p.

Page, J. L., N. Dodd, T. O. Osborne, and J. A. Carson. 1978. The influence of livestock grazing on non-game wildlife. Cal-Neva Wildlife 1978:159-173.

Paige, C., and S. A. Ritter. 1999. Birds in a sagebrush sea. Managing sagebrush habitats for bird communities. Partners in Flight, Western Working Group, Boise, ID.

Palmer, T. 1991. The Snake River: window to the West. Island Press, Washington, D.C.

Parkinson, S. K., K. Anderson, J. Connor, and J. Milligan. 2001. Sediment transport, supply, and stability in the Hells Canyon reach of the Snake River. In: Technical appendices for Hells Canyon Hydroelectric Project. Idaho Power, Boise. Technical Report E.1-1.

Platts, W. S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification—with application to ecosystem classification. Surface Environment and Mining Program, USDA, U.S. Forest Service.

——————. 1991. Livestock grazing. Influences of forest and rangeland management on salmonid fishes and their habitat. American Fisheries Society Special Publication 19:389-423.

Ratti, J. T., and M. B. Lucia (University of Idaho, Moscow, ID). 1998. Literature and status review of big game species in Hells Canyon. In: Technical appendices for Hells Canyon Hydroelectric Project. Idaho Power, Boise, ID. Technical Report E.3.2-34.

Rinehart, E. F. 1932. The Idaho range, past and present. M.Sc. Thesis. University of Idaho, Moscow, ID. 55 pp.

Rogers, L. E, and J. D. Hedlund. 1980. A comparison of small mammal populations occupying three distinct shrub-steppe communities in eastern Oregon. Northwest Science 54:183-186.

Rood, S., and S. Heinze-Milne. 1989. Abrupt downstream forest decline following river damming in southern Alberta. Canadian Journal of Botany 67:1744-1749.

Rood, S. B., and J. M. Mahoney. 1995. River damming and riparian cottonwoods along the Marias River, Montana. Rivers 5:195-207.

__________. 1990. Collapse of riparian poplar forests downstream from dams in western prairies: probable causes and prospects for mitigation. Env. Management 14:451-464.

Rood, S. B. , J. M. Mahoney, D. E. Reid, and L. Zilm. 1995. Instream flows and the decline of riparian cottonwoods along the St. Mary River, Alberta. Can. J. Bot. 73:1250-1260.

Rood, S. B., K. Taboulchanas, C. E. Bradley, and A. R. Kalischuk. 1999. Influence of flow regulation on channel dynamics and riparian cottonwoods along the Bow River, Alberta. Rivers 7:33-48.

Ross, S. H., and C. N. Savage. 1967. Idaho earth science. Idaho Bureau of Mines and Geology, Moscow, ID. Sci. Ser. No. 1. 271 p.

Saab, V. A. 1998. Effects of recreational activity and livestock grazing on habitat use by breeding birds in cottonwood forests along the south fork Snake River. USDA, Forest Service, Rocky Mountain Research Station, Boise, ID.

Saab, V. A., C. E. Bock, T. D. Rich, and D. S. Dobkin. 1995. Livestock grazing effects in western North America. Pages 311-353 *in* T. E. Martin and D. M. Finch, editors. Ecology and management of neotropical migratory birds: a synthesis and review of critical issues. Oxford University Press, New York, NY.

Schlesinger, W. H., J. F. Reynolds, G. L. Cunningham, L. F. Huenneke, W. M. Jarrell, R. A. Virginia, and W. G. Whitford. 1990. Biological feedbacks in global desertification. Science 247:1043-1048.

Schmidt, J. C., P. E. Grams, and R. H. Webb. 1995. Comparison of the magnitude of erosion along two large regulated rivers. Water Res Bulletin 31:617-631.

Schroedl, G. F. 1973. The archaeological occurrence of bison in the southern plateau. Washington State University, Pullman, WA.

Schumm, S. A. 1977. The idealized fluvial system. The Fluvial System. John Wiley & Sons.

Scott, M. L., J. M. Friedman, and G. T. Auble. 1996. Fluvial process and the establishment of bottomland trees. Geomorphology 14:327-339.

Sear, D. A. 1995. Morphological and sedimentological changes in a gravel-bed river following 12 years of flow regulation for hydroelectric. Regulated Rivers 10:247-264.

Shaw, W. M. 1952. Job completion reports for Idaho game population census and range study. Idaho Department of Fish and Game, Boise, ID. A Pittman-Robertson Study, Project W 85-R-4.

Shaw, W. M., and A. E. Nielson. 1950. Idaho game population census and range study. Idaho Department of Fish and Game, Boise, ID. Quarterly Progress Report, Project 85-R-2.

Shaw, W. M., L. Pengelly, R. J. McCormack, D. Smith, and A. E. Nielson. 1954. Job completion reports for Idaho game population census and range study. Idaho Department of Fish and Game, Boise, ID. A Pittman-Robertson Study. Project W 85-R-4. June 1, 1953 to June 30, 1954.

Shaw, W. M., R. M. Rogers, R. J. McCormack, D. L. Tanner, and A. E. Nielson. 1955. Job completion reports for Idaho game population census and range study. Idaho Department of Fish and Game, Boise, ID. A Pittman-Robertson Study. Project W 85-R-6. June 1, 1954 to June 30, 1955.

Shaw, W. M., R. M. Rogers, R. J. McCormack, D. L. Tanner, A. E. Nielson, B. McConnell, and D. R. Smith. 1956. Job completion reports for Idaho game population census and range study. Idaho Department of Fish and Game, Boise, ID. A Pittman-Robertson Study. Project W 85-R-7. June 1, 1955 to June 30, 1956.

Shaw, W. M., R. M. Rogers, R. J. McCormack, D. L. Tanner, A. E. Nielson, and J. Morrison. 1957. Job completion report—A federal aid to wildlife restoration project, Idaho game population census and range study. Idaho Department of Fish and Game, Boise, ID. A Pittman-Robertson Study. Project W 85-R-9. September 1, 1957 to December 15, 1957.

Shaw, W. M., R. M. Rogers, R. J. McCormack, D. L. Tanner, A. E. Nielson, J. Morrison, and E. Norberg. 1958. Job completion report—A federal aid to wildlife restoration project, Idaho game population census and range study. Idaho Department of Fish and Game, Boise, ID. A Pittman-Robertson Study. Project W 85-R-10. September 1, 1958 to December 15, 1958.

Shaw, W. M., R. M. Rogers, R. J. McCormack, D. L. Tanner, A. E. Nielson, R. C. Norell, J. Morrison, and W. R. Cunningham. 1960. Job completion report—A federal aid to wildlife restoration project, Idaho game population census and range study. Idaho Department of Fish and Game, Boise, ID. A Pittman-Robertson Study. Project W 85-R-11. September 1, 1959 to February 1, 1960.

Simons & Associates. 1990*a*. Platte River system hydrologic analysis and addendum responding to agency comments. Prepared for Nebraska Public Power District and Central Nebraska Public Power and Irrigation District.

__________. 1990*b*. Platte River system geomorphic analysis, Appendix V, Geomorphology, joint response, May 5, 1990. Prepared for Nebraska Public Power District and Central Nebraska Public Power and Irrigation District.

__________. 1990*c*. Physical process computer model of channel width and woodland changes on the North Platte, South Platte, and Platte Rivers. Prepared for Nebraska Public Power District and Central Nebraska Public Power and Irrigation District.

__________. 1995. Responses to questions on USFWS pulse flow recommendations related to channel geomorphology, hydrology and sediment transport. Prepared for Nebraska Public Power District and Central Nebraska Public Power and Irrigation District.

__________. 2000. Physical history of the Platte River in Nebraska: focusing upon flow, sediment transport, geomorphology, and vegetation. Prepared for Nebraska Public Power District and Central Nebraska Public Power and Irrigation District.

Simons, D. B, and F. Sentürk. 1975. Sediment transport technology. Water Resources Publications.

——————. 1992. Sediment transport technology. Water and Sediment Dynamics.

Stromberg, J. C., and D. T. Patten. 1992. Mortality and age of black cottonwood stands along diverted and undiverted streams in the eastern Sierra Nevada, California. Madrono 39:205-223.

__________. 1990. Riparian vegetation instream flow requirements: a case study from a diverted stream in the eastern Sierra Nevada, California, USA. Env. Management 14:185-194.

Thomas, J. W., C. Maser, and J. E. Rodiek. 1979. Wildlife habitats in managed rangelands the great basin in southeastern Oregon. USDA Forest Service Gen. Tech. Rep. PNW-80. Pacific Northwest Forest and Range Experiment Station, Olympia, WA.

Tisdale, E. W. 1961. Ecological changes in the Palouse. Northwest Science 35:134-138.

——————. 1979. A preliminary classification of Snake River canyon grasslands in Idaho. University of Idaho, Moscow, ID. For. Wildl. and Range Exp. Sta. 8 p.

——————. 1986*a*. Canyon grasslands and associated shrublands of west central Idaho and adjacent areas. University of Idaho, Moscow, ID. For. Wildl. and Range Exp. Sta. Bulletin 40. 42 p.

——————. 1986*b*. Native vegetation of Idaho. Rangelands 8:202-207.

Tisdale, E. W., and M. Hironaka. 1981. The sagebrush-grass region: a review of the ecological literature. University of Idaho, Moscow, ID. For. Wildl. and Range Exp. Sta. 31 p.

Tisdale, E. W., M. Hironaka, and M. A. Fosberg. 1969. The sagebrush region in Idaho: a problem in range resource management. University of Idaho, Moscow, ID. Ag. Exp. Sta. Bulletin 512. 12 p.

[COE] U.S. Army Corps of Engineers. 1948. Review report on Columbia River and tributaries. Fish and Wildlife Service, North Pacific Division, Portland, OR. Appendix P.

U.S. Census Office. 1896. Agriculture by irrigation in the western part of the United States at the eleventh census, 1890. House of Representatives Miscellaneous Documents 340 part 20, first session of the fifty-second Congress. Report on the statistics of agriculture in the United States at the eleventh census: 1890. U.S. Government Printing Office, Washington, D.C.

[USDA] U.S. Department of Agriculture. 1968. History of the Payette National Forest. Payette National Forest, McCall, ID.

__________. 1972. Hells Canyon–Seven Devils–Rapid River comprehensive land use plan. Payette National Forest, McCall, ID.

__________. 1980. Final environmental impact statement, Hells Canyon National Recreation Area, comprehensive management plan. Wallowa-Whitman, Nez Perce, and Payette National Forests, Washington, D.C.

__________. 1988. Payette National Forest final environmental impact statement. Payette National Forest, McCall, ID.

__________. 1990. Land and Resource Management Plan. Baker City (OR): Wallowa-Whitman National Forest.

__________. 1990. Land and resource management plan. Wallowa-Whitman National Forest, Baker City, OR.

[USDI] U.S. Department of Interior. 1986. Baker resource management plan, draft environmental impact statement. U.S. Department of the Interior, Bureau of Land Management, Vale District, Vale, OR. 120 p.

__________. 1987. Cascade Resource Area resource management plan. Bureau of Land Management, Boise, ID.

__________. 1989. Baker Resource Area resource management plan. Baker Bureau of Land Management, Baker City, OR.

__________.1964. A survey of the fish and wildlife resources of the Middle Snake River Basin, Idaho, Oregon, and Washington. Bureau of Commercial Fisheries and Bureau of Sport Fisheries and Wildlife, Portland, OR.

[USFS] U.S. Forest Service. 1981. Final environmental impact statement for Hells Canyon National Recreation Area comprehensive management plan. U.S. Department of Agriculture, Wallowa-Whitman National Forest.

[USFWS] U.S. Fish and Wildlife Service. 1948. Review report on Columbia River and tributaries. Appendix P, Fish and Wildlife. Prepared for Corps of Engineers, North Pacific Division.

[USGS] U.S. Geological Survey. 1999. Water resources data, Idaho, water year 1999. Washington, D.C.

U.S. Secretary of Agriculture. 1936. The western range: letter from the Secretary of Agriculture in response to Senate Resolution No. 289. A report on the western range—a great but neglected natural resource. U.S. Senate, 74th Congress, 2nd session. Document 199. U.S. Government Printing Office, Washington, D.C.

Vallier, T. L. 1998. Islands and rapids: a geological story of Hells Canyon. Confluence Press, Lewiston, ID.

Wentworth, E. N. 1948. America's sheep trails. Iowa State College Press, Ames, IA. 667 p.

Wiens, J. A. 1985. Habitat selection in variable environments: shrub-steppe birds. Pages 227-251 *in* M. Cody, editor. Habitat selection in birds. Academic Press, London, England.

Wiens, J. A., and J. T. Rotenberry. 1981. Habitat associations and community structure of birds in shrub-steppe environments. Ecological Monographs 51:21-41.

Williams, G., and M. Wolman. 1984. Downstream effects of dams on alluvial rivers. U.S. Department of the Interior, USGS Professional Paper 1286.

Yensen, D. 1980. A grazing history of southwestern Idaho with emphasis on the Birds of Prey Study Area. U.S. Bureau of Land Management Snake River Birds of Prey Research Project, Boise, ID.

__________. 1981. The 1990 invasion of alien plants into southern Idaho. Great Basin Naturalist 41:176-182.

__________. 1982. A grazing history of southwestern Idaho with emphasis on the Birds of Prey study area. U.S. Bureau of Land Management, Boise, ID.

Young, J. A., and C. G. Young. 1992. Seeds of woody plants of North America. Discorides Press, Portland, OR.