Draft
Lower Snake
Subbasin Summary

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Northwest Power Planning Council

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Lower Snake Subbasin Summary

Table of Contents

List of Figures

List of Tables

Lower Snake Subbasin Summary

FISH AND WILDLIFE RESOURCES

Subbasin Description

General Location

Lower Snake River Subbasin, Columbia Plateau Province (Figure 1).
Lower Snake River dams and hatcheries (Figure 2).

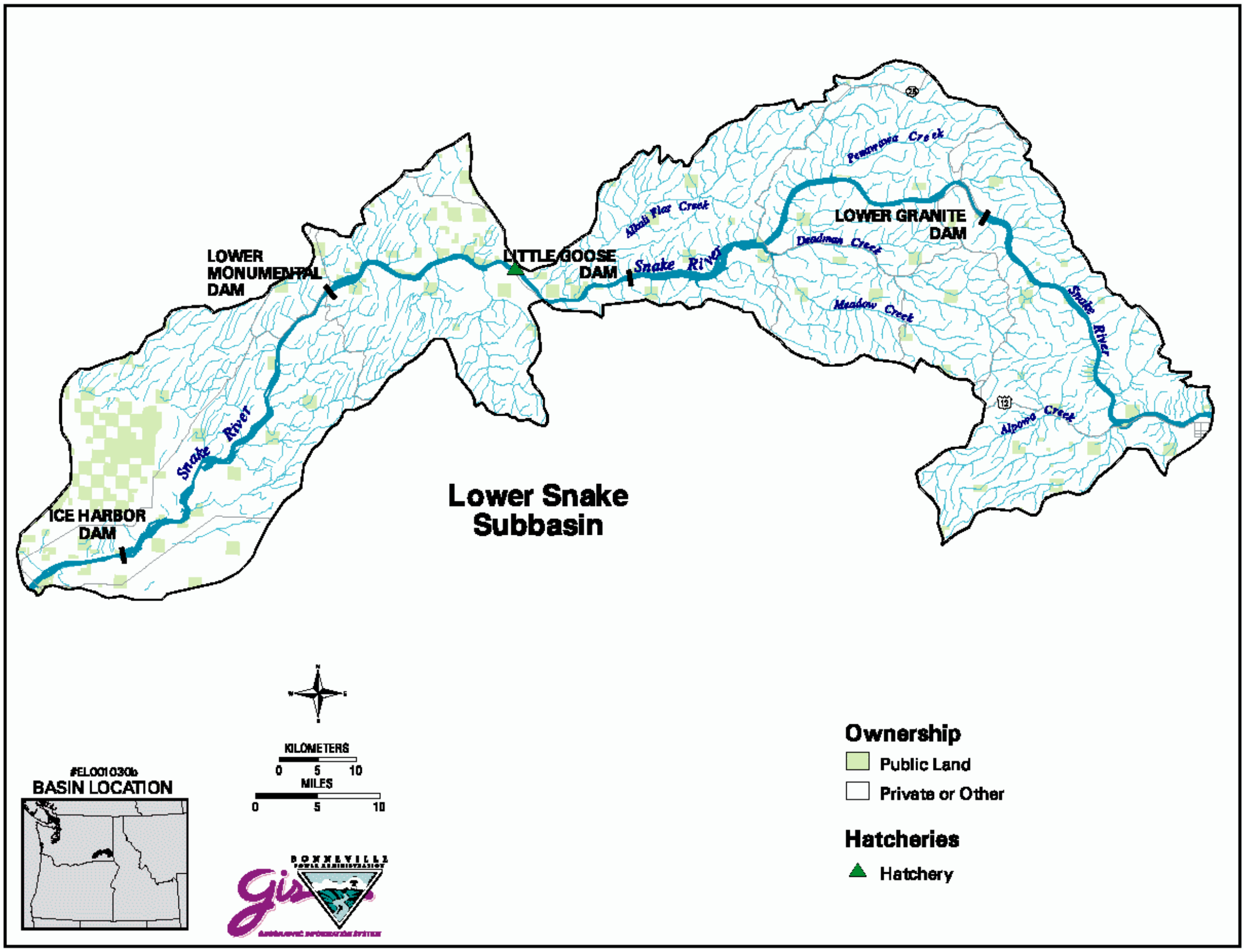


Figure 1. Lower Snake River Subbasin, Columbia Plateau Province

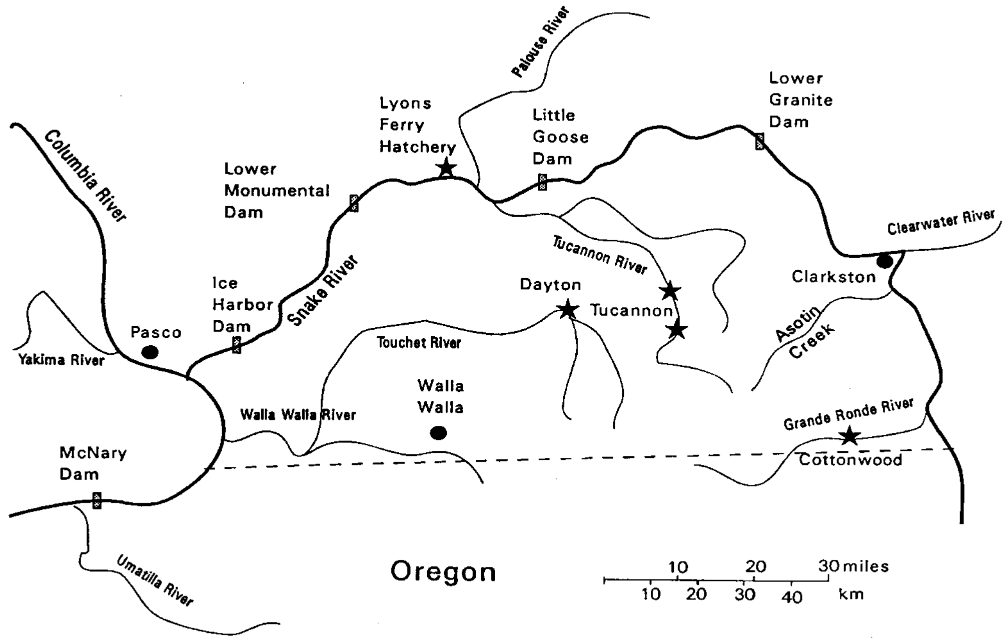


Figure 2. Lower Snake River dams and hatcheries (Mendel 1995)

Tributaries

Several small tributaries with perennial water flow that likely contain fish populations are included in this subbasin. They generally drain an arid landscape and they have similar climate and land use. Some of these streams drain the north side of the Snake River in Whitman County (e.g. Alkali Flat Creek, Penawawa, Almota, Wawawai and Steptoe Canyon creeks) others drain from the south, primarily in Garfield County (Alpowa, Deadman and Meadow creeks). Little is known about most of these streams, but there is a recent effort by several agencies to sample fish populations and habitat conditions in them. Only two tributaries with the most information will be described in this document.

Alpowa Creek

Alpowa Creek, located in southeastern Washington (Figure 3) begins in the Blue Mountains at an elevation of approximately 4,000 feet above sea level and joins the Snake River at Lower Granite Lake about seven miles west of Clarkston, Washington. Major seasonal and ephemeral tributaries of Alpowa Creek include Page, Pow Wah Kee Gulch, Clayton Gulch, and Stember creeks.

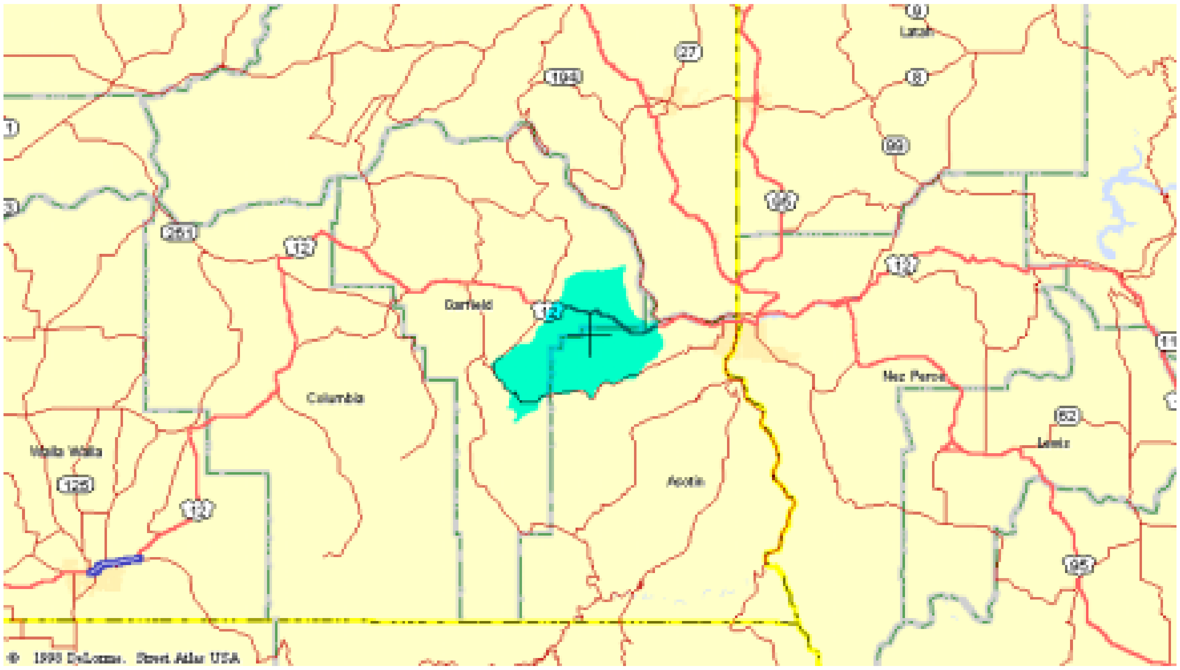


Figure 3. Location of Alpowa Creek in the Lower Snake River Subbasin.

Deadman Creek

Garfield County contains several watersheds (e.g., Pataha, Deadman, Meadow Creek, New York Gulch, Dry Gulch creeks) that drain into the Snake River. For this summary, these creeks have been grouped and identified as the Deadman Creek watershed (Figure 4) located in WRIA 35 and included in sub-region 17060106 of the Pacific Northwest as delineated by the Water Resources.

Area on the Northside of Snake River in Whitman County

An area of 281,000 acres lies north of the Snake River in Whitman County (Figure 5). This area contains watersheds of (Alkali Flat Creek and Penawawa Creek). For this summary, these creeks have been grouped and identified as the “Area north of the Snake River in Whitman County. This area has drainages very similar to Deadman Creek in Garfield County.

Small Area North of Tucannon and Pataha Creek in Columbia County

An area of 14,000 acres lies north of the Tucannon and Pataha Creek in Columbia County (Figure 6). This area contains mostly pasture some farmland on the very top of the ridges. For this summary, this area has been grouped and identified as the “Area north of Tucannon and Pataha Creek in Columbia County.

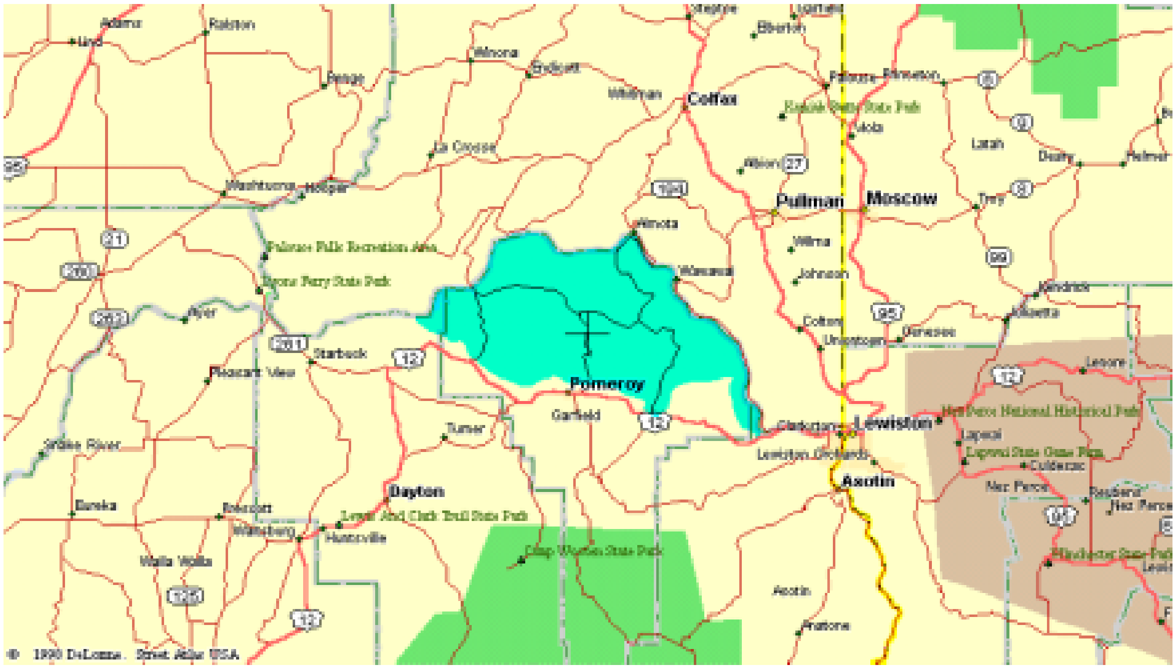


Figure 4. Location of Deadman Creek watershed in the Columbia Plateau Province.

Figure 5. Location of the area north of the Snake River in Whitman County

Figure 6. Location of area north of the Tucannon and Pataha Creek in Columbia County.

Drainage Area

Reservoirs

The four dams on the Lower Snake River impound more than 96% (137 miles) of the Snake River in Washington from Asotin, Washington, to the confluence with the Columbia River at Pasco, Washington. Also impounded is the lower 3.7 miles of the Clearwater River in upper Lower Granite Reservoir. The remaining 6.0 miles of the Snake River below Ice Harbor Dam forms the uppermost reach of McNary Reservoir (Lake Wallula) on the Columbia River. The entire reach lies within a canyon cut through the Columbia plateau. The physical characteristics of each reservoir were summarized in Bennett *et al.* (1983), and all reservoirs generally share similar morphometry (Table 1). Lower Granite is the longest reservoir, whereas Little Goose has the largest surface area. Mean depth ranges from 48-57 feet; Ice Harbor Reservoir is the shallowest. Three major tributaries enter this section. The Clearwater River joins the Snake River in upper Lower Granite and the Palouse and Tucannon rivers join near the midpoint of Lower Monumental Reservoir.

Tributaries

Alpowa Creek

The entire drainage area of the Alpowa Creek watershed is 82,944 acres (130 square miles). Most of this area is very arid landscape with several seasonal canyons that enter the mainstem Alpowa Creek.

Deadman Creek

The total watershed area is 214,560 acres of which 121,000 acres are cropland. The watersheds of Garfield County, excluding Pataha and Deadman creeks contain over 55 miles of perennial streams.

Table 1. Physical characteristics of Lower Snake River reservoirs in Washington and Idaho (Bennett et. al. 1983)

	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Normal pool elevation-m (ft) NGVD	134.0 (440.0)	164.0 (540.0)	194.0 (638.0)	225.0 (738.0)
Normal pool fluctuation-m	0.9	0.9	1.5	1.5
Reservoir length-km (miles)	51.4 (31.9)	46.2 (28.7)	59.9 (37.2)	62.8 (39.0)
Surface area-hectares (acres)	3,390.0 (8,375.0)	2667.0 (6,590.0)	4057.0 (10,025.0)	3602.0 (8,900.0)
Proportion of impounded reach-%	26.5	19.0	28.9	25.6
Maximum depth; flat pool-m (ft)	33.5 (110.0)	39.6 (130.0)	41.1 (135.0)	42.1 (138.0)
Mean depth; flat pool-m (ft)	14.5 (48.6)	17.4 (57.2)	17.2 (56.4)	16.6 (54.4)
Maximum width-m (ft)	1,609.0 (5,280.0)	1286.0 (4,220.0)	1432.0 (4,700.0)	1128.0 (3,700.0)
Mean width-m (ft)	610.0 (2,000.0)	579.0 (1,900.0)	518.0 (1,700.0)	6473.0 (2,110.0)
Major tributaries	None	Palouse River, Tucannon River	None	Clearwater River

Topography/Geomorphology

Several mountain ranges, with intervening valleys and plains, lie within the Snake River Basin, a semiarid expanse formed by successive flows of basaltic lava.

The Snake River flows across a major physiographic region of the Pacific Northwest known as the Snake River Plateau and along the southern portion of the Columbia Plateau. The Snake River Plateau extends from southwestern Oregon across southern Idaho and includes parts of Nevada and Utah. The Columbia Plateau extends south from the upper curve of the Columbia River to the Blue Mountains, west to the Cascades, and east above the Snake River, just east of the Washington-Idaho state line. These two regions are comprised mainly of lava flows covered with soil. In areas where the Snake River has cut canyons, the dark basalt rock is a primary surface feature. Many of the soils of the Snake River Plateau are light and highly erodible with low rainfall limiting the ability of vegetative cover to reestablish once removed. This results in heavy sediment loads in the river, especially during the spring runoff season.

The Miocene and Pliocene basalt flows that covered the region and diverted the Columbia River northward and westward to its present location are largely responsible for the topography of the Columbia Basin. Each basalt formation accumulated from individual flows ranging in thickness from 10-300 feet. Known as the Columbia River Basalt, the lava flows overlie the Precambrian Belt-Purcell Supergroup. The current topography of the region results from a combination of erosion and underlying structural deformation of the basalt.

The Alpowa Creek and its tributaries have cut canyons into the Columbia River Basalt since the Miocene epoch, resulting in terraces comprised of weathered stream gravel. Since Alpowa Creek currently has insufficient discharge to transport this quantity of gravel, the outcrops indicate past episodes of higher velocity and flow (Foley 1976), suggesting periods of aggradation and mass wasting dominated the geologic formation of Alpowa Creek.

Topography of the Deadman watershed is primarily long slopes intersected by steep canyons. Landforms are mainly flat to moderately sloping. Slopes are complex, being irregular, concave and convex in shape. Elevations range from 650 feet above sea level at the confluence of Deadman Creek with the Snake River to 2,800.

Climate

The Pacific Ocean, Cascade Mountains, and prevailing westerly winds largely influence the climate of this subbasin. The Cascades intercept the maritime air masses as they move eastward, creating a rain shadow effect that reaches as far as the Blue Mountains. These moisture patterns combined with differences produce warm and semiarid conditions along the reservoir system to cool and relatively wet at the tributary headwaters.

Alpowa Creek

Approximately 70-85% of the precipitation in the Alpowa Creek drainage falls from November through April. The watershed experiences precipitation mostly as rain. Although precipitation records for the Alpowa Creek area are absent, data exists for the nearby cities of Anatone and Pomeroy. In Anatone, precipitation varies from 0.71–2.12 inches in August and May, respectively, with the winter months and May showing the greatest variability in average monthly precipitation. The average monthly precipitation recorded at Pomeroy ranged from 0.59-2.16 inches in July and January, respectively, with the greatest variability in average precipitation occurring in the winter and spring. Amounts of precipitation in the Alpowa watershed varies from 14-18 inches depending on topography.

Deadman Creek

Within the Deadman Creek watershed, average annual precipitation ranges from 11 inches on cropland in the western portion of the watershed to 25 inches near Mayview at the head of Casey Creek. Most of the precipitation occurs between September and June. Temperatures range from -22 degrees ^{o}F to 109 degrees ^{o}F. The frost-free growing season within the watershed averages 110-140 days.

Soils

Throughout the subbasin, the mountain and plateau soils are dominated by wind-blown silt (loess) deposits. Volcanic ash from the eruption of Mt. Mazama can be found at higher elevations around mountain summits and north-facing canyon slopes. Plateau tops and shoulder slopes are characterized by silt loams moderately to well drained and highly erosive. Numerous soil series (e.g., Larkin, Tolo, Gwin, Walla Walla, Asotin, Chard, Athena, and Palouse) can be found in the Lower Snake River Subbasin.

Land and Water Use

Reservoirs

Lands surrounding the lower Snake River reservoirs are mainly in private ownership. The only public lands adjacent to the reservoirs are administered by the U.S. Corps of Engineers (USCOE) and isolated parcels owned by the State of Washington. The four lower Snake River reservoirs generally fill the width of the steep-sided canyon, leaving relatively little flat land for cultivation adjacent to the reservoirs. Grassland range is the predominant land cover along the reservoirs. Some relatively small and isolated crop land areas occur on the valley floor and river terraces, particularly toward the western end of the subbasin.

The Lewiston-Clarkston area is characterized by a concentration of residential, industrial, and commercial land uses. In addition, isolated pockets of urban uses are located in small communities, including Almota, Riparia, and Windust. Unlike many reaches of the Columbia-Snake River System, much of the Lower Snake River is not paralleled by highways (Corps 1999). Railroad embankments occupy areas that otherwise might have been suitable for riparian vegetation.

Tributaries

Alpowa Creek

Agriculture in the Alpowa Creek watershed and surrounding region is dominated by non-irrigated farming in the uplands, irrigated farming in the lower valleys, and cattle ranching.

Grazing is prevalent throughout the Alpowa watershed. Cattle ranching occurred on 51,000 of the Alpowa basin's 83,000 total acres in 1981, while farmlands cover approximately 27,000 acres, or 33% of the drainage (Soil Conservation Service *et al*. 1984; USDA 1981). The average size of a farm in Garfield County is 1,750 acres, and 1,933 in Asotin County—three times more than the state averages and as of 1997 had an average net worth of $650,000 each (Washington Agricultural Statistics Service 1997a, 1997b). Grazing has occurred in the riparian areas to varying degrees, and much of the riparian vegetation has been heavily impacted (Mendel 1981; Mendel and Taylor 1981; U. S. Department of Agriculture 1981).

The majority of the farmland in the Alpowa watershed is non-irrigated. Mean annual precipitation, length of growing season, and depth of soil largely determine crop production in the watershed. Winter wheat, spring grain, peas, and bluegrass seed are the major non-irrigated crops grown in the uplands of the watershed. Cropping systems most frequently used are winter wheat summer fallow; winter wheat spring grain-summer fallow; wheat-peas; annual winter wheat; annual spring barley; and annual winter barley. Farming occupies the ridge tops and small areas adjacent to the creek. In 1983, agricultural land in the upper watershed was dominated by dryland cropping with winter wheat followed by summer fallow, the cropping pattern that produces the most erosion in the region (Frazier *et al*. 1983).

Proportionally, the watershed contains few irrigated lands (Employment Security Department 1998a, 1998b). Hay, small grains, and pasture are irrigated crops grown in the bottomlands near Alpowa Creek. Where croplands are located adjacent to the channel, the impact from agriculture can be much greater. The earliest recorded observations of the Alpowa watershed described it as "little more than a brook in summer, but its waters serve to irrigate some 300 acres of orchard lands near where it joins the Snake" (Russell 1897). The Pomeroy Conservation District (PCD) has estimated about ten irrigation diversions for irrigating smaller acreage currently exist in the Alpowa watershed.

Wheat growers in this region get more economic return from winter wheat than any other crop. Consequently, agencies like conservation districts have had difficulty convincing growers to switch from conventional cropping systems and tillage practices to best management practices (BMPs) such as no-till farming. However, as better farm implements become available and awareness grows about the economics of conservation, growers in the area are slowly beginning to practice more BMPs.

A number of efforts are being undertaken in the Alpowa Creek watershed to reduce the impact of farming on the ecosystem. No-till farming is becoming increasingly popular. This method of farming leaves the crop residual on the ground, helping to hold the soil in place and reduce erosion. Other efforts being employed in the area include terraces and buffer strips that help reduce erosion, increase cover for birds and small mammals, and trap nutrients before they reach the streams.

In general, little forestry activity occurs in the Alpowa watershed. Timber harvest occurs on portions of the forested upper watershed, but this area is relatively small. As of 1981, only 3,882 acres had been harvested and 504 roaded (Soil Conservation Service *et al*. 1984). However, interpretation of aerial photos from the early 1990s by the Washington GAP Analysis project indicates that much of the forested land in the watershed continues to be disturbed by logging.

Since timber production is not significant in terms of forest surface within the Alpowa watershed, statistics for timber harvest are only available for Garfield County (Table 2). In 1997, 5% of the trees cut were Douglas fir, 1.2% ponderosa pine, 40.4% true firs, 38% miscellaneous conifers, and 15.4% hardwoods. The proportion of products from old growth trees shows that 81% of the 1993 products were from old growth trees. However, this percentage declined sharply to 33% in 1994 and 51.6% in 1995. The variability results from Forest Service policies, because all old growth products came from forestlands under their administration. Products from private owners came only from young growth trees, indicating a lack of quality in forest resources (Washington Department of Natural Resources 1998).

Clearcutting has been the usual harvesting technique in this zone, and considering its erosion potential, may contribute impacts to aquatic ecosystems within the Alpowa watershed. Statistics from 1991 to 1993 in Garfield County indicate that 48% of the harvested forestland was logged through the use of clearcutting, and 51% with all kinds of partial cuts. In any case, the total harvested surface was less than 2% of the total forestland of the county (Collins 1997).

Deadman Creek

Human activities have significantly changed the terrestrial makeup of the drainage, which is mostly under private ownership except for small parcels allotted to the state of Washington and Bureau of Land Management. The economy of the watershed is based primarily on agricultural production with non-irrigated cropland farming and livestock production as the dominant agricultural enterprises.

Table 2. Forest production in Garfield County from 1993-1996 in thousands of board feet (Washington Department of Natural Resources 1998).

Year	Private Ownership	Forest Service	Total
1993	1,355	5,788	7,143
1994	902	1,457	2,359
1995	690	855	1,545
1996	734	10,472	11,206
Total	3,681	18,572	22,253

The largest land use in the Deadman Creek watershed is crop agriculture (Figure 7). Approximately 97,465 acres or 45% of the drainage is farmed (Soil Conservation Service *et al*. 1984), with the vast majority of this land non-irrigated. Cropping systems most frequently used are winter wheat—summer fallow; winter wheat—spring grain—summer fallow; annual winter wheat; annual spring barley; and annual winter barley. Most of the irrigated cropland, located in bottomland areas along Deadman Creek and its tributaries are used for hay, small grains and some rotation pasture.

Historically, bluebunch wheatgrass (*Agropyron spicatum*) and Sandberg's bluegrass (*Poasecunda*) are thought to have dominated the arid grasslands of which the Deadman Creek ecosystem is a part (Tisdale 1961). These native grasslands were home to a variety of small animals, including white-tailed jackrabbit, sage grouse, and sharp-tailed grouse (Black *et al*. 1997). The vertebrate distribution model developed the Washington State GAP Analysis program indicates these species are no longer present in the Deadman Creek drainage.

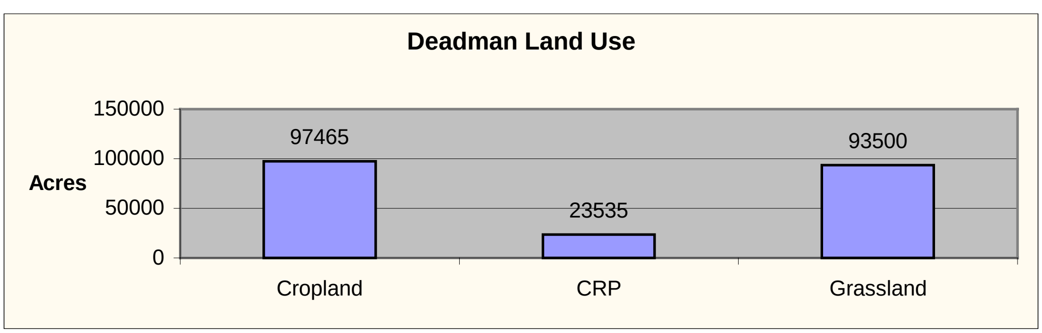


Figure 7. Land-use type in Deadman Creek watershed (Soil Conservation Service *et al*. 1984).

Since 1900, 94% of the grasslands in the Palouse Bioregion have been converted to crop, hay, or pasture lands (Black *et al*. 1997). The Southeast Washington Cooperative River Basin Study found only 25% of the vegetation within the Deadman Creek watershed similar to the early seral ecological stage of the potential natural vegetation for the area (Heady and Child 1994). This same area was found to contribute more than 3.7 tons of sediment per year to streams in the watershed (Soil Conservation Service *et al*. 1984). The dominant vegetative patterns in the watershed as mapped by the Washington State GAP Analysis Project.

A number of efforts are being undertaken in the Deadman Creek watershed to reduce the impact of farming on the ecosystem. No-till farming is becoming increasingly popular. Other efforts being employed in the area include terraces and buffer strips that help reduce erosion, increase cover for birds and small mammals, and trap nutrients before they reach the streams.

Livestock grazing is the second largest land use in the watershed. A broad-scale analysis conducted by researchers at the University of Idaho on the changes in grass, shrubs, and forest cover types of the Palouse Bioregion illustrates the magnitude of the disturbance. The Deadman Creek ecosystem falls within the southern half of this bioregion, considered to be one of the most endangered in the world.

Early settlers grazed their cattle and sheep in an area until they started to lose weight. Such concentrated grazing made possible the invasion of non-native annual species of cheatgrass (Langston 1995). The native perennial grasses were especially susceptible since they evolved without large herds of grazing mammals and the very low summer precipitation increased the grazing pressure at a time when the grasses were stressed (Tisdale 1961). Additionally, cattle selectively grazed the native bunchgrasses, further reducing their population. Once removed, native grasses had difficulty re-establishing without seed sources. Daubenmire (1970) suggested each period of overuse by domestic animals simply reduces the density of the large perennial grasses to a lower level than the preceding, and highly adaptive alien species claim the relinquished territory.

Cattle are now grazed on approximately 93,500 acres, or 44% of the Deadman Creek watershed (Soil Conservation Service *et al*. 1984). This land use occurs predominantly in areas too steep, stony, shallow, or frequently flooded for farming. These same attributes can also make the growth of native vegetation precarious. Cattle are attracted to the succulent forage, shade, reliable water supply, and more favorable microclimate that riparian areas provide. Consequently, improperly managed cattle grazing can be a serious disturbance to riparian areas and thus the cause of deterioration to aquatic ecosystems. Maximizing grazing often involves withdrawal of stream flow or the drainage of wetlands to irrigate and increase available land. Cattle remove protective vegetation resulting in increased erosion, flood flows, and water temperatures (Bauer and Burton 1993). Selected consumption of the more palatable plant species reduces the complexity of the system and the diversity of habitats available to wildlife (Knutson and Naef 1997). Cattle waste reaching the stream increases the nutrient content of the stream sometimes resulting in aquatic plant and algal blooms, and introducing undesirable bacteria. Grazing along stream banks can cause collapse, introducing still more sediment to the stream and changing the channel morphology by increasing stream width, decreasing stream depth, and removing valuable fish habitat (Bauer and Burton 1993).

There is direct evidence that cattle are damaging the riparian areas along Deadman Creek. Conditions indicate that the presence of cattle may be a contributor to the decline in aquatic habitat quality. For example, there is no documentation indicating that cattle are being prevented from entering the streams. Fecal coliform levels in Deadman Creek were above the Department of Ecology standard of 100 cfu/100 ml during every month that samples have been pulled. Therefore, it can be presumed that since cattle ranching is a primary land use in the watershed, livestock are able to access the riparian areas, remove vegetation, increase sedimentation, and deposit nutrients into the system. There is little documentation for the implementation of best management practices on the large percentage of private land used for grazing in the watershed.

There has been considerable debate within the rangeland science community as to the practical definition of rangeland condition. The traditionally established classification is based on soil quality, forage values, wildlife habitat, and the present state of the vegetation in relation to the potential plant community. More recently, range management has shifted the focus to reflect the percent similarity between the current range site condition and its ecological condition within succession. Using this system, the overall condition of rangelands within the Deadman Creek watershed is rated as poor.

Hydrology

Reservoirs

The Snake River Basin has a total drainage area of approximately 108,700 square miles upstream of its confluence with the Columbia River near Pasco, Washington. Approximately 5% of the Snake River's total drainage area is located downstream of its confluence with the Clearwater River at Lewiston, Idaho, and this region is relatively arid compared to the Snake River's upstream drainage areas. Therefore, only a relatively small amount of runoff occurs along the Lower Snake River downstream of the Clearwater River confluence. Runoff is contributed primarily from the Tucannon and Palouse Rivers, which both empty into the Snake River between Lower Monumental and Little Goose dams. Most of Idaho and lesser amounts of Oregon, Washington, Wyoming, Nevada, and Utah are within the Snake River Basin.

Tributaries

Alpowa Creek

Alpowa Creek drains the northeastern slopes of the Blue Mountains while flowing eastward to the Snake River at River Mile (RM) 130.5. The elevation of the watershed ranges from 883 feet at the mouth to 4,485 feet near Iron Springs. The relief ratio (elevation change/maximum basin length) of the watershed is .043. Based on U. S. Geological Survey (USGS) 7.5 minute quadrangles, Alpowa Creek is classified as a 4th order stream using Strahler's method with a mainstem length of 22.4 miles and a drainage of 130.6 square miles. The entire watershed has 193.4 miles (mostly seasonal drainages) of stream length and a drainage density (stream length/basin area) of 1.48 miles/square miles (Table 3). The basin has a maximum length of 16 miles from east to west and a maximum width of 11.4 miles from north to south. For the purposes of this characterization the Alpowa watershed is divided into sub-watersheds based on the USGS hydrologic unit code (Interior Columbia Basin Ecosystem Management Project 1997).

Table 3. Sub-watershed area with stream length and drainage density.

Watershed Name	Area (mi^2)	Stream Length (mi)	Drainage Density (mi/mi^2)
Clayton Gulch	17.0	28.4	1.67
Megginson Gulch	7.0	9.6	1.37
Page Creek	22.6	30.5	1.35
Pow Wah Kee Gulch	30.0	41.7	1.39
Stember Creek	14.0	24.1	1.72
Upper Alpowa Creek	40.0	59.1	1.48
TOTAL	130.6	193.4	1.48

The watershed has a dendritic pattern, showing a relatively uniform geologic structure caused by the gentle uplift and warping of horizontal basalt units. The main channel of Alpowa Creek is the only creek in the watershed that maintains perennial flow. Stember Creek maintains year-round flow most years. Other areas in the watershed will maintain perennial flows for a length downstream of springs, but then flow subsurface. Steep valleys, deeply incised into flat-lying basalt, with relatively flat ridgetops characterize the Alpowa Creek watershed. Grasslands dominate the watershed with forested areas restricted to north-facing slopes and the upper watershed. The soils that mantle the flat ridgetops are generally deep loess deposits, while the soils on the valley sides are shallow and rocky. The potential for water storage in the soil is variable from high potential areas adjacent to the channel and on top of the ridges, to relatively low on the valley sides.

Figure 8 shows the channel gradients of Alpowa Creek and its primary tributaries. Generally, a stream with a steeper longitudinal profile is associated with bedrock that is resistant to erosion, such as the flat-lying basalt layers of the Alpowa watershed. Steeper gradients also show a more rapid flood response, represented by a sharper peak on the flood hydrograph (Gordon *et al*. 1992). The shorter tributaries, such as Clayton Gulch, Megginson Gulch, and Stember Creek, show a different channel profile pattern than the longer tributaries, including the mainstem Alpowa Creek. The shorter tributaries show a shallow slope in the headwaters, then a period of steeper slope, returning to a shallower slope in the lower sections. The larger tributaries show a more concave shape, with steeper headwaters gradually lessening in slope to the mouth.

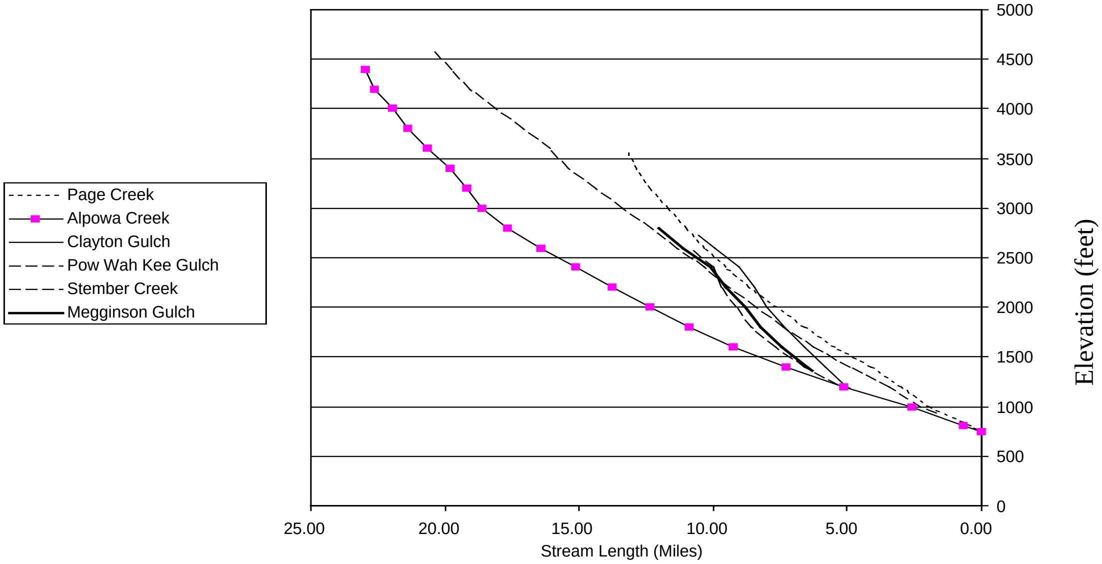


Figure 8. Longitudinal profiles of major creeks in the Alpowa watershed.

The maximum streamflow in the Alpowa watershed generally occurs during the spring when the region sees high precipitation accompanying snowmelt. Minimum streamflow generally occurs in the summer months and early fall, when precipitation is low and irrigation withdrawals are highest. Alpowa Creek maintains perennial flow in part due to large springs located in the mid- and upper reaches of the creek. These springs are important in providing cool water in sufficient supply to maintain an anadromous fish population. The USGS operated two crest stage stream gages on small sub-basins within the Alpowa watershed (Table 4). The crest stage gages are used to measure the annual peak, or maximum annual flow.

Table 4. Stream gages in the Alpowa watershed (USGS data).

	Location	Drainage Area (mi^2)	Type of Measure	Period of Record	# of Obs.
13343510	Alpowa Creek at Peola, WA	0.5	Crest Stage	1971-77	5
13343520	Clayton Gulch near Alpowa, WA	5.6	Crest Stage	1961-76	15

The expected accuracy of the 10-year flood is +/- 25% because of the brief record (Gordon *et al*. 1992). Table 5 gives the values of the 2-, 5-, and 10-year floods. The station located at Peola has too brief of a record to plot a flood frequency curve. Table 6 lists the streamflow measurements on Alpowa Creek collected by WSU once a month from September 1998 through the present at site Alpowa 1 at the mouth of the creek.

Table 5. Discharge for 2-, 5-, and 10-year floods at Clayton Gulch (WSU data).

Recurrence Interval	Discharge (cfs)
2-year flood	101
5-year flood	206
10-year flood	286

Table 6. Discharge measured at the Alpowa 1 water quality monitoring site (WSU data).

Sample Date	Discharge (cfs)
09-16-98	9.4
10-16-98	12.3
11-17-98	12.0
12-16-98	13.5
01-14-99	12.8
02-16-99	14.9
03-15-99	13.1
04-15-99	11.0
05-17-99	9.2
05-26-99	11.0
06-15-99	9.1
07-13-99	7.0
08-16-99	8.9

Peak flow frequencies for several sites in the watershed were computed using regression equations developed by the USGS (Sumioka *et al*. 1998). The regression equations relate peak discharge to drainage area in square miles and mean annual precipitation in inches and provide estimates for return periods of 2, 10, 25, 50, and 100 years. Table 7 shows the results for Page Creek, Upper Alpowa, Pow Wah Kee Gulch, Stember Creek, and Lower Alpowa.

The Stember Creek calculation includes Megginson Gulch. Stember Creek and Megginson Gulch are the steepest of the major tributaries and likely convey the flood peaks more rapidly than the lower slope tributaries such as Page Creek and Pow Wah Kee Gulch. Stember Creek also delivers the highest discharge per unit area according to the regression equation used.

Table 7. Calculated discharge for exceedance probabilities.

Watershed	Area (Square miles)	Precipitation (Inches)	Return Period (years)	Discharge (cfs)	Error (+/- percent)
Page Creek	22.4	16.1	2	160	80
(Site #A2)			10	620	57
			25	990	55
			50	1340	55
			100	1740	56
Upper Alpowa	38.7	18.0	2	270	80
(Site #A4)			10	930	57

Watershed	Area (Square miles)	Precipitation (Inches)	Return Period (years)	Discharge (cfs)	Error (+/- percent)
			25	1430	55
			50	1900	55
			100	2430	56
Pow Wah Kee Gulch	29.7	18.1	2	230	80
(Site #A3)			10	790	57
			25	1240	55
			50	1650	55
			100	2120	56
Stember Creek	21.0	17.9	2	330	80
(Site #A5)			10	1110	57
			25	1710	55
			50	2250	55
			100	2870	56
Lower Alpowa Creek	129.1	17.1	2	570	80
(Site #A1)			10	1840	57
			25	2780	55
			50	3620	55
			100	4570	56

The design flood (Q_{100}) for the Highway 12 bridge which crosses Alpowa Creek near Site #A1 was 5,400 cfs (B. Baker, Washington Department of Transportation, personal communication August 1999). This figure falls within the range of values calculated for Site #A1 at the .01 exceedance probability.

Peak flow in the Alpowa Creek generally occurs due to rain-on-snow events and thunderstorms. Thunderstorms mostly occur during late July to September, while rain-on-snow events mostly occur during winter or early spring. Out of the 15 annual peak flow events reported by the USGS at Clayton Gulch during 1961-1976, four occurred during the late spring and summer months and likely had little snowmelt component (Table 8). The flood of record for this station was measured on August 24, 1954 at 1,600 cfs (Thomas *et al*. 1963). This value shows the potential flows generated by extreme summer precipitation events. All of the peak flows measured on Alpowa Creek at Peola showed winter peaks occurring in January, February, or March (Table 9).

Groundwater plays an important role in the hydrology of the Alpowa watershed. Springs provide much of the summer baseflow and a cool water source necessary for steelhead and cold water resident fish. From aerial photos it is evident that large vegetation in the channel is often associated with mapped spring locations. From the brief field reconnaissance, it appears that many of the springs are where the channel has intercepted an interflow zone between basalt layers.

Table 8. Annual peak flows for Clayton Gulch near Alpowa, Washington

Date	Discharge (cfs)	Discharge/Area (cfs/ mi^2)
06-03-61	203	36.25
02-03-63	298	53.21
01-25-64	111	19.82
12-22-64	142	25.36
03-28-66	73	13.04
06-13-67	58	10.36
12-25-67	54	9.64
01-06-69	67	11.96
01-23-70	25	4.64
01-09-71	270	48.21
08-15-72	284	50.71
05-24-73	114	20.36
01-16-74	40	7.14
01-14-75	174	31.07
01-16-76	86	15.36

Table 9. Annual peak flows for Alpowa Creek at Peola, Washington

Date	Discharge (cfs)	Discharge/ Area (cfs/ mi^2)
01-09-71	0.5 (estimated)	1
02-07-72	11.0	22
03-01-73	5.5	11
01-16-74	11.0	22
01-14-75	1.5	3
02-16-76	9.4	18.8
03-06-77	0.1	.2

Deadman Creek

Deadman Creek, which drains the northern portion of Garfield County flows westward to the Snake River, where it joins at RM 84.75. The elevation of the watershed ranges from 650 feet at the mouth to 2,500 feet near Kirby. The relief ratio (elevation change/maximum basin length) of the watershed is .013. Mainstem length of 26 miles and a drainage of 335 square miles. The entire watershed has 68 miles of stream length and a drainage density (stream length/basin area) of .33 miles/square miles (Table 10). The basin has a maximum length of 25 miles from east to west and a maximum width of 13 miles from north to south. For the purposes of this characterization the Deadman watershed is divided into sub-watersheds (Figure 9) based on the USGS hydrologic unit code (Interior Columbia Basin Ecosystem Management Project 1997).

Table 10. Sub-watershed area with stream length and drainage density.

Watershed Name	Area (mi^2)	Stream Length (mi)	Drainage Density (mi/mi^2)
Ping Gulch	13	5.52	.42
Lynn Gulch	14.63	6.4	.44
Meadow Creek	68.37	23.4	.34
Deadman Creek	107.6	33	.31
Total	203.6	68.3	.33

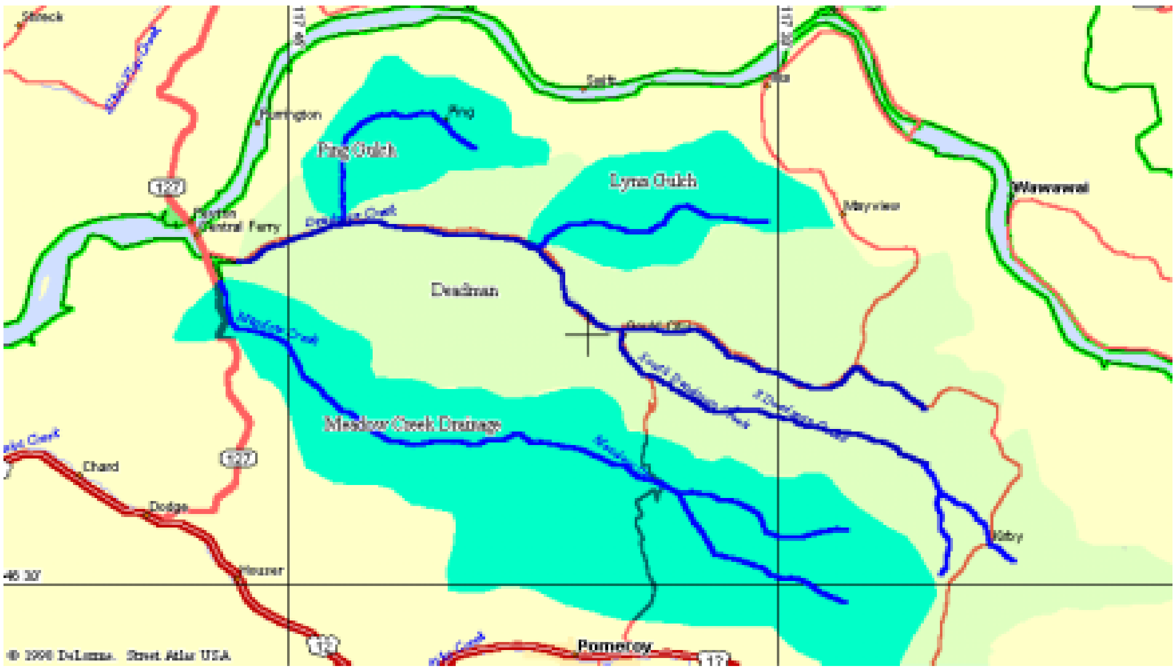


Figure 9. Subwatersheds of Deadman Creek

Figure 10 shows the channel gradients of Deadman Creek and its primary tributaries. Generally, a stream with a steeper longitudinal profile is associated with bedrock that is resistant to erosion, such as the flat-lying basalt layers of the Deadman watershed. Steeper gradients also show a more rapid flood response, represented by a sharper peak on the flood hydrograph (Gordon *et al*. 1992).

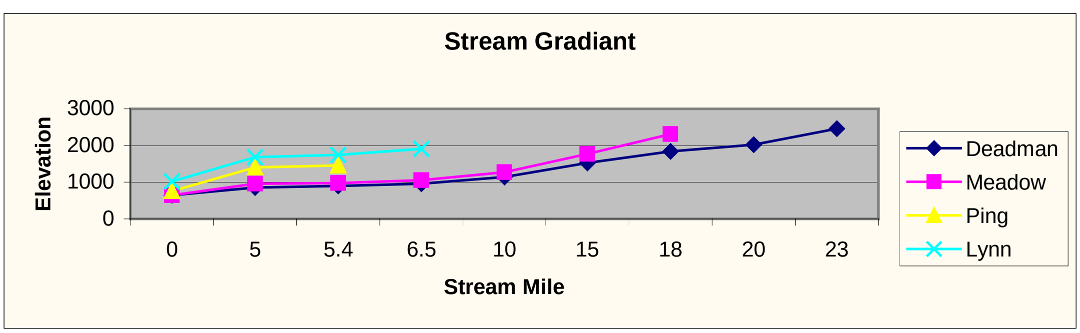


Figure 10. Stream gradients of Deadman Creek

Water Quality

Reservoirs (Corps 1999)

Long-term monitoring stations along the Lower Snake River have been used by a number of state and federal agencies going back as far as 1975 (Table 11and Table 12). The sampling locations, frequency, and number of years sampled varies between the various agencies. Much of this monitoring focused on a few key parameters including temperature, pH, conductivity, turbidity, dissolved oxygen, and total dissolved gas supersaturation (TDG). The Corps monitored these parameters, as well as Secchi transparency within each of the reservoirs at a limited frequency of one to four times a year. Occasionally, other parameters such as hardness, total suspended solids (TSS), turbidity, and nutrient levels were measured. The U.S. Environmental Protection Agency (EPA) and the individual states conducted ambient water quality monitoring programs to primarily assess compliance status and trends. The Washington Department of Ecology (WDOE) sampled intensively (*i.e.*, up to 10 samples per year) in 1975 for these same parameters plus fecal coliform bacteria. The USGS samples about once a year at two long-term monitoring stations on the Lower Snake River (Anatone (RM 167) and Burbank (RM 2.2), Washington). The Universities of Washington and Idaho analyzed pre-impoundment water quality at the Lower Granite Dam area from 1970-1972 (Falter *et al.*, 1973). Limited data have been collected, however, on concentrations of various toxins including heavy metals, pesticides, and other organic compounds.

Table 11. Summary of long-term water quality monitoring data for various sampling locations throughout the project area (Corps 1999).

River/Location	River Mile	Agency	Sampling Period	No. of Years	Sampling Frequency	Parameters[1]
Snake River						
Burbank, WA	2.2 8.7	USGS	1960-69, 72-78; 1979-1990	16	1/yr	Conventional parameters
Ice Harbor Dam, Tailwater	6.0	Corps	1991-pres	9+	Apr-Sep (Cont)	B, TDG, Temp, DO
Ice Harbor Dam, Forebay	9.7	Corps	1984-pres	15+	Apr-Sep (Cont)	B, TDG, Temp, DO
Ice Harbor Pool	18	Corps EPA WDOE	1975-90 1975 1975-90	9 1 15	3/yr 5/yr 6-10/yr	Conventional parameters except TSS & TN Conventional par except TSS, Turb, Hardness Conventional parameters except nutrients
Lower Monumental Dam, Tailwater	40.6	Corps	1991-pres	9+	Apr-Sep (Cont)	B, TDG, Temp, DO
Lower Monumental Dam, Forebay	41.6	Corps	1984-pres	15+	Apr-Sep (Cont)	B, TDG, Temp, DO
Lower Monumental Pool	44	Corps EPA	1975	1	5/yr	Temp, Cond, DO, pH, Turb

River/Location	River Mile	Agency	Sampling Period	No. of Years	Sampling Frequency	Parameters[1]
Little Goose Dam, Tailwater	69.5	Corps	1978-1992	9+	Apr-Sep (Cont)	B, TDG, Temp, DO
Little Goose Dam, Forebay	70.3	Corps	1984-pres	15+	Apr-Sep (Cont)	B, TDG, Temp, DO
Little Goose Pool	83	Corps EPA	1984-pres 1975	9 1	1/yr 5/yr	Temp, Cond, DO, pH, Turb
Lower Granite Dam, Tailwater	106.7	Corps	1991-pres	9+	Apr-Sep (Cont)	B, TDG, Temp, DO
Lower Granite Dam, Forebay	107.5	Corps	1984-pres	15+	Apr-Sep (Cont)	B, TDG, Temp, DO
Lower Granite, Lower Pool	106.5	Corps USGS EPA	1978-89 1975-78 1975-77	9 4 4	1-2/yr 1/yr up to 25/yr	Conventional parameters Temp & Cond mostly Temp, DO, Cond, Turb, pH, TP, & OP
Lower Granite, Upper Pool	120	Corps USGS	1978-92 1974-77	9 3	1-2/yr 1/yr	Temp, Cond Conventional parameters except TSS, TP, & OP
Anatone, WA	167	USGS Corps	1974-pres 1999	20+ 1	1/yr Apr-Sep (Cont)	Temp & Cond; other par less frequently B, TDG, Temp, DO
[1]Conventional parameters consist of temperature (Temp.), conductivity (Cond.), dissolved oxygen (DO), pH, total suspended solids (TSS), turbidity (Turb.), total nitrogen (TN), nitrate and nitrite (NO_2 and NO_3), and total phosphorus (TP). Other parameters include total dissolved gas, measured continuously (TDG), and barometric pressure (B).						

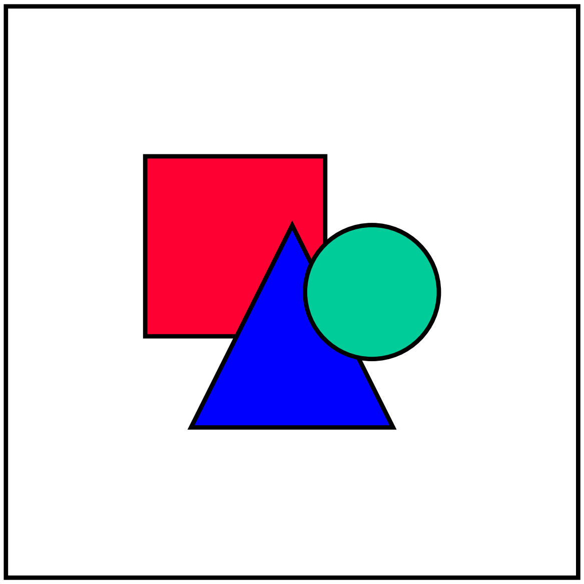
Table 12. Sampling stations in the Lower Snake River in 1997 (Corps 1999).

Station Name	River Mile	Reach	Reach Type	Purpose	
Snake					
SNR-148	-148	Asotin	Free-flowing	PP/Limno /ABA	Free-flowing Snake River, little controlled
SNR-140	-140	Lewiston /Clarkston	Free-flowing	Limno	Free-flowing Snake River used in previous studies. Analogous benefits at the Clearwater 1 station.
SNR-129	-129	Lower Granite Reservoir	Transition zone	Limno	Visited in previous studies, and represents the transition between riverine and lacustrine environments.
SNR-118	-118	Lower Granite Reservoir	Reservoir	PP/Limno /ABA	Represents the location in Lower Granite pool where complete mixing of the inflowing Snake and Clearwater Rivers has occurred. Previously visited and part of the primary productivity study.
SNR-108	-108	Above Lower Granite Dam	Reservoir	Limno	Site close to the forebay that was included in previous studies and located at deepest part of the reservoir.
SNR-106	-106/-105	Below	Free-	PP/Limno	hybrid of free-flowing/reservoir, but more

Station Name	River Mile	Reach	Reach Type	Purpose	
SNR-105		Lower Granite Dam	flowing/reservoir mix	/ABA	riverine.
SNR-83	-83/81	Little Goose Reservoir	Reservoir	PP/Limno/ABA	Only station that has consistently been sampled in Little Goose reservoir, and was included in the primary productivity study.
SNR-66	-68/67	Below Little Goose Dam	Free-flowing/reservoir mix	PP/Limno/ABA	Hybrid of free-flowing/reservoir, but more riverine.
SNR-50	-52/50	Lower Monumental Reservoir	Reservoir	PP/Limno/ABA	Snake River impoundment.
SNR-40	-40/37	Below Lower Monumental Dam	Free-flowing/reservoir mix	PP/Limno/ABA	Hybrid of free-flowing/reservoir, but more riverine.
SNR-18	-18	Ice Harbor Reservoir	Reservoir	PP/Limno/ABA	The only site that has routinely been sampled in the Ice Harbor reservoir.
SNR-6	-6	Below Ice Harbor Dam	Free-flowing/reservoir mix	PP/Limno/ABA	Hybrid of free-flowing/reservoir, but more riverine.
PP=Primary Productivity Sampling LIMNO=Limnological Sampling ABA=Attached Benthic Algae Sampling					

In 1994, the Corps initiated an extensive sampling program throughout the Lower Snake River Basin with the assistance of research teams from Washington State University (WSU), National Marine Fisheries Service (NMFS), and the University of Idaho (UI). The primary goal of this sampling program was to provide a more complete synopsis of the existing limnological and biological productivity conditions above, below, and throughout the Lower Snake River reach and to assess the effects, if any, that the various dams have on water quality. Sampling was conducted both in the impoundments and in the "free-flowing" reaches and major tributaries. Initially, in 1994 and 1995, data were collected on a monthly or bi-weekly basis within the Lower Snake River system. The sampling frequency was increased in 1997 to bi-weekly monitoring through the growing season in the Lower Snake River. An extensive suite of parameters was sampled during these investigations, including many of the same conventional parameters used in the long-term monitoring studies such as pH, alkalinity, conductivity, dissolved oxygen, nutrients, TSS, and turbidity. Various anions and cations were also monitored including chloride, silica, sulfate, calcium, magnesium, sodium, and potassium. In addition, biochemical oxygen demand and sediment oxygen demand were also measured at selected locations as well as various biological parameters including chlorophyll a, phytoplankton, zooplankton, attached benthic algae, and other primary productivity indicators.

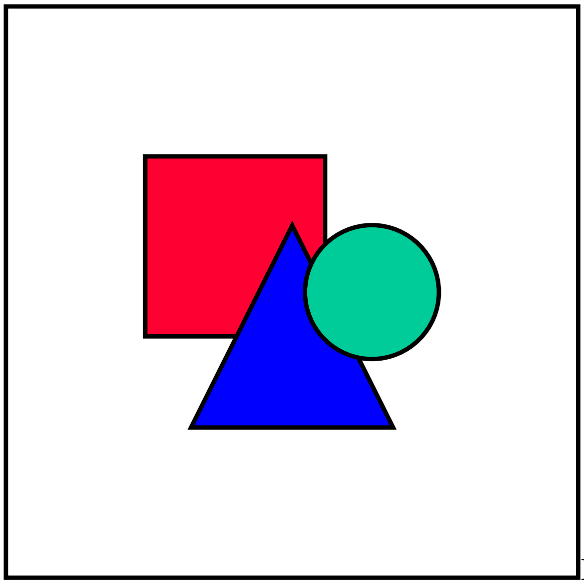
As many as 13 sampling stations were established along the mainstem of the Lower Snake River. Upstream and downstream stations bracketed each of the four dams accounting for eight stations. Other key sampling stations include those representing the major tributary inputs to the Lower Snake River, as well as two additional stations in the upper portions of the Lower Granite Reservoir at RMs 118 and 129.

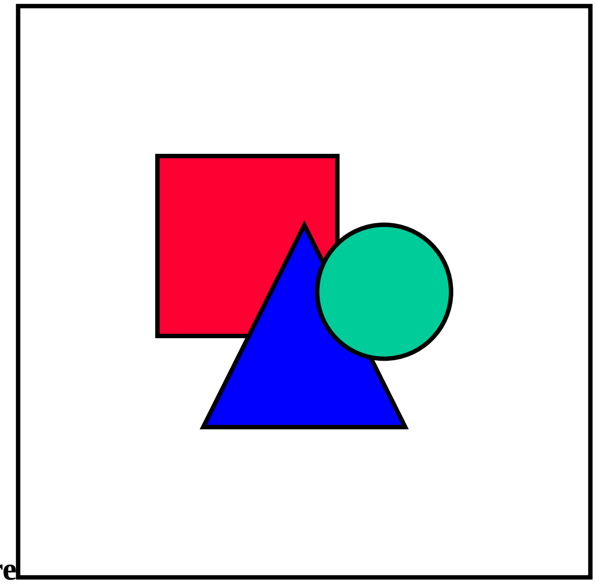


Sediment samples were collected along transects established across the reach of the Lower Snake River and upstream of each dam. Three additional transects were sampled in the McNary Reservoir for a total of 54 transects. Sampling during Phase 1 focused on identifying those locations within the study reaches where the river bed sediment consisted primarily of very fine sand (0.062-0.125 mm) and silt/clay-size (<0.062 mm) particles (CH2M Hill 1998). These locations were to be revisited during Phase 2 for the collection of sediment samples for the analysis of inorganic and organic chemical constituents. Only those areas where fine-grained sediments are present were of interest because it is assumed that only the fine-grained sediments will be eroded and transported by the free-flowing water if the drawdown alternative is implemented, and any organic or inorganic contaminants of concern would be most likely concentrated in the finer-grain-size fraction due to their physio-chemical properties.

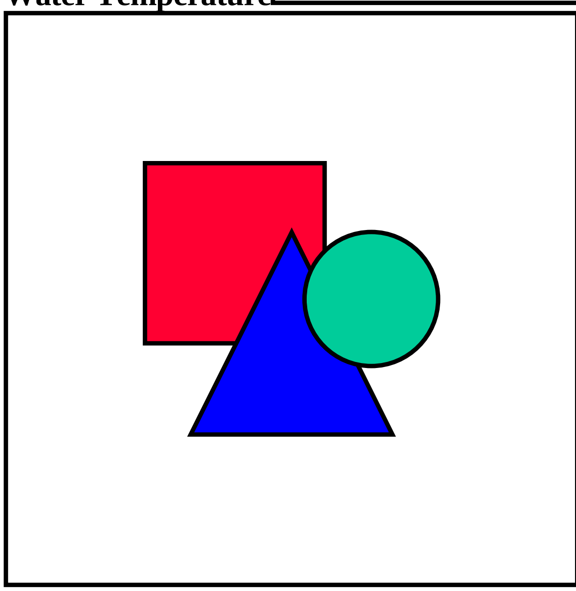
Phase 2 of the study involved collection of sediment core samples from the areas identified in Phase 1 as having the highest percentage of fine particles. At each of the sediment sampling locations, river water samples were also collected. The river water samples were collected to perform elutriate tests and to determine existing water quality conditions.

The sediment samples were analyzed for a variety of parameters including metals, semivolatiles, herbicides, pesticides, organics, mercury, and nutrients. Elutriates were prepared for pH 4, ambient pH, pH 10 and for an exotic condition. The exotic elutriation was prepared having a pH of 2.6 and an oxidation-reduction potential (ORP) of 1,100 millivolts. Only the results of the ambient pH were used for the sediment evaluation.


Monthly average flows ranged from a high of about 170 kcfs in May to a low of approximately 25 kcfs in November and December. Flows in August and September of 1997 were nearly twice as high as the historical average flows of 20 to 25 kcfs for these months. In 1995, the mean monthly flows were very close to the historical monthly averages for the first half of the year, and reflect slightly wetter conditions during the summer and fall months. In 1994, average monthly flow levels were consistently below the historical averages with a high of about 75 kcfs during May, and a low of around 10 kcfs for much of August and September. The August and September flow levels were nearly 50% lower than historical averages for these months. The average flow data for 1975 through 1977 contained two years that had above-average flows (1975 and 1976), and one year (1977), which was primarily below average. Although the flow rates at the Ice Harbor Dam varied from Lower Granite Dam, the same seasonal flow pattern and annual variability.



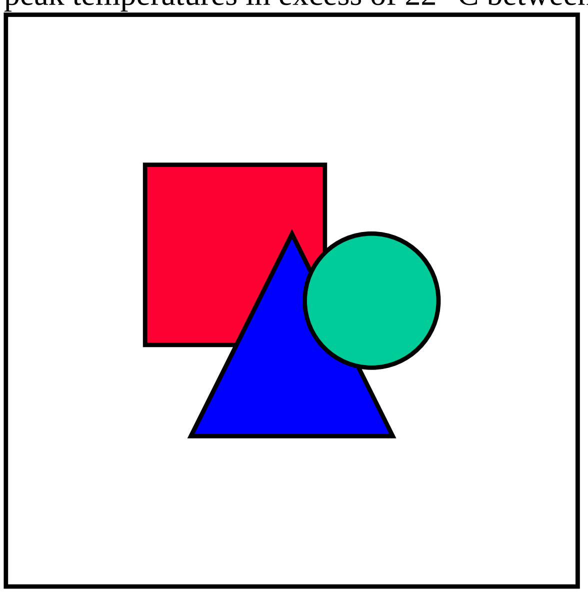
Water Temperature



Water temperature is one of the more critical parameters affecting fish migration behavior during the April through September adult and juvenile salmonid migration periods. The optimal temperature range during the summer juvenile and adult migration period is generally recognized to be between 10 to 20°C (45 to 68°F) (Bonneville Power Administration, BPA 1995). The upper tolerance limit is considered to be 21°C (70°F), depending on whether fish have had sufficient time to acclimate to increasing temperatures. Water temperatures above 21°C (70°F) can have lethal effects on salmonid fishes if these high temperature waters cannot be avoided (BPA 1995). However, salmon stocks have adapted certain life stages to higher seasonal temperatures in the southern part of their range.

Historic water summer temperatures in the Snake River basin far exceeded the optimal ranges mentioned above. Adaptations included spring and summer chinook migrating into higher elevation tributaries to spawn so their young could rear where water temperatures were cooler. Snake River coho, sockeye, and steelhead adapted similar to the spring/summer chinook. Fall chinook spawned in the mainstem (usually near the mouth of major tributaries), about 95% of them upstream from the Lower Snake River. Their life history was likely adjusted in avoidance of hot summer water temperatures in the Lower Snake River by migrating before the heat of the summer when shoreline rearing areas heated up. Juvenile fall chinook from above Hells Canyon probably reached the Lower Snake River before peak hot temperatures in the summer. Juvenile fall chinook from Hells Canyon, the Lower Clearwater River, and the Lower Snake River probably moved through the Lower Snake River to rear in the slightly cooler waters of the lower Columbia River (now McNary, John Day, The Dalles, and Bonneville Reservoirs) if they had not experienced a sufficient growth period in the middle or upper Snake River.

Water temperatures in the Lower Snake River are relatively cool in May and June during the peak flow and snowmelt period, with typical readings ranging from 10 to 14°C (50 to 57°F). By mid- to-late July, however, temperatures usually warm up to 22°C to 24°C (71.6 to 75.2°F) and remain above 20°C (68°F) until late September. The highest temperatures generally occur from August to mid-September (BPA 1995). The late-summer maximum temperatures suggest that the most significant effect of hydropower dam construction may be that the period of maximum temperatures has shifted from mid-July through August to mid-August through September (EPA and NMFS 1971; BPA 1995). This is based upon a comparison with temperature data collected prior to dam construction (1955-1958) in the Lower Snake River, where maximum temperatures were frequently above 22°C (72°F) from mid-July to late August (FWPCA 1967). Similarly surface water temperature data (1 m depth) collected at SNR-107, prior to construction of the Lower Granite Dam, reached peak temperatures in excess of 22° C between mid-July and late-August.



Since each of the Corps dams became operational, the Corps has recorded daily water temperatures passing through the dams and reported that information with adult fish count information. The fishery agencies and Corps agreed years ago that the scroll case water temperatures would be the best representation of the average water temperature the fish would experience. The scroll case draws water from all depths of the reservoir, and passes that water over the turbine blades to drive the generators of the dam.

Maximum scroll case temperatures are represented in Table 13 for Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dam. There is a break in the data for Little Goose Dam from 1982 through 1990 when adult fish were not counted. Also shown in the table is the period of time that the water temperature exceeded the state temperature standard (20°C or 68°F).

Table 13. Maximum water temperatures at Corps dams (Corps 1999)

Year	Ice Harbor					Lower Monumental				
	Degrees F	Degrees C	Days Over 68	First Day	Last Day	Degrees F	Degrees C	Days Over 68	First Day	Last Day
62	76	24.44	60	16 July	19 Sep					
63	76	24.44	71	13 July	21 Sep					
64	72	22.22	47	15 July	30 Aug					
65	75	23.89	42	21 July	31 Aug					
66	75	23.89	60	14 July	11 Sep					
67	76	24.44	75	12 July	30 Sep					
68	75	23.89	54	9 July	9 Sep					
69	73	22.78	57	19 July	13 Sep					
70	73	22.78	61	13 July	11 Sep	74	23.33	53	10 July	3 Sep
71	74	23.33	54	23 July	16 Sep	75	23.89	54	22 July	13 Sep
72	73	22.78	36	9 Aug	13 Sep	73	22.78	39	5 Aug	13 Sep
73	72	22.22	42	22 July	7 Sep	72	22.22	43	25 July	5 Sep
74	72	22.22	46	30 July	13 Sep	71	21.67	48	27 July	12 Sep
75	71	21.67	29	28 July	31 Aug	70	21.11	33	31 July	1 Sep
76	71	21.67	44	30 July	16 Sep	70	21.11	41	7 Aug	7 Sep
77	73	22.78	43	27 July	7 Sep	71	21.67	35	27 July	11 Sep
78	72	22.22	28	3 Aug	8 Sep	72	22.22	38	30 July	5 Sep
79	73	22.78	74	19 July	30 Sep	73	22.78	67	24 July	28 Sep
80	72	22.22	48	31 July	16 Sep	71	21.67	40	24 July	2 Sep
81	73	22.78	55	29 July	30 Sep	74	23.33	55	1 Aug	24 Sep
82	72	22.22	35	14 Aug	17 Sep	72	22.22	52	26 July	15 Sep
83	73	22.78	40	8 Aug	16 Sep	74	23.33	42	5 Aug	17 Sep
84	73	22.78	60	20 July	17 Sep	73	22.78	49	26 July	12 Sep
85	75	23.89	51	17 July	5 Sep	73	22.78	54	10 July	1 Sep
86	75	23.89	73	9 July	19 Sep	74	23.33	52	9 July	20 Sep
87	72	22.22	81	4 July	22 Sep	71	21.67	71	12 July	20 Sep
88	72	22.22	53	27 July	17 Sep	72	22.22	50	25 July	12 Sep
89	71	21.67	50	25 July	12 Sep	71	21.67	49	25 July	11 Sep
90	73	22.78	70	24 July	1 Oct	73	22.78	59	30 July	26 Sep
91	74	23.33	49	1 Aug	18 Sep	74	23.33	44	5 Aug	17 Sep
92	71	21.67	43	16 July	10 Sep	71	21.67	50	10 July	13 Sep
93	68	20.00	0	--	--	68	20.00	0	--	--
94	70	21.11	18	16 July	5 Aug	71	21.67	30	*13 July	*20 Sep
95	70	21.11	18	25 July	11 Aug	70	21.11	23	19 July	10 Aug
96	70	21.11	41	23 July	1 Sep	70	21.11	41	20 July	29 Aug
97	71	21.67	44	21 July	5 Sep	71	21.67	28	3 Aug	8 Sep
98	73	22.78	52	*19 July	*8 Oct	73	22.78	75	17 July	30 Sep

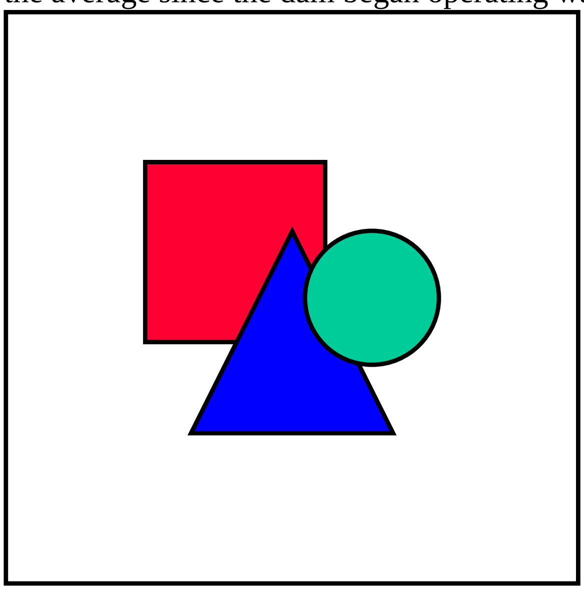
Year	Little Goose					Lower Granite				
	Degrees F	Degrees C	Days Over 68	First Day	Last Day	Degrees F	Degrees C	Days Over 68	First Day	Last Day
62										
63										
64										
65										
66										
67										
68										
69										
70										
71	76	24.44	54	18 July	9 Sep					
72	73	22.28	42	1 Aug	12 Sep					
73	74	23.33	46	13 July	2 Sep					
74	74	23.33	51	23 July	14 Sep					
75	70	21.11	37	25 July	30 Aug	76	24.44	35	21 July	25 Aug
76	71	21.67	38	28 July	13 Sep	72	22.22	51	18 July	10 Sep
77	72	22.22	26	10 Aug	4 Sep	76	24.44	49	28 July	5 Sep
78	72	22.22	29	30 July	27 Aug	75	23.89	35	20 July	10 Sep
79	74	23.33	64	22 July	24 Sep	74	23.33	59	17 July	17 Sep
80	73	22.78	43	22 July	3 Sep	74	23.33	39	21 July	28 Aug
81	73	22.78	61	23 July	21 Sep	78	25.56	64	17 July	18 Sep
82	73	22.78	49	29 July	15 Sep	74	23.33	46	26 July	12 Sep
83			No data	--	--	74	23.33	41	30 July	9 Sep
84			No data	--	--	74	23.33	46	23 July	6 Sep
85			No data	--	--	74	23.33	49	7 July	28 Aug
86			No data	--	--	74	23.33	62	30 June	12 Sep
87			No data	--	--	73	22.78	74	26 June	15 Sep
88			No data	--	--	73	22.78	85	25 June	20 Sep
89			No data	--	--	74	23.33	47	13 July	28 Aug
90			No data	--	--	77	25.00	77	3 July	18 Sep
91	76	24.44	55	23 July	16 Sep	76	24.44	55	12 July	12 Sep
92	72	22.22	49	4 July	10 Sep	72	22.22	25	*1 July	*28 Aug
93	72	22.22	40	8 Aug	29 Sep	69	20.56	8	18 Aug	5 Sep
94	72	22.22	28	*8 July	*2 Oct	73	22.78	32	*17 July	*11 Sep
95	72	22.22	26	16 July	9 Aug	68	20.00	0	--	--
96	71	21.67	53	12 July	2 Sep	70	21.11	23	22 July	16 Aug
97	71	21.67	57	1 Sep	26 Sep	71	21.67	26	21 Aug	17 Sep
98	72	22.22	82	12 July	1 Oct	70	21.11	36	*10 July	*25 Sep

NOTES: Highest temperatures usually occur in August at all dams, but with unseasonably warm weather, may occur in late July or with prolonged hot weather, in September. Blanks for Little Goose (1983-90) are for years when data was not reported.
*Temperatures over 68 degrees F occurred between 2 periods:

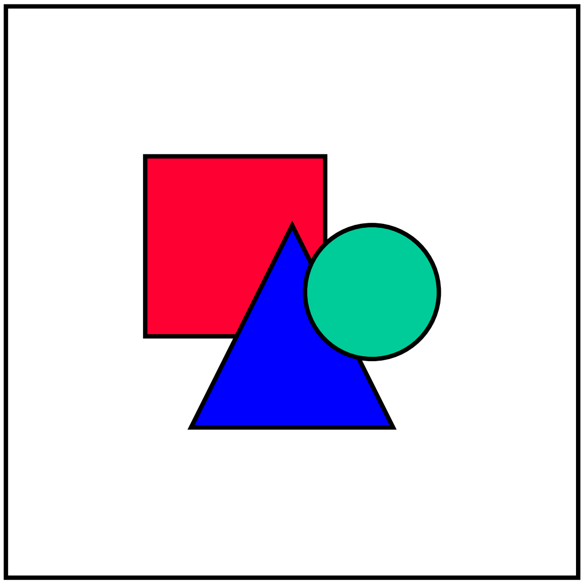
LM, 1994 13 July-21 July, 9 days over 68 F 31 Aug-20 Sep, 21 days over 68 F LGO, 1994 8 July-4 Aug, 28 days over 68 F 24 Aug-2 Oct, 40 days over 68 F	LWG, 1992 1 July, 1 day over 68 F 5 Aug-28 Aug, 25 days over 68 F 13 Aug-11 Sep, 29 days over 68 F LWG, 1998 10 Jul-22 Jul, 5 days over 68 F 7 Aug-25 Aug, 7 days over 68 F 2 Sep-25 Sep, 24 days over 68 F

The general impression from these data is that maximum water temperatures have gone down since the reservoirs were created. The highest maximum temperatures (24.4°C or 76°F) generally occurred within the first year or two after the reservoir was created at all of the facilities except Lower Granite where in 1981 and 1990, 78°F and 77°F temperatures were recorded. Days when the maximum exceeded the standard started at Ice Harbor Dam as early as the 4th of July and as late as the middle of August. Temperatures exceeded the standard as late as the end of September. The duration of the exceedance appears to be more a function of the annual flow volume influenced by the duration of hot summer weather rather than related to water warming in the reservoirs.

Since 1991, cool water releases from Dworshak Reservoir have had a substantial impact on the maximum temperature and days of exceedance. From 1992 through 1998, the maximum temperature at Lower Granite Dam ranged from 68 to 72°F, whereas the average temperature since the dam began operating was 73.4°F, reaching a high of 77°F in 1990. The number of days of exceedance from 1992 to 1998 ranged from 0 to 36, whereas the average since the dam began operating was 44.3 days, ranging from 25 to 85 days.



Peak surface water temperatures at Lower Granite Dam during the sampled years were correlated to differences in average flow rates. For example, in 1977, average flow rates at Lower Granite Dam were below the historical average for most of the year. In contrast, the surface water temperatures observed were consistently higher than those observed in the high flow years of 1975 and 1976, and reached a peak of nearly 25°C. Conversely, the average monthly flow rate in August 1997 was approximately 150% greater than the average monthly flow rate in August 1994. The peak occurred between July and September, when observed temperatures were generally lower than those observed in 1994. Surface water temperature data collected in Ice Harbor Reservoir showed a similar relationship to flow, with higher temperatures being observed during the low-flow years of 1977 and 1994.

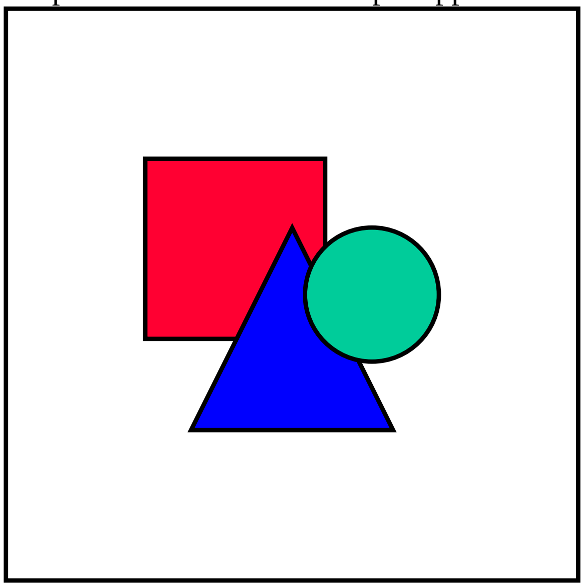


Peak water temperatures also appear to be influenced by ambient air temperatures, solar radiation, and percentage of total discharge contributed from Dworshak Reservoir. The influence of air temperature on peak water temperature is notable for 1995, when water temperatures reached a peak value that was lower than those observed in both 1994 (when relatively large releases from Dworshak Reservoir were initiated) and 1997 (a high flow rate year). This lower peak temperature observed in 1995 is likely attributable to the cooler-than-normal mean monthly air temperatures observed between June and late September.

Flow rates also seem to affect the duration of elevated water temperatures. The slower flow rates and increased surface area of water within the impoundments can cause surface waters to reach higher maximum temperatures and then cool down more slowly in the fall (BPA, 1995). In reviewing the data, 1977 and 1994 clearly stand out as having two to three months with surface temperatures above 20°C (68°F), as compared to less than two months observed in other years. In addition, it took at least a week longer in 1994 for the water temperatures at SNR-108 to drop back below 20°C (68°F). This longer period of elevated temperatures or the delay in cooling would be expected to adversely affect fish migration patterns.

At station CLR-326, upstream of the Snake River confluence, peak temperatures remained below 20°C (68°F) throughout the sampling period. Surface water temperature data collected from various stations along the Lower Snake River during the low-flow year of 1994 indicates that a higher maximum temperature was reached in Lower Granite reservoir (24.3 C) and upstream at SNR-140 (23.8 C) than during 1997. Previous research has indicated that thermal stratification in the Lower Snake River impoundments does not appear to occur to any significant extent (Funk *et al.* 1985). However, in 1997, a high flow year, the maximum temperature difference between surface and bottom waters was 4.7°C (8.2°F). This was observed on August 11 at Station SNR-108 in the Lower Granite Reservoir, the deepest reservoir station with the largest temperature gradient between zero and 10 m depth.

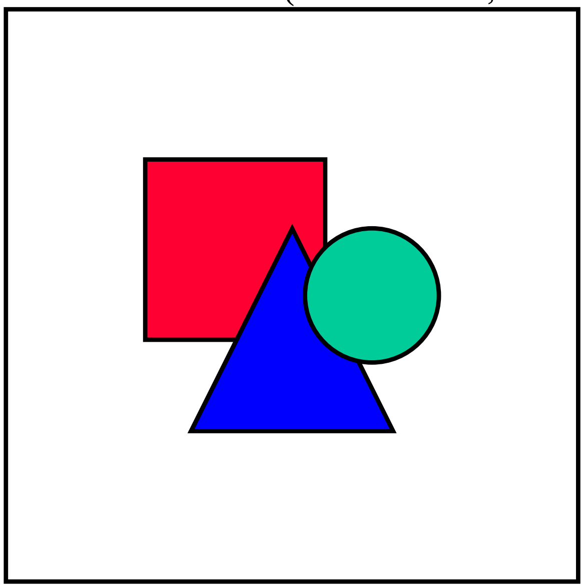
Temperature profile data from 1994, a low-flow year, depict a larger difference between surface temperatures and temperatures at depth following 28 days of large water releases from Dworshak Reservoir. The reservoir does not stratify, but may grade due to the sinking of more dense cooler water. This is most apparent in Lower Granite Reservoir (*e.g.*, SNR-108 and SNR-129) where the difference between surface temperatures and temperatures at 35 meters depth approached 9° C.



Historically, the maximum temperature difference reported for surface and bottom waters was 4.7°C (8.2°F), measured in 1977 at SNR-108 (a high-flow year), and more typical differences are around 2.0°C (4°F) (Funk *et al.* 1985). It is noteworthy that both the 1997 and 1994 data were collected during a period of large water releases from Dworshak Reservoir (20.4 kcfs in 1997 and 25+ kcfs in 1994). Thus, the significant inputs of cooler water from Dworshak Reservoir, and the higher than normal river flows may have resulted in the larger than normal temperature gradients that were observed at depth. The remaining reservoir stations generally had a difference of less than a 2 to 3°C (3.6 to 5.4°F) throughout the water column (Normandeau 1999a). An increase in thermal gradation could lead to lower dissolved oxygen levels in the deeper waters and increased nutrient releases into the water column from bottom sediments if anoxic conditions were to occur with prolonged gradation or the formation of stratification.

In 1994, releases from Dworshak Dam began early in July, reaching a maximum of 25 kcfs by mid-month, and were completed by the end of the month. During this time period, the median flow contribution from the Clearwater River accounted for 54% of the total inflow to Lower Granite Reservoir and as much as 65% of the total flow on one occasion. Based on temperature data collected from D.H. Bennett from the UI, these cold water releases resulted in a 5°C (11°F) drop in water temperature in July in Lower Granite Reservoir at a depth of 6 meters. Differences in surface temperature data collected in Ice Harbor Reservoir (SNR-18) before and after 28 days of releases from Dworshak Dam in 1994 were less pronounced, with a maximum difference of 2.2°C. Similarly, Karr *et al.* (1997) noted a decrease in temperature at mid-depth from 5.3 C (9.5 F) at Lower Granite Dam to 2.4 C (4.4 F) at the Ice Harbor Dam. Temperature reductions were noted throughout much of the water column, although a steep gradient was present near the surface (Karr *et al.*

1997). In 1995, releases began in mid-July and continued to the end of August. The maximum release rate was 13.8 kcfs and accounted for about 45% of the downstream flows, and a temperature drop of 3° C (5.5° F) at the Lower Granite Dam (Karr *et al.* 1997). A similar release pattern was conducted in 1997 as well. Under these flow release conditions, downstream temperatures were apparently lowered by up to 10°C (50°F) in the Clearwater River and only by up to 1 to 2°C (2 to 4°F) in Lower Granite Reservoir. The impact on water temperature is delayed, and reduced with increasing distance downstream from Dworshak Dam (Karr *et al.* 1997; Normandeau 1999a).



In contrast to water temperatures, the highest dissolved oxygen (DO) concentrations are typically observed during spring runoff and tend to decline with increasing temperature. The USGS data going back to 1975 indicate that low minimum DO levels of 2.3mg/L have been recorded below Lower Granite Dam (RM 106.5).

Peak water temperatures were measured on July 28, August 23, and September 9, 1971, and these sampling occasions were also three of the four lowest DO readings obtained that year.

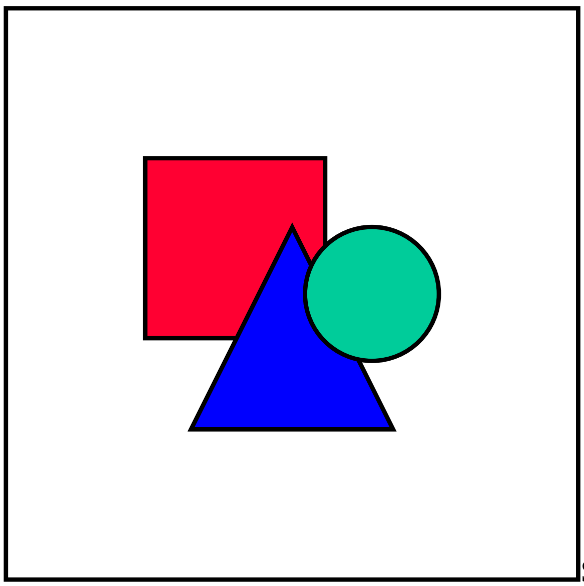
At the Lower Snake River stations, DO concentrations were for the most part above 8.0 mg/L during 1997 except during one late-summer event at each station. The timing of the seasonal low level seemed to occur first upstream (SNR-140) and then progressively moved downstream. The average low concentration for these three Snake River stations during this one sampling event was about 7.0 mg/L. A review of data collected in other years, particularly during the historically low flow conditions in 1994, reveal only minor differences. During an early September sampling event, at Station SNR-108, the average DO concentration dipped to near 6.8 mg/L but remained above 8.0 mg/L for all other sampling events.

Dissolved Oxygen

The lowest oxygen concentrations recorded during 1997 typically occurred during September. At station SNR-40, which is in the tailwater section below the Lower

Monumental Dam, the lowest water column concentrations ranged from 6.7 to 6.8 mg/L, or less than 75% saturation from the surface to the bottom with an overall depth of 8.0 meters. The next downstream station, SNR-18, which is in the Ice Harbor Reservoir, had DO concentrations ranging from 6.9 to 7.1 mg/L or roughly 76 to 79% saturation at depths above 20 meters during the same time interval.

A few locations had lower concentrations at depth. Station SNR-108, which is at the deepest point in the Lower Granite Reservoir, had low readings of 5.3 and 3.4 mg/L or 59 and 38% saturation at depths of 30 and 35 meters, respectively. At depths above 20 meters, DO levels ranged from 7.0 to 7.6 mg/L or 80 to 87% saturation. In 1994 and 1995, the lowest readings recorded at SNR-108 at a depth of 34 meters were 2.3 and 4.9 mg/L, respectively. A comparison of DO data collected in 1975 and 1977 at approximately the same time of year suggests that concentrations of DO at depth have decreased over time.



Station SNR-83 in the Little Goose Reservoir just below the confluence of Deadman Creek also had relatively low values of 5.5 and 4.7 mg/L or 62 and 52% saturation at depths of 10.0 and 30.0 meters, respectively, during early September 1997. Above 10 meters, DO levels ranged between 5.8 to 7.2 mg/L or 67 to 84% saturation. However, prior to this event and by early October, DO levels at all the Snake River stations were near or above 90% saturation.

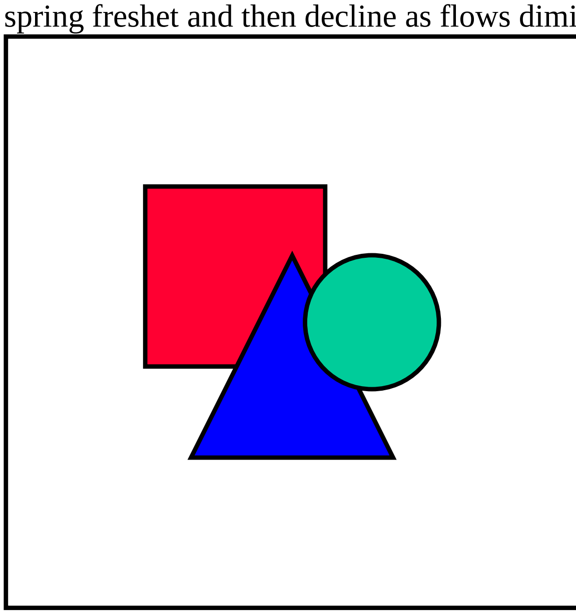
Total Suspended Solids (TSS)

Table 14describes the mean TSS concentrations (mg/L) and 95% confidence intervals for a select number of sample sites within the project area, covering a period of up to 24 years. These data indicate that in most cases the average concentrations for each site either increased slightly or were relatively similar. However, it is noteworthy that the 18 mg/L mean determined for SNR-148 in 1997 was due, in large part, to the 65 mg/L value that was observed during early June, when runoff was close to maximum; otherwise, concentrations were less than 10 mg/L most of the time.

Table 14. Average and 95-percent confidence intervals for growing season total suspended solids concentrations (mg/L) at 1 m for selected sampling sites and years (Corps 1999).

	1975		1976		1977		1994		1995		1996		1997	
	Avg	**CI**	**Avg**	**CI**	**Avg**	**CI**	**Avg**	**CI**	**Avg**	**CI**	**Avg**	**CI**	**Avg**	**CI**
SNR-18	ND	ND	ND	ND	ND	ND	ND	ND	10	3 17	11	3 20	9	4 14
SNR-83	ND	ND	8	4 12	14	8 21	ND	ND	6	0 12	10	4 16	20	(2) 41
SNR-108	ND	ND	6	2 10	11	7 15	ND	ND	4	3 6	8	2 13	8	3 14
SNR-118	ND	ND	ND	ND	ND	ND	ND	ND	6	2 9	ND	ND	10	<1 20
SNR-129	ND	ND	24	3 46	14	9 19	ND	ND	7	3 11	15	2 29	9	1 16
SNR-148	ND	ND	19	9 30	27	20 34	ND	ND	ND	ND	ND	ND	18	(2) 37
CLW-1	ND	ND	15	4 27	8	3 13	ND	ND	ND	ND	ND	ND	4	0 8

It is generally thought that larger particles transported by the rivers settle out in the transition zone in the vicinity of Lewiston, Idaho, and downstream into Lower Granite Reservoir. Finer material that passes Lower Granite Reservoir remains suspended. As such, the data suggest that there may have been a decrease in the larger fraction of the suspended solids transported by the in-flowing rivers, yet the amount of fines that travel down through the series of dams has remained about the same. Occasionally, elevated concentrations near the surface occur in the reservoirs as a result of localized algal blooms, port operations, and tributaries. Typically, TSS concentrations are highest during the spring freshet and then decline as flows diminish through late summer and into the fall.



Within the Lower Snake River, the upstream station (Station SNR-140) had peak TSS levels of 60 and 65 mg/L at the surface and bottom depths, respectively. Station SNR-129, at the uppermost portion of the Lower Granite reservoir, appeared to have the highest peak level of 72 mg/L at a depth of 20 meters, and an average concentration of nearly 50 mg/L throughout the water column. Discharge in the Lower Snake River was around 175 kcfs at the time, and the average TSS level throughout the remaining portions of the system was about 30 mg/L with no distinct differences between the impounded and non-impounded reaches. Again, the highest levels were generally observed at the greater sampling depths. By the June 29 sampling date, the average TSS level declined to just below 20 mg/L, except at Station SNR-83, which had an unusually high level of 70 mg/L at the surface and much lower levels below. This high TSS level was likely the result of patch conditions that often occur on the reservoirs. For the remainder of the sampling season, TSS levels were consistently below 20 mg/L, and most often below 10 mg/L.

There are no state water quality standards for TSS. However, turbidity standards in Idaho and Washington limit increases to 5 nephelometric turbidity units (NTU) when the background is less than 50 NTU except when the flood exceeds the 7-day, 10-year flood frequency. Turbidity levels of the Snake River exceeded state water quality standards in June 1997 at most stations (Table 15).

Table 15. 1997 turbidity measurements (FTU[1]) in surface waters at selected Snake River stations (Corps 1999).

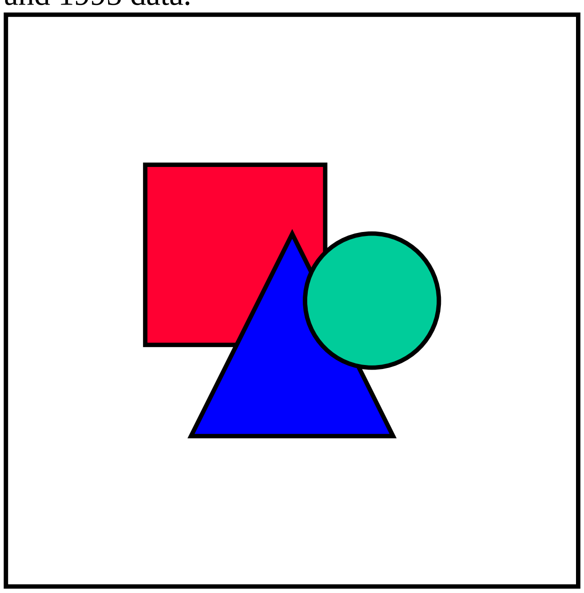
Date	SNR-18	SNR-83	SNR-108	SNR-118	SNR-129	SNR-140
6/2 to 6/9/97	16	17	18	17	17	20
6/28 to 7/1/97	5	9	3	5	5	8
7/3/97	7	NC	NC	NC	NC	NC
7/14 to 7/19/97	4	3	3	2	2	3
7/28 to 7/31/97	4	2	2	3	3	2
8/11 to 8/14/97	5	3	2	2	2	2
9/8 to 9/11/97	3	2	1	2	2	2
9/15/97	3	NC	NC	NC	NC	NC
9/22 to 9/25/97	3	2	2	2	2	2
10/6 to 10/9/97	2	3	3	2	2	2
[1]FTU (formazin turbidity units) are equivalent to NTU (nephelometric turbidity units)						

None of the TSS concentrations observed in 1997 would have lethal effects on adult or juvenile salmon (Newcombe and Jensen 1996). Concentrations of 25 mg/L for 4 hours have been shown to reduce feeding rate; higher concentrations up to 1,000 mg/L have shown no deleterious effects on adult salmon other than coughing and apparent stress. One study showed 50% mortality of juvenile coho salmon at 509 mg/L TSS (Newcombe and Jensen 1996).

Of the various soluble inorganic forms of nitrogen, nitrate plus nitrite (NO3 + NO2) was the principal component, often comprising more than 90% of the soluble fraction. Nitrate nitrogen concentrations exhibited inter-annual variations at several of the sites, but long-term trends were not apparent. However, two important issues were identified regarding the inorganic nitrogen species. Nitrate concentrations were consistently greater than ammonia values at almost all stations. The two upstream Lower Snake River stations, SNR-140 and SNR-148, had median NO3 levels that were much higher, ranging between 0.33 and 0.35 mg/L, while the median NO_3 levels throughout the Lower Snake River reach ranged from 0.13 to 0.19 mg/L. These data suggest that the high levels contributed from the middle Snake River reach are slightly diluted by the low levels in the Clearwater River, resulting in moderately high NO_3 levels in the Lower Snake River.

Nitrogen

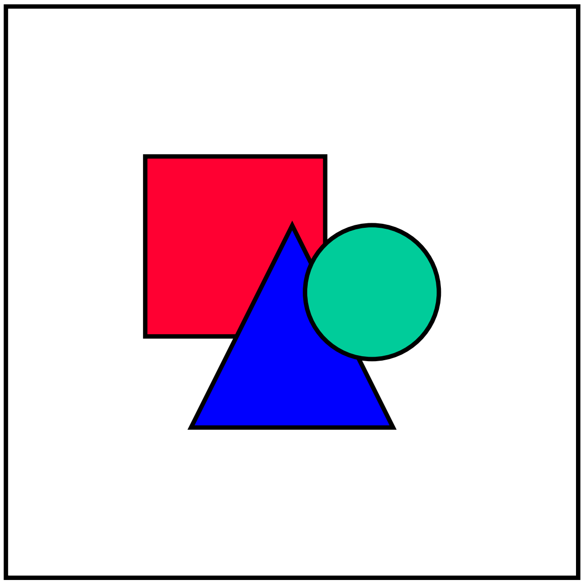
Total nitrogen (total-N) levels, which include both the inorganic and organic components, were relatively high in the Snake River stations. Total-N levels at the upstream Snake River station (SNR-140) were generally higher than those observed at the other sampling stations. In general, concentrations decreased throughout the Lower Snake River. In the spring and summer, the total-N levels increased from about 0.30 to 0.60 mg/L at the Lower Snake River stations. The total-N levels increased considerably in the fall with peak levels at the Snake River stations reaching 0.8 to 1.1 mg/L in October. This late-season increase may be due to a reduction in plant uptake associated with aquatic plant and algae dying back or going dormant as well as agricultural harvesting in the watershed. Early fall rains after prolonged dry periods also increase nutrient concentrations. A corresponding increase in TSS levels was not detected. The seasonal pattern of nitrogen concentrations is also apparent in nitrate data collected in 1971 at SNR-107, prior to construction of the Lower Granite Dam and SNR-108 in 1995. Nitrate levels were generally highest in spring and fall, likely due to the lower biological uptake during the non-growing season. Concentrations of nitrate were generally similar during the growing season for the 1971 and 1995 data.



This late-season increase in the Snake River levels most likely caused the levels at Station CLR-295, in the McNary Reservoir, to nearly double from around 0.20 to 0.40 mg/L, while the upstream Columbia River station remained constant at just under 0.20 mg/L through the fall period.

Ortho-P

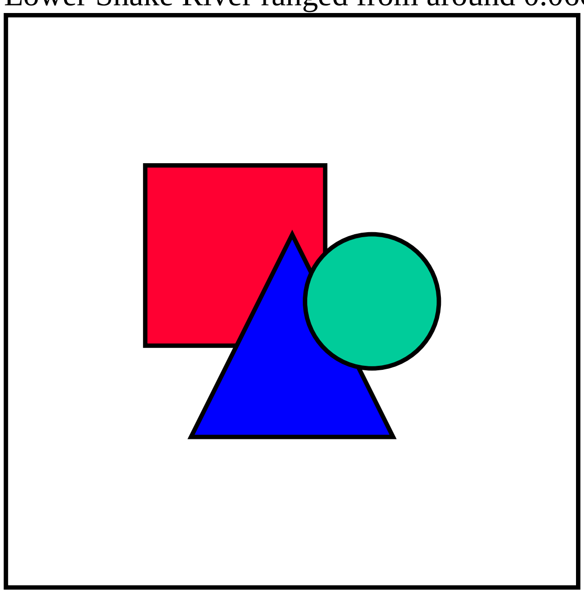
Recent and historical data suggest that ortho-P levels in the Lower Snake River tend to be highest in the spring and fall, with relatively low concentrations in the summer. The lower levels during the summer are most likely due to biological uptake by aquatic plant and algal growth. As plant growth diminishes in the fall, the phosphorus levels increase, which was most evident at the reservoir stations where algal growth is usually most abundant.



Throughout the Lower Snake reach, ortho-P levels through mid-August peaked at 0.018 mg/L and increased to 0.022 to 0.063 mg/L from mid-September through October. Clearly, ortho-P is much more available throughout the Lower Snake River reach relative to other major rivers in the area.

Total Phosphorus

The highest levels in the study area were measured in the upper portions of the Lower Snake reach. During the spring freshet, TP levels (water column average) throughout the Lower Snake River ranged from around 0.060 to 0.11 mg/L.



The high TP levels during this time of year are most likely attributable to the suspended sediment contained in the peak flow period. For much of the 1997 growing season, TP levels generally ranged from 0.035 to 0.060 mg/L and then steadily increased in the fall.

Similar concentrations were observed in 1994 and 1995, where concentrations ranged from 0.025 to 0.060 mg/L in the summer and then increased to around 0.09 mg/L in the fall.

According to the Washington state water quality standards, total phosphorus levels above 0.020 and 0.035 mg/L are considered to be critical thresholds in terms of preventing excessive algal growth when ambient trophic conditions are considered to be in the lower and upper mesotrophic categories, respectively. Oligotrophic conditions represent high quality waters with good water clarity and low algal production and eutrophic conditions represent high nutrient levels, excessive algal growth and poor water clarity. Mesotrophic conditions are somewhere in the middle and typically represent moderate levels of algal production, water clarity and light transparency.

Limnological conditions in the Lower Snake River impoundments have generally been considered to be in the upper mesotrophic to eutrophic category (Normandeau 1999a). Based on a review of the 1997 data, the average phosphorus levels throughout Lower Snake River appear to be in the 0.030 to 0.040 mg/L range during the mid-summer and slightly higher to near the 0.060 to 0.070 mg/L range during June and fall months. This would suggest that the average phosphorus levels in the Lower Snake River for much of the entire growing season would likely be above the WDOE phosphorus guideline of 0.035 mg/L that was established to maintain existing conditions and prevent eutrophic conditions.

Sediment

A total of 487 grab sediment samples were collected. Of the 487 grab samples, 356 were sieved to develop particle-size distributions. The remaining 131 samples (or 26.9%) were not sieved either because there was no sample recovery or because the sample consisted only of gravel and/or cobble. The average grain size distributions for the sediment samples collected from above the Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams are summarized in Table 16.

The mean grain size for the channel bed sediments range from very fine sand to silt/clay. The highest concentration of relatively coarser sediments (fine to medium sand) was found in Lake Sacajawea, above Ice Harbor Dam. The highest concentration of silt/clay size sediments was found in Lake West, above the Lower Monumental Dam. Fine-grain sediments are concentrated on the channel bottom in Lake West. The concentration of these fine grain sediments is most likely associated with the discharge of the Palouse River into Lake West. This contribution is evidenced by the elevated TSS concentrations in the water quality samples collected from the Palouse River (refer to TSS section of this report). Soil erosion within the Palouse River drainage basin has been documented as a chronic problem due to historical land use practices (Ebbert and Roe, 1998). Recent studies have also documented that the adoption of erosion control practices within the drainage basin has resulted in an observable decline in suspended sediment concentrations in the Palouse River (Ebbert and Roe 1998), and as a result, probably also into Lake West.

Four sediment samples collected from the Lower Granite Lake were analyzed for dioxins (tetrachloro-dibenzo-p-dioxin or TCDD). The reason for only collecting samples from this portion of the study area was that it is located immediately downstream of the Clarkston-Lewiston area, where industrial discharges may have released this organic compound.

Table 16. Summary of sieve test results for sediment samples collected from the Lower Snake River in 1997 (Corps 1999).

Sediment Size	Average Grain Size (in percent)				Cumulative Percent			
	IHR	LM	LGO	LGR	IHR	LM	LGO	LGR
Gravel	2.4	2.8	1.9	0.4	2.4	2.8	1.9	0.4
Very Fine Gravel	0.1	0.6	0.7	0.3	2.5	3.4	2.6	0.7
Very Coarse Sand	0.1	1.0	0.7	0.5	2.6	4.4	3.3	1.2
Coarse Sand	1.1	1.1	2.8	1.7	3.7	5.5	6.1	2.9
Medium Sand	18.3	2.8	10.2	6.9	22.0	8.3	16.3	9.8
Fine Sand	18.3	6.7	13.1	17.1	40.3	15	29.4	26.9
Very Fine Sand	23.3	13.2	16.8	20.1	63.6	28.2	46.2	47.0
Silt/Clay	35.8	71.8	53.8	52.4	99.4	100.0	100.0	99.4
Note: IHR = Ice Harbor Reservoir (Lake Sacajawea), 41 samples LM = Lower Monumental Reservoir (Lake West), 77 samples LGO = Little Goose Reservoir (Lake Bryan), 127 samples LGR = Lower Granite Reservoir (Lower Granite Lake), 104 samples								

Dioxins

Total dioxins were detected in two of the four samples analyzed, with their concentration ranging from 0.69 to 1.00 ppt (parts per trillion) at an analytical detection limit of 0.4 ppt. The two samples having detectable concentrations of total dioxins were collected from sampling stations LGR 8-3 (0.69 ppt) and LGR 13-7 (1.00 ppt), which are located in the upper portion of Lower Granite Lake. These concentrations are within the lower range of concentrations identified in studies of the Lower Columbia River and the lower Willamette River (Bi-State Study and 1990 Portland Army Corps of Engineers Survey) (Corps 1998c).

In Lower Granite Lake the total dioxin concentrations decrease from upstream to downstream, with no detectable concentrations of total dioxins identified in the samples collected from stations LGR 5-8 and LGR 6-4. The trend of decreasing total dioxins concentrations with increasing distance downstream would suggest that the source(s) for these organic compounds is located upstream of the study area.

Glyphosate

Glyphosate (N-(phosphonomethyl)glycine) is a postemergence herbicide that has found widespread agricultural and domestic use. It is sold as a terrestrial and aquatic herbicide. A major metabolite of Glyphosate is aminomethylphosphonic acid (AMPA).

All top layer sediment samples (94 total samples) were tested for glyphosate and AMPA. Glyphosate was detected in 36% of the samples and AMPA was detected in 16% of the samples tested. The concentration of glyphosate ranged from non-detected to a maximum of 68.9 ppb (parts per billion) with an arithmetic mean of 12.52 ppb. The concentration of AMPA ranged from non-detected to a maximum of 29.3 ppb with and arithmetic mean of

7.48 ppb (Normandeau 1999b). No screening criteria have been established for either glyphosate or AMPA in sediments within the Columbia River Basin.

Glyphosate and AMPA were detected in sediment samples collected from each of the impoundments. The highest individual concentrations of glyphosate and AMPA were detected in samples collected from Lake Bryan (upstream of the Little Goose Dam) (Normandeau 1999b). The highest average reach concentration of glyphosate was found in the samples collected from Lake Sacajawea (Table 17).

Table 17. Summary of average glyphosate and AMPA concentrations (μg/L, Elutriate, and ppb, Sediment) For sediment samples collected during 1997 in the Lower Snake River (Corps 1999).

	Ice Harbor	**Little Goose**	**Lower Granite**	**Lower Monumental**	**Average**
Elutriate					
AMPA	ND	ND	ND	ND	ND
Glyphosate	0.58	0.69	ND	ND	0.57
Sediment					
AMPA	8.08	7.58	6.07	8.28	7.48
Glyphosate	16.80	10.42	10.60	14.85	12.52
Note: [1]ND= Not detected; ½ the detection level is used when concentrations < detection level. Ice Harbor Reservoir -Lake Sacajawea Lower Monumental Reservoir Lake West Little Goose Reservoir Lake Bryan Lower Granite Reservoir Lower Granite Lake					

The highest average reach concentration of AMPA was found in the samples collected from Lake West (upstream of Lower Monumental Dam).

The suspected source of glyphosate and AMPA in the Lower Snake River sediments is runoff from surrounding uplands and through transport via stream flow. Sources for these organic compounds may include agricultural, industrial, municipal or domestic uses within the watershed.

Organochlorine Pesticides

Several organochlorine pesticides were detected in the sediment samples collected from the Lower Snake River. The organochlorine pesticide compounds detected (and their frequency of detection) included, 4,4-DDD (11), 4,4-DDE (43), 4,4-DDT (5), aldrin (3), dieldrin (4), endrin (1), heptachlor (1) and lindane (3) (Normandeau 1999b, Table 18). The three principal organochlorine pesticide compounds detected in the sediments are related, with DDT being the parent compound and DDD-DDE being daughter products generated by the transformation of DDT in the environment (Callahan *et al*. 1979).

The predominant organochlorine compound detected was DDE, which ranged in average concentration from 2.68 in Ice Harbor to 6.48 in Lower Granite Reach, with an arithmetic mean concentration of 4.89 ppb. DDD was detected in 11 sediment samples with an average maximum concentration of 6.48 ppb in Lower Granite Reach and an arithmetic mean of 2.07 ppb. DDT was detected in only five samples with a mean arithmetic concentration of 1.62 ppb.

Table 18. Summary of Average Concentrations (ppb) of Organochlorine Pesticides and TPH in Sediments Collected during 1997 in the Lower Snake River (Corps 1999).

Sediment	Ice Harbor	Little Goose	Lower Granite	Lower Monumental	Average
4,4-DDD	ND	1.95	3.06	1.58	2.07
4,4-DDE	2.68	4.91	6.48	4.22	4.89
4,4-DDT	ND	1.64	1.72	1.56	1.62
Aldrin	0.75	0.84	0.87	0.82	0.83
Dieldrin	ND	1.74	ND	1.80	1.68
Endrin	ND	ND	ND	1.75	1.58
Lindane	ND	0.91	ND	0.90	0.85
TPH	67.63	45.86	58.25	49.15	55.41
ND= Not detected; average uses ½ of detection when concentrations < detection level.					

Total DDT (DDD, DDE and DDT) concentrations ranged from non-detect to 32.8 ppb with an average concentration of 8.23 ppb (Normandeau 1999b). The highest mean reach concentration for total DDT was 11.3 ppb for Lower Granite Lake. The average reach concentration of total DDT decreases steadily from Lower Granite Lake down to 5.7 ppb as recorded in Lake Sacajawea.

The maximum and average total DDT concentrations in the Lower Snake River sediments exceed the guidance levels set forth in "Puget Sound Dredged Disposal Analysis Guidance Manual: Data Quality Evaluation for Proposed Dredged Material Disposal Projects" (PTI 1989a) or recommended screening concentration (6.9 ppb), but are lower than the bioaccumulation trigger concentration of 50 ppb as established in the Dredged Material Evaluation Framework (DMEF) (Corps 1998c). Concentration levels above the screening level prompt biological testing to ascertain health risks to aquatic organisms using the DMEF (Corps 1998c).

The pesticides aldrin, dieldrin, endrin, heptachlor and lindane were all detected in five or less of the 94 sediment samples. The concentration of aldrin ranged from non-detect to 3.5 ppb, dieldrin from non-detect to 8.0 ppb, endrin from non-detect to 9.4 ppb, heptachlor from non-detect to 4.9 ppb and lindane from non-detect to 5.5 ppb (Normandeau 1999b). The maximum concentrations of aldrin, dieldrin, heptachlor, and lindane in the Snake River sediment are lower than their screening level concentration of 10 ppb. No screening level has been established for endrin in the DMEF (Corps 1998c).

A recent report by the USGS (Clark and Maret 1998) documents the results of the collection and analysis of bed sediments from the Snake River upstream of the study area. The only organochlorine compound detected in all of the bed sediment samples analyzed by the USGS was DDE at concentrations ranging from 1 to 11 ppb. These concentrations are similar to those reported for the sediment samples analyzed for this investigation. Reports of previous investigations performed on the lower Columbia River (Bi-State Study and Portland Corps 1997 Survey) also document that pesticides are typically only detected at low concentrations (Corps 1998c).

A modified version of EPA Method 418.1 was used for the analysis of the sediments to determine the concentration of petroleum products. Use of this analytical method only provides an indication of the amount of petroleum material in the sediments but does not quantitatively identify the specific type of petroleum material present.

The concentration of TPH ranged from non-detect to 256 ppm (LM 1-2) with an arithmetic mean of 55.41 ppm (Normandeau 1999b). Along the Lower Snake River, the average concentration of TPH generally increases in the downstream direction with the highest average reach concentration (62.13 ppm) found in Lake Sacajawea. No screening level has been established for TPH under the DMEF (Corps 1998c).

Metals

Of 18 metals analyzed, only cadmium, mercury, silver and strontium were not detected in 94 samples. Cadmium was detected in only two samples, mercury in 37 samples, silver was not detected in any of the samples, and strontium was detected in only four samples (Normandeau 1999b).

The metal consistently found in the highest concentrations was manganese. This metal is commonly detected in river sediments due to its high relative abundance in the natural environment.

Concentrations of manganese in individual sediment samples collected from the Lower Snake River during this investigation ranged from 250 ppm to 1,044 ppm with an average concentration of 430 ppm (Normandeau 1999b). In comparison, the concentration of manganese in sediment samples collected upstream of the study area by the USGS (Clark and Maret 1998), ranged from 370 ppm to 1,000 ppm with an average concentration of 564 ppm.

No consistent trends in sediment metal concentrations were observed going downstream from Lower Granite Lake to Lake Sacajawea (Table 19). When compared with the results obtained by the USGS (Clark and Maret 1998) in their investigation of the Snake River upstream of the study area several trends do become apparent. In the USGS investigation bed sediments were collected and analyzed for a broad range of trace elements. Upstream concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc (USGS) were lower than downstream concentrations.

Concentration values for metals in sediments are also available for the lower Columbia River drainage basin (Bi-State Study and 1997 Corps Survey). Of the reported values for the metals arsenic, cadmium, copper, lead, mercury, nickel, silver, and zinc in these previous investigations, only the concentration of arsenic and lead were found to be slightly higher for the samples collected from the Lower Snake River during this investigation.

Table 19. Summary of mean metal concentrations for sediment samples collected during Phase 2 (1997) in the Lower Snake River (Corps 1999).

Metal (mg/kg)	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Arsenic	6.3	3.9	6.0	5.2
Barium	170.6	157.2	192.7	180.8
Beryllium	0.6	0.6	0.7	0.7
Cadmium	ND	ND	ND	0.1
Chromium	20.2	17.7	22.4	23.0
Cobalt	10.9	8.2	11.1	12.0
Copper	20.8	16.8	24.8	29.8
Lead	10.5	8.8	12.6	12.9
Manganese	510.1	384.6	475.2	408.9
Mercury	0.1	0.1	0.1	0.1
Molybdenum	0.3	0.2	0.2	0.3
Nickel	14.2	12.4	15.6	16.6
Selenium	1.6	1.4	1.3	1.5
Silver	ND	ND	ND	ND
Strontium	0.1	0.1	ND	0.1
Thallium	0.2	0.2	0.2	0.2
Vanadium	45.1	37.9	47.2	60.9
Zinc	52.5	45.0	57.3	61.4
Note: all concentrations in mg/kg (ppm) Ice Harbor Dam - Lake Sacajawea Lower Monumental Dam - Lake West Little Goose Dam - Lake Bryan Lower Granite Dam - Lower Granite Lake				

Table 20. Summary of Mean Nutrient Concentrations for Sediment Samples Collected During Phase 2 (1997) in the Lower Snake River (Corps 1999).

Parameter	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Ammonia	81.3	59.6	64.3	75.7
Total Kjeldahl Nitrogen	1317.1	1146.1	1344.1	1746.5
Nitrate/Nitrite	0.7	0.6	0.7	1.4
Total Organic Nitrogen	1235.7	1086.7	1280.0	1671.3
Total Organic Matter	2.5	2.2	3.3	5.2
Phosphorus Bicarbonate	37.7	38.2	35.0	34.1
Sulfate	7.7	8.4	10.5	17.9
pH (standard units)	6.9	6.9	7.1	6.8
All results in mg/kg unless otherwise noted Ice Harbor Dam - Lake Sacajawea Lower Monumental Dam - Lake West Little Goose Dam - Lake Bryan Lower Granite Dam - Lower Granite Lake				

A total of 84 of the sediment samples were analyzed for a number of chemical parameters, designated as the nutrient group (although not all of the parameters are true nutrients). The sediments were analyzed for: ammonia, total Kjeldahl nitrogen (TKN), nitrogen as nitrate/nitrite, total organic nitrogen, total organic matter, pH, phosphorus bicarbonate and sulfate. The mean reach concentrations for each of the nutrient group parameters are summarized in Table 20. No screening levels have been established under the DMEF (Corps 1998c) for nutrients, and comparison with water quality standards is not appropriate.

Elutriate Fraction

The results of the laboratory analyses for the ambient pH elutriates, which are summarized in Table 20 and Table 21, are presented in Normandeau (1999b). Results include the number of samples analyzed, the number of samples above detection limits, the minimum value and maximum value detected, the arithmetic and geometric mean and the standard deviation for each parameter analyzed.

The ambient pH elutriates were tested for the presence of organophosphorus pesticides, which as a group consist of 25 different organic compounds. The only organophosphorus pesticide detected was ethyl parathion, in one sample (LGO 8-4), at a concentration of 1.0 ppb (mg/l). Although identified in the one elutriate sample, ethyl parathion was not detected in any of the sediment samples. Parathion is a regulated substance in fresh waters in the states of Oregon and Washington with a maximum allowable concentration of 0.013 ppb (chronic).

Table 21. Summary of average concentrations (ppb) of organochlorine pesticides and TPH in sediment collected during 1997 in the Lower Snake River (Corps 1999).

Pesticide	Ice Harbor	Little Goose	Lower Granite	Lower Monumental	Average
4,4-DDD	ND	1.95	3.06	1.58	2.07
4,4-DDE	2.68	4.91	6.48	4.22	4.89
4,4-DDT	ND	1.64	1.72	1.56	1.62
Aldrin	0.75	0.84	0.87	0.82	0.83
Dieldrin	ND	1.74	ND	1.80	1.68
Endrin	ND	ND	ND	1.75	1.58
Lindane	ND	0.91	ND	0.90	0.85
TPH	67.63	45.86	58.25	49.15	55.41
ND = Not detected; average uses ½ of detection when concentrations < detection level. Ice Harbor Dam - Lake Sacajawea Lower Monumental Dam - Lake West Little Goose Dam - Lake Bryan Lower Granite Dam - Lower Granite Lake					

No organochlorine pesticides were detected in any of the ambient pH elutriate samples. The organochlorine pesticides DDT (and its metabolites) aldrin, dieldrin, endrin, heptachlor and lindane had been detected in several of the sediment samples tested. The results of the elutriate tests suggest that although these compounds are present in the sediments they do not readily partition into water.

Glyphosate was detected in only 2 of the 94 ambient pH elutriate samples, while AMPA was not detected. Glyphosate was detected at a concentration of 0.69 µg/L in a sample collected from Lake Bryan and at a concentration of 0.58 µg/L in a sample collected from Lake Sacajawea. In comparison, the maximum contaminant level established for glyphosate by the USEPA in drinking water is 700 µg/L, well above the concentrations detected in the two elutriate analyses.

Each of the 94 ambient pH elutriates were tested for the same suite of metals that were analyzed on their corresponding sediments. The results of the individual samples are summarized in a table included in Normandeau, 1999b. For the 18 metals analyzed only beryllium, silver and thallium were not detected in the elutriate samples. Of these metals only silver was not detected in the original sediment samples.

The mean metal concentrations for the ambient pH elutriates are summarized by river reach in Table 22. The predominant metals detected include barium and manganese. The average concentration of barium, by river reach, in the ambient pH elutriates increases from 83.3 ppb for the samples collected from Lower Granite Lake to 243.6 ppb for the sediment samples collected from Lake Sacajawea. Although a corresponding trend in the concentration of barium in the sediment samples was not observed, it was one of the predominant metals detected. Its relatively high concentration in the ambient pH elutriates is most likely the result of its concentration in the sediments and its relatively high solubility in water (Hem 1989).

Table 22. Summary of mean metal concentrations for ambient pH elutriate samples collected during Phase 2 (1997) of the Lower Snake River project (Corps 1999).

Metal (ug/L)	**Ice Harbor**	Lower Monumental	**Little Goose**	**Lower Granite**
Arsenic	3.9	2.6	2.2	1.8
Barium	243.6	197.5	140.9	83.3
Beryllium	ND	ND	ND	ND
Cadmium	ND	ND	0.1	ND
Chromium	0.6	0.8	0.4	0.6
Cobalt	0.5	1.2	0.4	0.5
Copper	2.9	3.2	3.2	4.0
Lead	ND	0.1	0.1	0.1
Manganese	861.5	1432.1	799.9	504.4
Mercury	ND	0.1	0.1	0.1
Molybdenum	3.0	3.5	3.8	2.2
Nickel	2.8	4.1	0.7	0.9
Selenium	2.3	1.2	0.3	0.3
Silver	ND	ND	ND	ND
Strontium	0.4	0.3	0.3	0.2
Thallium	ND	ND	ND	ND
Vanadium	2.1	1.2	1.8	1.5
Zinc	37.7	17.8	16.9	12.9
Ice Harbor Dam - Lake Sacajawea Lower Monumental Dam – Lake West Little Goose Dam - Lake Bryan Lower Granite Dam - Lower Granite Lake				

The predominant metal identified in the ambient pH elutriates was manganese. The average concentration of manganese, by river reach, in the ambient pH elutriates ranged from 504 ppb for the samples collected from Lower Granite Lake to 1,432 ppb for the samples collected from Lake West. In general, the trend in manganese concentrations in the ambient pH elutriate samples increases with distance downstream. As observed with barium, there does not appear to be a clear relationship between the concentration of manganese in the sediment samples and in the ambient pH elutriates.

The maximum metal concentrations detected in the ambient pH elutriates (Normandeau 1999b) were also compared with the recommended surface water quality standards of the state of Oregon Department of Ecology (ODOE), the United Nations (agricultural water quality goals), EPA, and WDOE to identify any CoC. The maximum concentration of four metals: arsenic, copper, manganese, and mercury were found to exceed their applicable water quality standards.

Because these metals also occur naturally in the environment, their concentrations were compared with representative background values to determine if they represent a CoC. The results of the ambient pH elutriate tests were compared with historical water quality data collected by the USGS from the Snake River near Anatone, Washington. The maximum detected concentration of arsenic, copper, and mercury were found to be less than their average background concentrations and as a result were not considered to represent CoC.

The ambient pH elutriate samples were also analyzed for the following nutrients: ammonia, nitrate/nitrite, phosphate, sulfate and TKN (Normandeau 1999b). The mean concentration of each of these nutrients for the four reaches along the Lower Snake River are summarized in Table 23.

Table 23. Summary of mean nutrient concentrations for ambient pH elutriate samples collected during Phase 2 (1997) in the Lower Snake River (Corps 1999).

Parameter (mg/l)	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Ammonia	3.6	2.5	2.6	3.6
Total Kjeldahl Nitrogen (TKN)	8.8	5.7	4.1	6.2
Nitrate/Nitrite	0.2	0.2	0.3	0.4
Phosphate	0.1	0.1	0.1	0.1
Sulfate	19.6	17.9	26.9	29.7
Note: Ice Harbor Dam - Lake Sacajawea Lower Monumental Dam – Lake West Little Goose Dam - Lake Bryan Lower Granite Dam - Lower Granite Lake * - pH Dependent, Not Available P – Proposed				

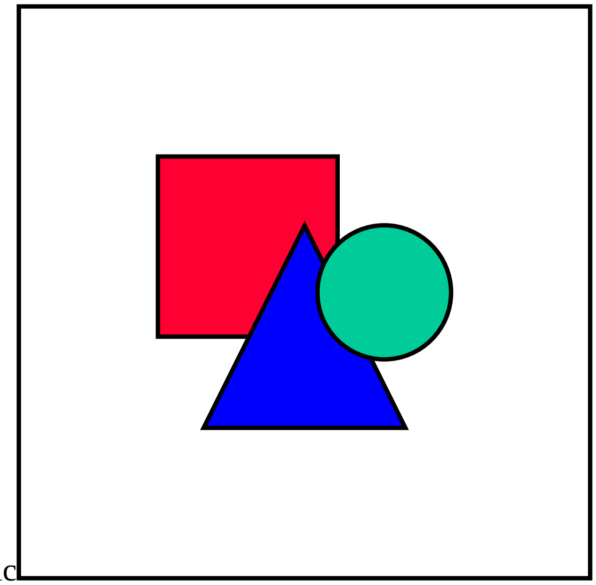
The dominant form of nitrogen found in the elutriate samples was ammonia, which also was also the predominant form of nitrogen identified in the sediment samples. The dominance of ammonia may reflect the limited oxygen environment of the channel bed sediments as a result of the decomposition of organic material. The consumption of oxygen by the decay of organic material would lead to the reduction of nitrate/nitrite, thus limiting their concentrations in both the sediment and elutriate samples.

Chlorophyll *a*

Chlorophyll *a* concentrations measured from samples collected at various sites during the growing season between 1994 and 1997 did not display any clear patterns of increasing or decreasing levels (Table 24). However, data collected during the 1997 growing season were highly variable both temporally and spatially. Although not universal for all stations, the highest seasonal chlorophyll a levels were generally observed in June and were associated with an abundance of diatoms. There appears to be no distinct differences in the chlorophyll a levels between the Snake and Columbia river systems. Both the upstream Snake River station (SNR-148) and the McNary Reservoir station (CLR-295) had similar peak levels in June, which is in contrast to most other parameters.

Table 24. Average and 95- percent confidence intervals for growing season Chlorophyll a concentrations (μg/L) in the surface water at selected sampling sites and years (Corps 1999).

Site	1994		1995		1996		1997	
	Avg	CI	Avg	CI	Avg	CI	Avg	CI
SNR-18	7.8	3.1 12.6	3.8	1.5 6.1	8.7	3.7 13.6	5.6	3.1 8.2
SNR-83	6.2	4.0 8.4	8.5	-2.0 18.9	9.1	4.2 13.9	7.9	5.8 10.0
SNR-108	6.0	2.4 9.6	7.8	2.9 12.7	11.4	8.0 14.9	8.1	6.3 9.9
SNR-118	7.7	1.7 13.8	7.0	3.0 11.1	ND	ND	6.8	5.2 8.4
SNR-129	9.7	4.7 14.7	6.0	4.6 7.5	8.7	6.6 10.8	8.6	5.3 12.0

Previous research suggests that average chlorophyll a levels above 5.0 and 14.5 mg/l are indicative of mesotrophic and eutrophic conditions, respectively. Chlorophyll a levels will typically range between 3.0 and 11.0 mg/l and 3.0 and 78.0 mg/l for mesotrophic and eutrophic  conditions, respectively (Wetzel 1983). Concentrations of chlorophyll a generally are between the criteria for mesotrophic and eutrophic, with an average concentration between 3.8 and 11.4 mg/l, and an upper confidence interval (95%) of 18.9 mg/l for the period between 1994 and 1997.

Based on estimated median concentrations for 1997, Station SNR-108, in the Lower Granite Reservoir, had the highest median chlorophyll a level of 8.74 mg/l, and a mean concentration of 8.1 mg/l. In the Snake River, there was a general progressive decline in levels moving downstream with the seasonal median level for Station SNR-18 in the Ice Harbor Reservoir at 3.2 mg/l (and a mean concentration of 5.6 mg/l). The opposite was true in the Columbia River where the median concentrations appeared to increase downstream. The median concentration at the upstream station (CLR-397) was 6.72 mg/l and gradually increased to 8.01 mg/l at Station CLR-295 in the McNary Reservoir. Given the relatively low chlorophyll a levels measured at Ice Harbor, it is unclear as to whether the increase in the Columbia River is attributable to inputs from the Snake River.

Phytoplankton

There were few differences in the number and types of phytoplankton observed at the impounded pool sites above dams and transitional sites below dams within the Lower Snake River system. For most of the study area, diatoms (Bacillariophyta) were typically dominant throughout much of the season, but especially during the peak flow period. At this time, diatoms typically accounted for more than 90% phytoplankton biovolumes. The cryptophytes (Rhodomonas minuta and R. m. nannoplanctica) became dominant or co-dominant (by numerical density) at most sites in the lower 50 miles of the Snake River during the second half of the season. However, because of their small size, they comprised a relatively small fraction of assemblage biovolume. Phytoplankton blooms (dominated by the genus Aphanizomenom and Anabaena) do occur in the Lower Snake River reservoirs. These blooms are typically brief, lasting only a few weeks, but significant in their total community dominance during that time period and potential subsequent impacts on oxygen concentrations and invertebrate food supply. There have been documented occurrences of surface scum resulting from these taxa. Research has noted much littoral detrital accumulation from senescing planktonic algae blooms during the later summer that deposits on attached benthic algal communities. This senescing planktonic algae likely provides a significant late-summer nutrient input to the attached benthic algal communities, as well as a direct food source for littoral benthic macroinvertebrates.

Other commonly observed taxa within the lower Snake River reservoirs include the diatoms Melosira islandica (18.3% of the total collection), Cyclotella meneghiniona (11.7%) and Fragillaria crotonensis (11.3%), and the cryptophytes Rhodomonas minuta (7.3%) and its variant R. m. nannoplanctica (14.4%). Few other taxa exceeded 2% of the total collection except the diatom species Asterionella formosa (4.5%) and Melosira granulata (3.7%), diatoms of the genera Diatoma (5.3%) and Synedra (3.4%), the green algal genus Scenedesmus (2.3%), and the blue-green Anabaena spp. (4.3%).

Attached benthic algae are a secondary source of primary productivity in the Lower Snake River. As algae that are attached to rocks and other hard substrate, they provide a food source for benthic organisms such as aquatic insect larvae, amphipods, and oligochaetes. The 1997 empirical data on ABA were based primarily on measurements of chlorophyll a concentrations samples collected from tile and mylar substrates placed in the field for a 14-day incubation period. Mean concentrations (mg/m²) of five "species" of photosynthetic pigments (evaluated from tile substrates) were reported including chlorophyll a (mono-and trichromatic), b, and c, and phaeophytin.

The upstream station (SNR-148) had consistently high values of the chlorophyll a throughout the season ranging from 29.06 to 93.6 mg/m² with the highest value occurring in October. Only the downstream station in the Ice Harbor Reservoir (SNR-18) had chlorophyll a values that were higher, which were frequently above 100 mg/m² from July through early September. In the Lower Granite Reservoir (SNR-118), the ABA chlorophyll a values ranged from 23.04 to 73.35 mg/m², which are generally lower than that recorded at the upstream station SNR-148.

Trichromatic chlorophyll a levels (the measure of chlorophyll used in the 1975 and 1976) EPA surveys of Falter *et al*. (1976) measured in the high-flow year 1997 at the free-flowing SNR-148 were in the 30-100 mg/m² range at 1.5 m depth. In the low-flow 1998, the range was 60-110 mg/m² at 1.5m depth. The ABA trichromatic chlorophyll a levels obtained in 1975 and 1976 at this site were 10-20 mg/m². There was essentially no overlap between the ranges of 1976 and 1997-98. The earlier data are from glass-slide incubations while the later data are from a combination of natural rock, tile, and a mylar substrate. Even though substrates were different, these ABA data over the 24-year time spread are probably one of the better indicators available of increasing productivity of the Snake River coming into the project area over this time period.

The mean biomass, as measured by the ash-free, oven dry weights (AFODW), for the attached benthic algae samples collected in 1997 follows a similar pattern with the Ice Harbor Reservoir station (SNR-18) having highest biomass of 10.94 to 37.09 g/m². The AFODW for the Lower Granite Reservoir samples (SNR-118) ranged from 9.09 to 25.25 g/m². Samples from the upstream lower Snake station (SNR-148) had ADOFWs ranging between 4.39 and 15.17 g/m². Historical data indicate that ABA ash-free biomass in 1976 averaged 1.64 g/m² at SNR-148. In contrast, the results from 1997, when samples collected from a comparable depth and time period and a non-silt collecting mylar substrate, averaged 6.65 g/m², and in 1998 7.95 g/m. The different measure of ABA ash-free biomass further suggests that productivity in the Lower Snake River is increasing. AFODW samples collected from the upper McNary Reservoir (CLR-326) had AFODWs ranging from 2.26 to 30.27 g/m² with the highest level occurring later in the season toward the end of September. Samples collected in the free-flowing Hanford section (CLR-369) had relatively low biomass values with AFODWs for most samples below 6.0 g/m² and a seasonal range of 0.64 to 14.09 g/m². The McNary Reservoir and the Lower Snake River Reservoirs apparently produce a considerable amount of attached benthic algae biomass along the littoral and shoreline areas. However, much of the system has accumulated fine sediments, which limit the amount of ABA and epilithic periphyton. This finding may prove interesting in evaluating the proposed natural river drawdown alternative, because ABA is generally more prolific in riverine conditions rather than in a reservoir environment.

Tributaries

Alpowa Creek

Alpowa Creek drains an agriculturally dominated watershed. Sediment levels (both concentration and turbidity), stream temperature, and fecal coliform are three major water quality parameters of concern in this watershed. In 1981, Stream temperature during the summer months and high sediment loads especially during winter and spring high flows were recognized as water quality problems for fish in Alpowa Creek (Mendel and Taylor 1981). The WDOE surface water quality standards identify Alpowa Creek as a Class A stream. The classification of a water body in the state of Washington is based on its beneficial uses.

Data to assess the water quality of Alpowa Creek are limited to studies conducted in 1981 (Mendel and Taylor 1981; Soil Conservation Service 1981) and a current monitoring effort by the WSU, Center for Environmental Education (CEE) for the PCD. Because the latter project began in September 1998, data is not yet available to assess stream temperature as a potential limiting factor to native fish during the summer of 2000. Data collected during 2000 will result in some interpretations as to when and where in the watershed stream temperature may limit fish habitat.

The purpose of the collaborative CEE/PCD project is to assess the success of agricultural management practices within the Alpowa Creek watershed. The monitoring protocol focuses on the most critical water quality parameters identified in the watershed: stream temperature, sediment, and fecal coliform. These parameters are measured every two weeks. Additional parameters, measured every two months, include: ammonia, nitrate, total Kjeldahl nitrogen (TKN), and total phosphorus (TP). Stream discharge is measured at three stations monthly, and storm events are sampled when they occur. Benthic macroinvertebrates are collected quarterly and were first collected in the spring of 1999.

Three monitoring sites are established on Alpowa Creek (Figure 11).

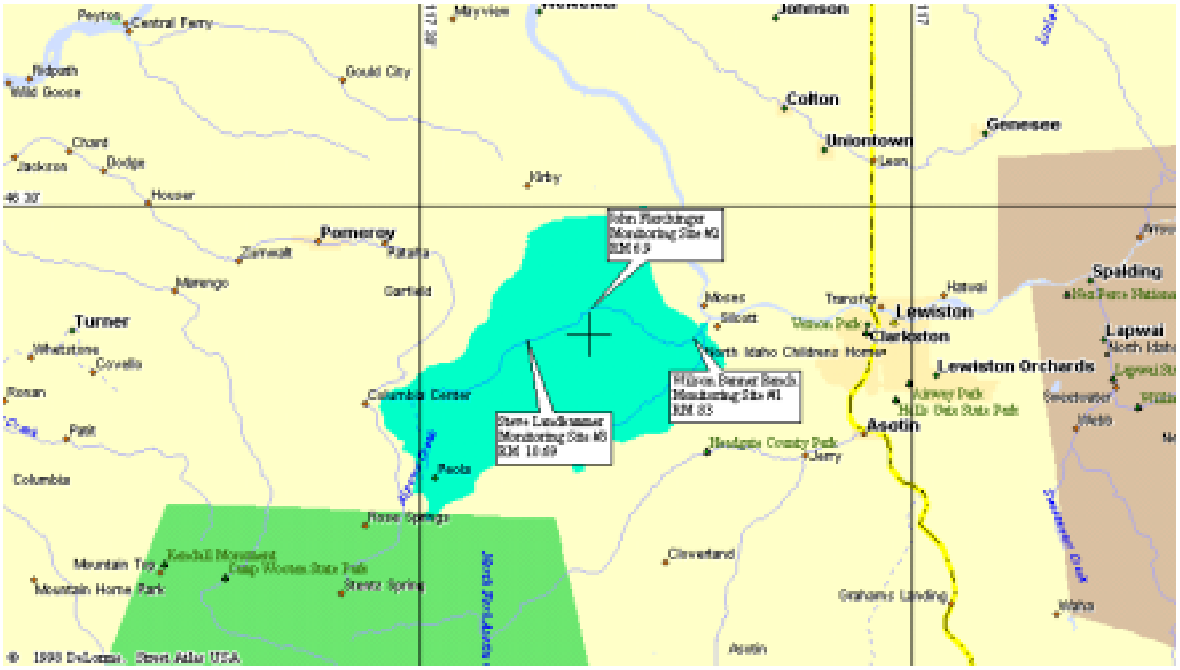


Figure 11. Alpowa Creek Monitoring Sites.

One critical water quality problem in Alpowa Creek is elevated water temperature, especially during mid-summer (Soil Conservation Service (SCS) 1981; Mendel and Taylor 1981). Reduced base flow, summer irrigation withdrawals, and a lack of riparian vegetative cover along many stretches are likely contributors to high summer temperatures. The middle and lower reaches of Alpowa Creek support grazing and agriculture activities that have removed much of the woody riparian and streambank vegetation.

Water temperature exceeded WDOE standards for a Class A stream (18°C) during September 1998 (Figure 12). Considering the temperature in September was 19°C (Center for Environmental Education 1999), it is probable that the average water temperature during July and August may also be higher than the WDOE standard.

Although recent temperature data are not available from April to August, temperature trends during this period were measured in 1981 (Mendel and Taylor 1981). Minimum and maximum stream temperatures were recorded at three locations in Alpowa Creek during the summer 1981. The upstream site (IFG) was located 5.5 miles upstream of the junction of Alpowa Road and Highway 12 (SW 1/4, SE 1/4, section 27, T 11N, R 43E), middle site at 1.2 miles upstream of the junction below the bridge at Weisenfel’s (SW 1/4, NW 1/4, section 20, T 11N, R 44E), and the downstream site at Wilson’s bridge about 30 feet below the dam (between sections 25 and 30, T 11N, R 45E). By late May 1981, stream temperature at the upstream station reached at least 21°C. Considerably warmer temperatures were measured later in the summer (Table 25). While it is impossible to know, given this data, what percentage of the time stream temperatures exceeded a specific critical level (i.e., 18°C as considered by WDOE for Class A waters), these water temperatures are clearly unfavorable to native salmonids during critical life history periods (Table 26).

In many cases, maximum stream temperatures during mid-summer are more extreme and potentially lethal for some native fish species. Two temperature observations were made at the mouth of Alpowa Creek on July 22 and 23, 1975. At 4 pm on July 22, stream temperature was 28.8°C, and at 1:35 pm on July 23, it was 27.3°C (Environmental Protection Agency 1975, cited in Environmental Protection Agency 1999). Steelhead fry emerge from the substrate in Alpowa Creek probably between May and July, and juveniles are rearing through the summer months when temperatures are highest, posing a potential stress during these life history periods.

Additional data found for Alpowa Creek were from late February through June, 1989 (Environmental Protection Agency 1999; (Table 27)). The limits of this data are that temperature and flow were not measured regularly, continuously, or at the same time of day. Still, they provide some indication of potential limitations for migrating adult steelhead and juvenile rearing.

From September 1998 through March 1999, the temperature of Alpowa Creek varied from site to site. Generally, temperature increases in a downstream direction. With the exception of September, the average temperature of Alpowa Creek (October –March) at site 3 was higher than Alpowa 1 and 2. During September (and most likely throughout the summer) the temperature increased with a decrease in streamflow. This trend is most likely a result of summer irrigation diversions, which reduce stream flow and quantity, increasing temperature.

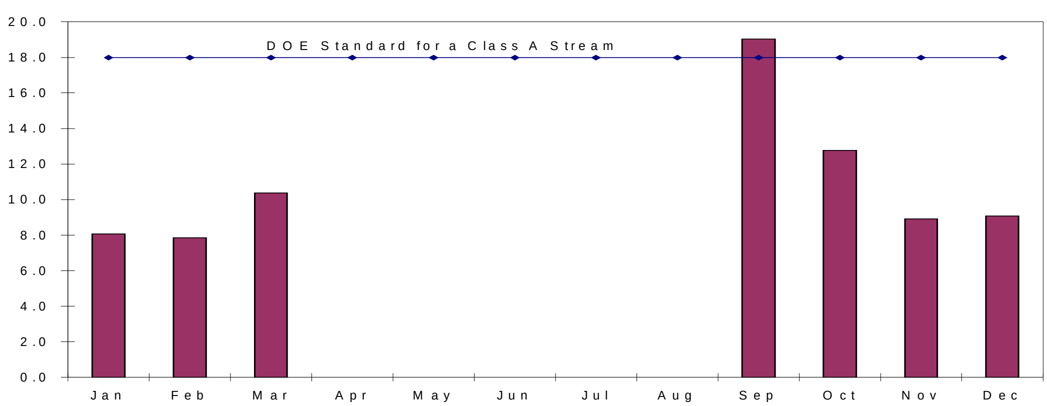


Figure 12. Average Monthly stream temperature of Alpowa Creek, September 1998—March 1999.

Table 25. Maximum and minimum stream temperatures (°C) at three locations in Alpowa Creek during 1981 (modified from Mendel and Taylor 1981).

Time period	IFG site (upper)		Weisenfel's (middle)		Wilson's (lower)	
7/13-7/21	N/A	N/A	25	N/A	29	N/A
7/21-7/30	N/A	N/A	25	14	27	13
7/30-8/6	N/A	N/A	27	12	28	14
8/6-8/14	25	14	28	12	30	16
8/14-8/25	23	12	27	12	29	14
8/25-9/11	22	11	22	N/A	26	12
9/11-9/25	18	8	19	12	24	9

Table 26. Temperature requirements during life history periods for steelhead.

Life History Period	Time Period in Alpowa Creek	Temperature Requirements (°C)
Spawning	March-May	3.9-9.4[a]
Embryonic development/emergence	March-July	8.5-14.0[b]
Juvenile rearing	Year-round	7.3-14.6[c]
Juvenile migration	Feb.-May	< 14.5[b]
Adult migration	Feb.-May	< 17.5[b]

[a]from Bell 1986: For embryonic development, these are upper and lower thresholds beyond which mortality increases. Lower and upper lethal temperatures for juvenile steelhead are 0.0 and 23.9°C.
[b]from Beschta *et al*. 1987
[c]*from Hicks* 1999

Table 27. Mean monthly stream temperature and discharge in Alpowa Creek during 1989.

Month	Stream temperature (°C) (number of observations which mean is based on)	Discharge (cfs) (number of observations which mean is based on)
February	5.0 (2)	20.5 (2)
March	11.5 (12)	31.4 (12)
April	16.5 (6)	16.8 (6)
May	16.5 (4)	13.4 (5)
June	19.4 (5)	9.8 (5)

Since the confluence of Pow Wah Kee Gulch with Alpowa Creek is above the Alpowa 1 site and below the Alpowa 2 site, one would assume slightly higher temperatures at Alpowa 1 than at Alpowa 2. This assumption is not supported by the data. One possibility is that one or more of the unlabeled springs that feed Alpowa Creek above Alpowa 3 may be warm or hot springs, which may have contributed to the temperature differences.

Additional information on Alpowa Creek water quality may be available on a qualitative basis through communication with long-time local landowners. For example, during the 1996 floods many reaches of rivers in the Tucannon sub-basin were damaged and altered as a result of scouring streambeds and banks (B. Bowe, WSU Biological Systems Engineering, personal communication May1999). Each of these mechanisms can potentially increase stream temperature by exposing large amounts of cobble that act as solar collectors, and by reducing vegetative cover on the stream banks. As the monitoring projects of the PCD and CEE continue, trends in the data will emerge.

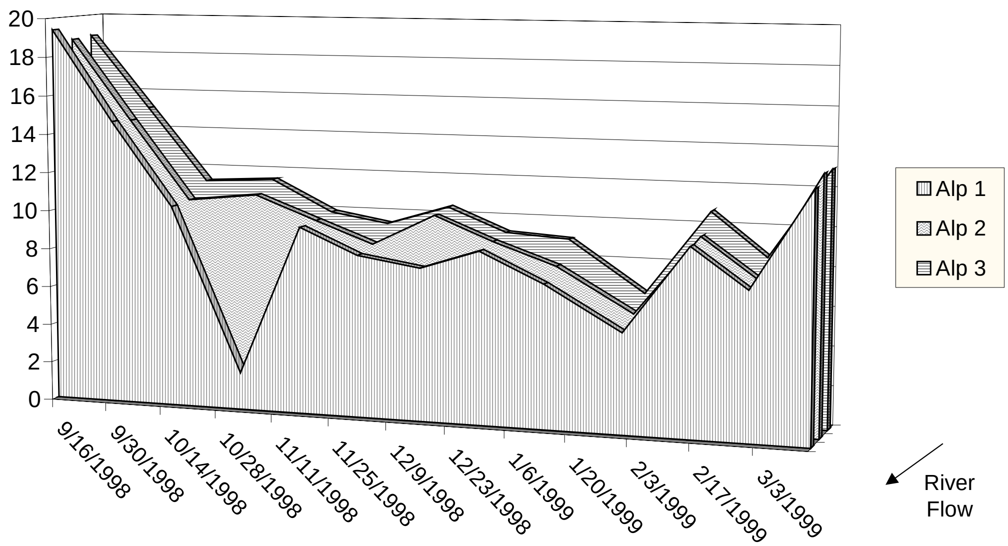


Figure 13. Water temperature (°C) of Alpowa Creek at three sample sites (Center for Environmental Education 1999).

Total suspended solid concentrations varied seasonally and among the three stations. From mid-December to mid-January, Alpowa 1 and Alpowa 2 exceeded 80 mg/L. From mid-February to mid-March the TSS concentration at all three sites exceeded this level (Figure 13). At the end of December, TSS at Alpowa 2 was 181 mg/L, while in early March TSS at Alpowa 1 was 151 mg/L (Center for Environmental Education 1999).

The seasonal variation in TSS generally coincides with peaks in stream discharge. The higher TSS in December probably is due to a rain-on-snow event. Stream discharge increases in response to precipitation or snowmelt in the watershed. High winter precipitation and snowmelt during spring increase runoff, and therefore produce more sediment in the watershed.

When precipitation is the major factor influencing sedimentation to Alpowa, as the peak in December represents, Alpowa 2 samples contain the highest TSS concentrations. However, when spring snowmelt is the driving factor of TSS in the creek, TSS in Alpowa 1 exceeds that of Alpowa 2. In general, with the exception of Alpowa 2, spring snowmelt and precipitation account for higher TSS concentrations than precipitation alone during the winter. On January 15, 1999 during a storm event, TSS measured 2170 mg/L at Alpowa 1 (Center for Environmental Education 1999).

The WDOE standard for fecal coliform in a Class A stream is that waters must not exceed a geometric mean of 100 cfu/100 ml. In addition, not more than 10% of all samples tested may exceed a geometric mean of 200 cfu/100 mL. In general, Alpowa Creek exceeds the WDOE standard of 100 cfu/ 100 mL every month tested with the exception of February (Figure 14). Fecal coliform bacteria are microscopic animals that live in the intestines and excrement of warm-blooded

The geometric mean fecal coliform level from Alpowa Creek during September 1998-March 1999 were 161 cfu/100 mL, exceeding the WDOE standard of 100 cfu/100 mL. Of 39 data values, 38% of them exceeded 200 cfu/100 mL. The highest coliform levels were from Alpowa 2 during December and January (Figure 15). Livestock feedlots were observed at this location and near Alpowa 3, indicating this as a possible source of fecal coliform to the creek. There are also approximately eight ranch homes (B. Bowe, WSU Biological Systems Engineering, personal communication May 1999) in the area, or upstream, that may have failing septic systems. It is difficult to evaluate contamination from these sources as they lay underground, and testing requires the cooperation of the property owner. While waste from livestock in the area is considered to be the major source of coliform in Alpowa Creek, this assumption remains questionable due to the comparably low coliform levels at Alpowa 1. As this site is downstream of Alpowa 2 and livestock feedlots are also in the area, one would expect fecal coliform levels at this site to be comparable, if not higher, than those of samples taken at Alpowa 2.

Streamflow measurements taken in Alpowa Creek during 1981 ranged between 6.7-7.1 cubic feet per second (cfs) between May 5 and October 22 (Mendel and Taylor 1981). Streamflow data is also available during the spring and early summer of 1989 (Table 25). There appears to be adequate stream flow to allow most salmonids to migrate through the system during the summer. Stream temperature, however, is the limitation during this period.

Stream flow data recorded by the USGS during the early 1970’s in the headwaters of Alpowa Creek at Peola (# 13343510) and in the downstream portion of Alpowa Creek at Clayton Gulch (# 13343520) indicate that the storm events in the upstream and downstream areas occur at different times. For example, when flow at Peola on January 9, 1971,was only 0.5 cfs, at Clayton Gulch it was 270 cfs on the same day. Recent field reconnaissance in the Clayton Gulch watershed shows evidence of a substantial amount of sediment and debris flow from past flood events. In the current water quality monitoring effort, discharge measurements are not available for Alpowa 2 and Alpowa 3 sites. Consequently, it is difficult to predict change in water quality at different flow regimes.

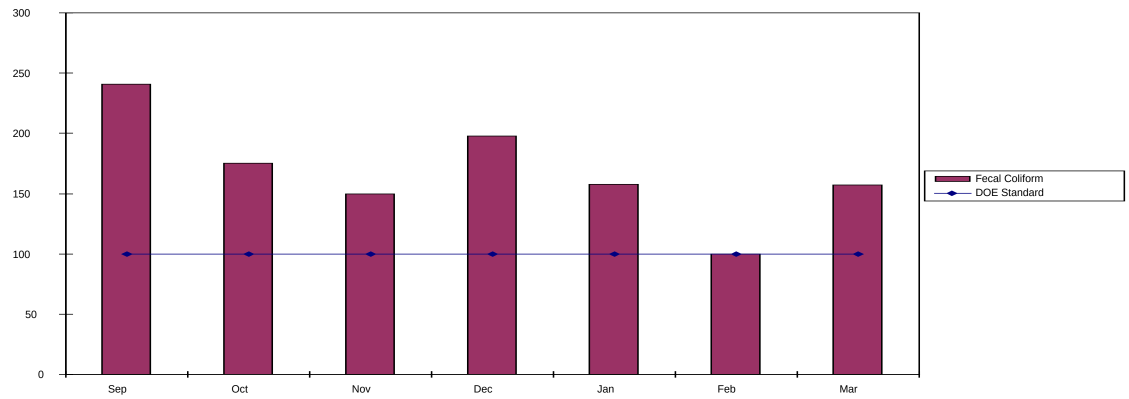


Figure 14. Geometric mean of monthly fecal coliform in Alpowa Creek, September 1998-March 1999 (Center for Environmental Education 1999).

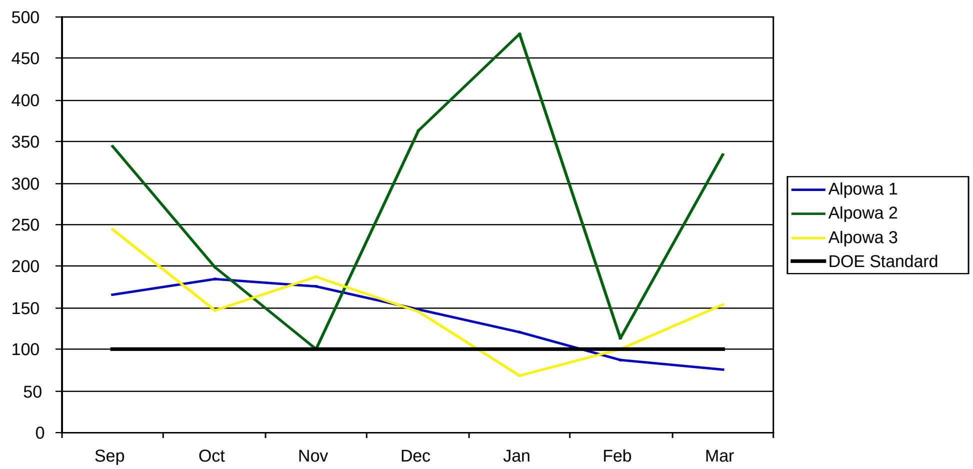


Figure 15. Geometric mean of monthly fecal coliform levels by site from September 1998-March 1999.

Table 28. Nitrate and total phosphorus concentration in Alpowa Creek (Center For Environmental Education 1999).

Date	Nitrate, ppm			Total Phosphorus, ppm		
	Alp 1	Alp 2	Alp 3	Alp 1	Alp 2	Alp 3
9/16/98	0.735	0.604	0.542	0.065	0.000	0.074
11/17/98				0.139	0.068	0.056
1/14/99				0.118	0.121	0.111
3/15/99	0.127					

Total phosphorus concentrations in all three sampling sites in Alpowa exceeded the limit of 0.05 mg/L except at Alpowa 2. No specific trend was found with the limited samples, but a general trend is that Alpowa 1 site had higher TP concentrations during November and January samplings. It is also evident from January samplings that TP is higher during high discharge in the creek than at other times. The only previous nutrient data for Alpowa

Creek was collected on September 11, 1981 at an upstream site (IFG) and another site (R). Total phosphorus measured 0.07 ppm and 0.12 ppm respectively at these sites. Nitrate concentrations at the same two sites were 0.28 ppm and 0.29 ppm (Table 28).

Deadman Creek

Sediment levels (both concentration and turbidity), stream temperature, and fecal coliform are three major water quality parameters of concern in this watershed. Stream temperature during summer months and high sediment loads during winter and spring high flows are water quality problems for fish in Deadman Creek.

The WDOE surface water quality standards identify Deadman Creek as a Class A stream. The classification of a water body in the state of Washington is based on its beneficial uses.

Data to assess the water quality of Deadman Creek are limited to a water quality-monitoring project currently underway with the WSU CEE for the PCD. Because the project began in September 1999, data collected during the summer of 2000 and 2000 (Table 29) will allow us to make some interpretations as to when and where in the watershed stream temperature may limit fish habitat. Three monitoring sites are established on Deadman Creek (Figure 16).

One critical water quality problem in Deadman Creek is elevated water temperature, especially during mid-summer. Reduced base flow, summer irrigation withdrawals, and a lack riparian vegetative cover along many stretches are the likely contributors to these high summer temperatures. The entire length of Deadman Creek support grazing and agriculture activities, which have removed much of the woody riparian and streambank vegetation.

Water temperature exceeded WDOE standards for a Class A stream (18°C) from May - September 1999. While it is impossible to know, given this data, what percentage of the time stream temperatures exceeded a specific critical level (i.e., 18°C as considered by WDOE for Class A waters), these water temperatures are clearly unfavorable to native salmonids during critical life history periods (Table 30). In many cases, maximum stream temperatures during mid-summer are more extreme and potentially lethal for some native fish species. Steelhead fry may emerge from the substrate in Deadman Creek probably between May and July, and juveniles are rearing through the summer months when temperatures are highest, posing a potential stress during these life history periods.

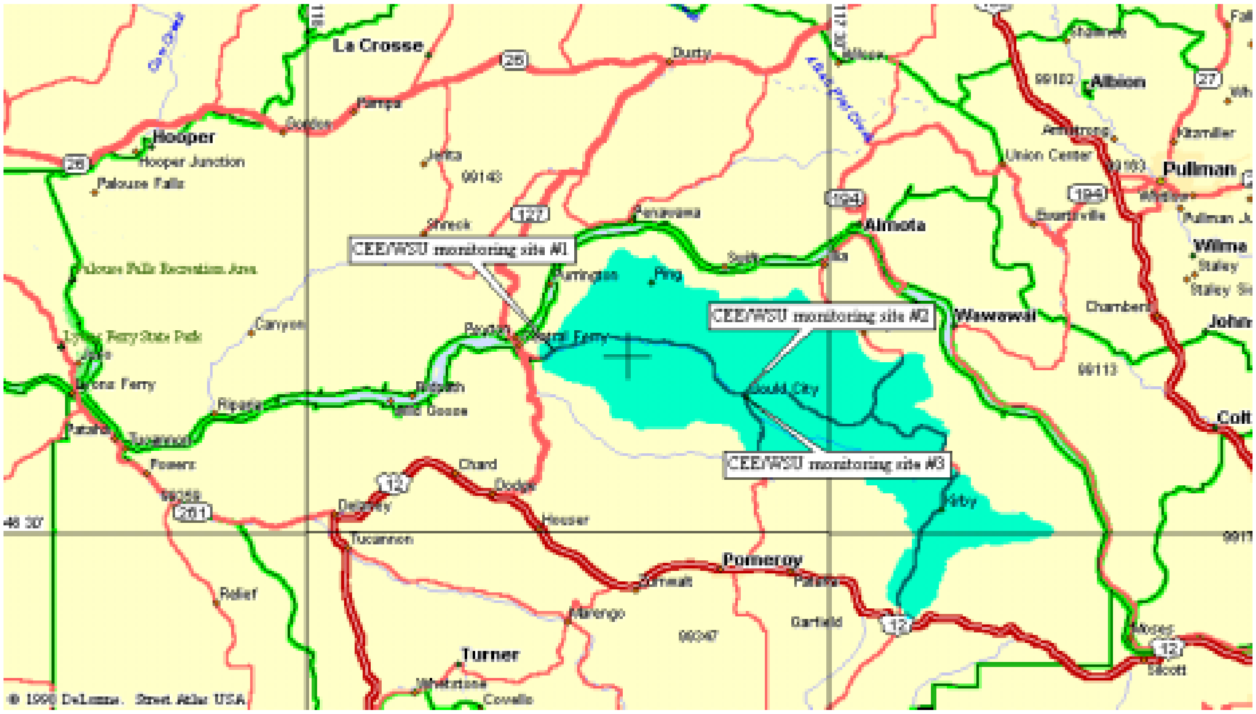


Figure 16. .Deadman Creek Monitoring Sites (WSU/CEE 1998-2000).

Table 29. Water Quality Sampling Data for Deadman Creek (WSU/CEE 1998-2000)

Sample Site	Fecal Coliform (cfu/100ml)	Total Suspended Solids (mg/L)	Temp (deg C)	Temp (deg F)	Ammonia (ppm)	Nitrate (ppm)	Total Kjeldahl Nitrogen (ppm)	Total Phos (ppm)	Discharge (cfs)
Deadman 1	1413.51	317.71	12.91	55.24	0.25	2.49	1.08	0.07	10.97
Deadman 2	687.34	32.33	14.11	57.41	0.27	2.00	0.63	0.05	8.44
Deadman 3	425.66	21.30	13.10	55.59	0.37	1.73	0.89	0.04	7.68

Table 30. Temperature requirements during life history periods for steelhead

Life History Period	Time Period in Deadman Creek	Temperature Requirements (°C)
Spawning	March-May	3.9-9.4[a]
Embryonic development/emergence	March-July	8.5-14.0[b]
Juvenile rearing	Year-round	7.3-14.6[c]
Juvenile migration	Feb.-May	< 14.5[b]
Adult migration	Feb.-May	< 17.5[b]

[a] Bell 1986:
[b] Beschta *et al.* 1987
[c] Hicks 1999

From September 1998 - March 1999, water temperatures in Deadman Creek varied from site to site. During September (and most likely throughout the summer) the temperature increased with a decrease in streamflow. This trend is most likely a result of summer irrigation diversions, which reduce stream flow and quantity, increasing temperature.

Additional information on Deadman Creek water quality may be available on a qualitative basis through communication with long-time local landowners. For example, during the 1996 floods many reaches of rivers in the Tucannon sub-basin were damaged and altered as a result of scouring streambeds and banks (B. Bowe, WSU Biological Systems Engineering, personal communication May1999). Each of these mechanisms can potentially increase stream temperature by exposing large amounts of cobble that act as solar collectors, and by reducing vegetative cover on the stream banks. As the monitoring projects of the PCD and CEE continue, trends in the data will emerge.

Total suspended solid concentrations varied seasonally among the three stations. The seasonal variation in TSS generally coincides with peaks in stream discharge. The higher TSS in December probably is due to a rain-on-snow event. Stream discharge increases in response to precipitation or snowmelt in the watershed. High winter precipitation and snowmelt during spring increase runoff, and therefore produce more sediment in the watershed. Precipitation is the major factor influencing sedimentation to Deadman. An overall average for the Deadman Watershed is 42.71 at the mouth. This is about ½ the upper limit for optimum health of salmonids.

Fecal coliform in Deadman Creek exceeds the WDOE standard of 100 cfu/ 100 mL about 50% of the tests with the overall averages above the standard. The geometric mean fecal coliform level from Deadman Creek exceeds the WDOE standard of 100 cfu/100 mL. It is difficult to evaluate contamination from any one source. Waste from livestock in the area is considered to be the major source of coliform in Deadman Creek

Streamflow measurements taken in Deadman Creek during May through July 1999 ranged between 2.5-5.3 cubic feet per second (cfs). There appears to be adequate stream flow to allow most salmonids to migrate through the system during the summer. Stream temperature, however, is the limitation during this period.

The WDOE does not have standards for phosphorus and nitrogen in surface waters. Total phosphorus concentrations in all three sampling sites in Deadman exceeded the limit of 0.05 mg/L.

Vegetation

Asherin and Claar (1976) inventoried the riparian habitats and associated wildlife along the Lower Snake River for the Corps of Engineers. They found a total of 49 different vegetative and land forms along the Lower Snake River. Table 31 lists a total of 345 different species of plants found within the Lower Snake River summary area (Ashern and Claar 1976; ACOE 1976).

Table 31. Plants found in the Lower Snake River subbasin.

Common Name	Scientific Name

Subalpine fir	*Abies lasiocarpa*
Grand fir	*Abies grandis*
Mountain maple	*Acer glabrum*
Box elder	*Acer negundo*
Silver maple	*Acer saccharinum*
Common yarrow	*Achillea millefolium*
Russian knapweed	*Acroptilon repens*
Jointed goatgras	*Aegilops cylindrica*
Horsechestnut	*Aesculus hippocastanum*
Agoseris	*Agoseris gradiflora*
Crested wheatgrass	*Agropyron cristatum*
Thickspike wheatgrass	*Agropyron dasystachyum*
Intermediate wheatgrass	*Agropyron intermedium*
Quackgrass	*Agropyron repens*
Bluestem wheatgrass	*Agropyron smithii*
Blue bunch wheatgrass	*Agropyron spicatum*
Slender wheatgrass	*Agropyron trachycaulum*
Redtop bentgrass	*Agrostis alba*
Tree of Heaven	*Ailanthus altissima*
American waterplantain	*Alisma plantago-aquatica*
Giant onion	*Allium geyeri var. tenerum*
White alder	*Alnus rhombifolia*
Sita alder	*Alnus sinuata*
Pale alyssum	*Alyssum alyssoides*
Thumbleweed amaranth	*Amaranthus graecizans*
Powell amaranth	*Amaranthus powellii*
Redroot amaranth	*Amaranthus retroflexus*
Bur ragweed	*Ambrosia acanthicarpa*
Common ragweed	*Ambrosia artemisiifolia*
Saskatoon serviceberry	*Amelancier alnifolia*
Tarweed fiddleneck	*Amsinckia lycopsioides*
Menzies fiddleneck	*Amsinckia menziesii*
Rigid fiddleneck	*Amsinckia retrorsa*
Tessellate fiddleneck	*Amsinckia tesselata*
Common bugloss	*Anchusa officinalis*
Field camomile	*Anthemis arvensis*
Mayweed camomile	*Anthemis cotula*
Bur Chervil	*Anthriscus scandicina*
Smooth Indian hemp	*Apocynum cannabinum*
Mouseearcress	*Arabidopsis thaliana*
Common burdock	*Arctium minus*
Sandwort	*Arenaria pusilla*
Thymeleaf sandwort	*Arenaria serpyllifolia*
Threeawn	*Aristida longiseta*
Common wormwood	*Artemisia absinthium*
Tarragon	*Artemisia drancunculus*
Sagebrush	*Artemisia leibergii*
Sagebrush	*Artemisia lindleyana*
Louisiana sagebrush	*Artemisia ludoviciana*
Stiff sagebrush	*Artemisia rigida*
Big sagebrush	*Artemisia tridentata*
Showy milkweed	*Asclepias speciosa*
Garden asparagus	*Asparagus officinalis*
Aster	*Aster campestris*
Aster	*Aster spp.*

Western aster	*Aster occidentalis*
Milk-vetch	*Astragalus arrectus*
Hairy milk-vetch	*Astragalus inflexus*
Pursh locoweed	*Astragalus purshi*
Spaulding's milk-vetch	*Astragalus spauldingii*
Milkvetch; locoweed	*Astragalus spp.*
Piper's milk-vetch	*Atragalus riparius*
Wild oat	*Avena fatua*
Arrowleaf balsamroot	*Balsamorhiza sagittatta*
Water birch	*Betula occidentalis*
Paper birch	*Betula papyrifera*
Nodding beggerticks	*Bidens cernua*
Beggerticks	*Bidens frondosa*
Tall beggerticks	*Bidens vulgata*
Blepharipappus	*Blepharipappus scaber*
Bolandra	*Bolandra oregana*
Mustards	*Brassica spp.*
Douglas brodiea	*Brodiaea douglasii*
Rattlesnake brome	*Bromus brizaeformis*
Japanese brome	*Bromus japonicus*
Soft brome	*Bromus mollus*
Ripgut brome	*Bromus rigidus*
Barren brome	*Bromus sterilis*
Cheatgrass	*Bromus tectorum*
Green-banded mariposa lily	*Calochortus macrocarpus maculosus*
Broad-fruit mariposa lily	*Calochortus nitidus*
False Flax	*Camelina microcarpa*
Shepherd's Purse	*Capsella bursa-patoris*
Hoary cress	*Cardaria draba*
Musk thisle	*Carduus nutans*
Green sedge	*Carex oederi*
Raynold's sedge	*Carex raynoldsii*
Sedge	*Carex spp.*
Chestnut	*Castanea mollissima*
Douglas hackberry	*Celtis douglasii (reticulata)*
Cornflower	*Centaurea cyanus*
Diffuse knapweed	*Centaurea diffusa*
Spotted knapweed	*Centaurea maculosa*
Yellow starthistle	*Centaurea solstitialis*
Bachelor's button	*Centaurea spp.*
Starry chickweed	*Cerastium arvense*
Sticky cerastium	*Cerastium viscosum*
Douglas chaenactis	*Chaenactis douglasii*
Lambsquarter's	*Chenopodium album*
Wormseed goosefoot	*Chenopodium ambrosioides*
Jerusalem oak	*Chenopodium botrys*
Red goosefoot	*Chenopodium rubrum*
Rush skeletonweed	*Chondrilla juncea*
Chorispora	*Chorispora tenella*
Golden Aster	*Chrysopsis hispida*
Rubber rabbitbrush	*Chrysothamnus nauseosus*
Tall green rabbitbrush	*Chrysothamnus viscindiflorus*
Common chicory	*Cichorium intybus*
Tuber waterhemlock	*Cicuta vagans*
Canada thistle	*Cirsium arvense*
Thistle	*Cirsium brevistylum*

Wavy-leaf thistle	*Cirsium undulatum*
Bill thistle	*Cirsium vulgare*
Minerslettuce	*Claytonia perfoliata*
Yellow spider flower	*Cleome lutea*
Tonella	*Collinnnsia floribunda*
Bristle-flowered collomia	*Collomia macrocalyx*
Poison hemlock	*Conium maculatum*
European morningglory	*Convolvulus arvensis*
Horseweed	*Conyza canadensis*
Black hawthorn	*Crataegus douglasii*
Tapertip hawksbeard	*Crepis acuminata*
Slender hawksbeard	*Crepis atrabarba*
Common crupina	*Crupina vulgaris*
Chufa	*Cyperus esculentus*
Clustered lady slipper	*Cyprepidium fasciculatum*
Jimsonweed	*Datura stramonium*
Pinnate tansymustard	*Descurainia pinnata*
Mountain tansymustard	*Descurainia richardsonii*
Venuscup teasel	*Dipsacus sylvestris*
Saltgrass	*Distichlis alkali*
Spring draba	*Draba verna*
Barnyardgrass	*Echinochloa crusgalli*
Russian olive	*Elaeagnus angustifolia*
Needle spikesedge	*Eleocharis acicularis*
Common spikerush	*Eleocharis palustria*
Giant wildrye	*Elymus cinereus*
Creeping wildrye	*Elymus triticoides*
Fireweed	*Epilobium angustifolium*
Glandulosum willowweed	*Epilobium glandulosum*
Autumn willowweed	*Epilobium paniculatum*
Willowweed	*Epilobiu m spp.*
Field horsetail	*Equisetum arvense*
Western scouringrush	*Equisetum hyemale*
Smooth scouringrush	*Equisetum laevigatum*
Marsh horsetail	*Equisetum palustre*
Horsetail	*Equisetum spp.*
Stinkgrass	*Eragrostis cilianensis*
Threadleaf fleabane	*Erigeron filifolius*
Shaggy fleabane	*Erigeron pumilus*
Fleabane	*Erigeron speciosus*
Daisy fleabane	*Erigeron strigosus*
	Eriogonum composition
Wyeth eriogonum	*Eriogonum heracleoides*
Canyon heather	*Eriogonum niveum*
Eriogonum	*Erigonum spp*.
Storksbill	*Erodium cicutarium*
Woolly eriophyllum	*Eriophyllum lanatum*
Western wallflower	*Erysimum asperum*
Ridge-seeded spurge	*Euphorbia glyptosperma*
Leafy spurge	*Euphorbia esula*
Tall fescue	*Festuca arundinacea*
Idaho fescue	*Festuca idahoensis*
Rattail fescue	*Festuca myuros*
Fescue	*Festuca occidentalis*
Sixweeks fescue	*Festuca octoflora*
English fescue	*Festuca pratensis*

Rough fescue	*Festuca scabrella*
Sandbur	*Franseria acanthicarpa*
Yellow fritillary	*Fritillaria pudica*
Blanket flower	*Gaillardia aristata*
Bedstraw	*Galium aparine*
Gaura; velvet weed	*Gaura parviflora*
Geranium	*Geranium viscosissimum*
Slenderleaf gilla	*Gilla linearis*
Mannagrass	*Glyceria spp.*
American licorice	*Glycyrrhiza lepodota*
Cottonbatting cudweed	*Gnaphalium chilense*
Cudweed	*Gnaphalium palustre*
Gum plant	*Grindelia nana*
Gum plant	*Grindelia squarrosa*
Sneezeweed	*Helenium macranthum*
Common Sunflower	*Helianthus annuus*
Helianthella; sunflower	*Helianthus uniflora*
Salt heliotrope	*Heliotropium curassavicum*
Alum root	*Heuchera cylindrica*
Orange hawkweed	*Hieracium aurantiacum*
Meadow hawkweed	*Hieracium pratense*
Oceanspray	*Holodiscus discolor*
Foxtail barley	*Hordeum jubatum*
Wall barley	*Hordeum leporinum*
Mouse barley	*Hordeum murinum*
Ballhead waterleaf	*Hydrophyllum capitatum*
Common St. Johnswort	*Hypericum perforatum*
Iris	*Iris spp.*
Poverty sumpweed	*Iva axillaris*
Common Juniper	*Juniperus communis*
Western juniper	*Juniperus occidentalis*
Rocky Mountain juniper	*Juniperus scopulorum*
Black walnut	*Juglans nagens*
Persian walnut	*Juglans regia*
Belvedere summer cypress	*Kochia scoparia*
Prickly lettuce	*Lactuca serriola*
Slender rabbit leaf	*Lagophylla ramosissima*
Henbit deadnettle	*Lamium amplexicaule*
Western larch	*Larix occidentalis*
Common duckweed	*Lemna minor*
Prairie pepperweed	*Lepidium densiflorum*
Broadleaf peppergrass	*Lepidium latifolium*
Clasping pepperweed	*Lepidium perfoliatum*
Virginia pepperweed	*Lepidium virginicum*
Dalmatian toadflax	*Linaria genistifolia dalmatica*
Yellow toadflax	*Linaria vulgaris*
Perennial flax	*Linum perenne*
Woodlandstar	*Lithophragma bulbifera*
Smallflower woodlandstar	*Lithophragma parvilflora*
Stoneseed	*Lithospermum arvense*
Western gromwell	*Lithospermum ruderale*
Lomatium	*Lomatium disectum*
Gray’s biscuitroot	*Lomatium grayi*
Nineleaf lomatium	*Lomatium triternatum*
Riverbar deervitch	*Lotus denticulatus*
Spanish clover	*Lotus purshianus*

Velvet lupine	*Lupinus leucophyllus*
Silky lupine	*Lupinus sericeus*
Lupines	*Lupinus spp.*
Sulfur lupine	*Lupinus sulphureus*
Lychnis	*Lychnis coronaria*
American bugleweed	*Lycopus americanus*
Rough bugleweed	*Lycopus asper*
Purple loosestrife	*Lythrum salicaria*
Hollygrape	*Mahonia repens*
Cheeses	*Malva neglecta*
Common horehound	*Marrubium vulgare*
Pepperwort	*Marsilea vestita*
Scentless May-weed	*Matricaria maritima*
Black medic	*Medicago lupulina*
Alfalfa	*Medicago sativa*
White sweet clover	*Melilotus alba*
Yellow sweetclover	*Melilotus officinalis*
Sweetclover	*Melilotus spp.*
Mint	*Mentha arvensis*
Rough blazingstar	*Mentzelia laevicaulis*
Monkey flower	*Mimulus guttatus*
Carpetweed	*Mollugo verticillata*
White mulberry	*Morus alba*
Red mulberry	*Morus rubra*
Mosses	*Moss spp.*
Bay Forget-me-not	*Myosotis laxa*
Forget-me-not	*Myosotis micrantha*
Catnip	*Nepeta cataria*
Common eveningprimrose	*Oenothera biennis*
Scotch thistle	*Onopordum acanthium*
Plains prickly pear	*Opuntia polyacantha*
Indian ricegrass	*Oryzopsis hymenoides*
Old witchgrass	*Panicum capillare*
Scribner panicum	*Panicum scribnerianum*
Parietaria	*Parietaria occidentalis*
Virginia creeper	*Parthenocissus quinquefolia*
Beard-tongue	*Penstemon triphyllus*
Prairie clover	*Petalostemon orantum*
Varileaf phacelia	*Phacelia heterophylla*
Silverleaf phacelia	*Phacelia leucophylla*
Threadleaf phacelia	*Phacelia linearis*
Reed canarygrass	*Phalaris arundinacea*
Syringa; mockorange	*Philadelphis lewisii*
Timothy	*Phleum pratense*
Common Twinpod	*Physaria didymocarpus didymocarpus*
Popcornflower	*Plagiobothrys tenellus*
Indian wheat	*Plantago patagonica*
Longleaf phlox	*Phlox longifolia*
Field pea	*Pisum arvense*
Buckhorn plantain	*Plantago lanceolata*
Woolly indianwheat	*Plantago purshi*
Engelmann spruce	*Picea Engelmannii*
Whitebark pine	*Pinus albicaulis*
Lodgepole pine	*Pinus contorta*
Limber pine	*Pinus flexilis*
Western white pine	*Pinus monticola*

Ponderosa pine	*Pinus ponderosa*
Patagonia Indianweed	*Plantago patagonica*
Longhorn plectritis	*Plectritis macrocera*
Bulbous bluegrass	*Poa bulbosa*
Canda bluegrass	*Poa compressa*
Howell's bluegrass	*Poa howellii*
Bluegrass	*Poa interior*
Wheeler bluegrass	*Poa nervosa*
Nevada bluegrass	*Poa nevadensis*
Kentucky bluegrass	*Poa pratensis*
Sandberg bluegrass	*Poa sandbergii*
Littlebells polemonium	*Polemonium micrathum*
Rabbitfoot polypogan	*Polypogon monspeliensis*
Prostrate knotweed	*Polygonum aviculare*
Knotweed	*Polygonum coccineum*
Swamp knotweed	*Polygonum hydropiperoides*
Curlytop ladysthumb	*Polygonum lapathifolium*
Knotweed	*Polygonum majus*
Dotted smartweed	*Polygonum punctatum*
Sakhalin knotweed	*Polygonum sachalinense*
Licorice-root fern	*Polypodium vulgare*
Rabbitfoot polypogon	*Polypogon monspeliensis*
Balsam poplar	*Populus balsomifera*
Great plain cottonwood	*Populus deltoides*
Lombardy popular	*Populus nigra*
Quaking Aspen	*Populus tremuloides*
Black cottonwood	*Populus trichocarpa*
Common purslane	*Portulaca oleracea*
Fennelleaf pondweed	*Potamogeton pectinatus*
Cinquefoil	*Potentilla r ecta*
Douglas fir	*Pseudotsuga menziesii*
Lanceleaf scurfpea	*Psoralea lancelata*
Common apricot	*Prunus armeniaca*
Mahaleb cherry	*Prunus mahaleb*
Peach	*Prunus persica*
Stone fruit	*Prunus spp.*
Blackthorn	*Prunus spinosa*
Chokecherry	*Prunus virginianus*
Antelope bitterbrush	*Purshia tridentata*
Common pear	*Pyrus communis*
Cultivated apple	*Pyrus malus*
Small flowered buttercup	*Ranunculus abortivus*
Buttercup	*Ranunculus purshii*
Buttercup	*Ranunculus uncinatus*
Cascara buckhorn	*Rhamnus purshiana*
Smooth sumac	*Rhus glabra*
Poison ivy	*Rhus radicans*
Skunkbrush	*Rhus trilobata*
Golden current	*Ribes aureum*
Wax current	*Ribes cereum*
Black current	*Ribes hudsonianum*
Snow gooseberry	*Ribes niveum*
Black locust	*Robinia pseudoacacia*
Watercress	*Rorippa nasturitium-aquaticum*
Arc cress	*Rorippa curvisiliqua*
Cultivated rose	*Rosa spp.*

Wild rose	*Rosa woodsii*
Evergreen blackberry	*Rubus laciniatus*
Northwest raspberry	*Rubus nigerrimus*
Trailing blackberry	*Rubus macropetalus*
Blackeyedsusan	*Rudbeckia hirta*
Sheep sorrel	*Rumex acetosella*
Yellow or curly dock	*Rumex crispus*
Western dock	*Rumex occidentalis*
Willow dock	*Rumex salicifolius*
Veiny dock	*Rumex venosus*
Duckpotato arrowhead	*Sagittaria cuneata*
Peachleaf willow	*Salix amygdaloides*
Whiplash willow	*Salix caudata*
Coyote willow	*Salix exigua*
Pacific willow	*Salix lasiandra*
MacKenzie willow	*Salix rigida*
Common Russianthistle	*Salsola kali*
Russian thistle	*Salsola pestifer*
Blue elderberry	*Sambucus glauca*
Tule bulrush	*Scirpus acutus*
American bulrush	*Scirpus americanus*
Softstem bulrush	*Scirpus validus*
Narrowleaf skullcap	*Scutellaria angustifolia*
Rye	*Secale cereale*
Rye	*Secale montanum*
Stonecrop	*Sedum douglasii*
Wallace selaginella	*Selaginella wallacei*
Yellow foxtail	*Setaria glauca*
Foxtail	*Setaria d isveri*
Tumbleweed mustard	*Sisymbrium altissimum*
Hedge mustard	*Sisymbrium officinale*
Hansen squirreltail	*Sitanion hystrix*
Bittersweet	*Solanum dulcamara*
Silverleaf nightshade	*Solanum elaeagnifolium*
Buffalobur	*Solarum rostatum*
Nightshade	*Solanum sarrachoides*
Canada goldenrod	*Solidago canadensis*
Giant goldenrod	*Solidago gigantea*
Elegant goldenrod	*Solidago lepida*
Missouri goldenrod	*Solidago missouriensis*
Western goldenrod	*Solidago occidentallis*
Goldenrod	*Solidago spp.*
Common sowthistle	*Sonch us oleraceus*
Johnsongrass	*Sorghum halepense*
Salmon globe mallow	*Sphaeralcea munroana*
Maple-leaved mallow	*Sphaeralcea rivularis*
Spirea	*Spirea trichocarpa*
Sand dropseed	*Sporobolus cryptandrus*
Chickweed	*Stellaria media*
Starwort	*Stellaria washingtonia*
Flowering straw	*Stephanomeria tenuifolia*
Needle-and-thread grass	*Stipa comata*
Australian peavine	*Swainsona salsula*
Columbia snowberry	*Symphoricarpos rivularis*
Common lilac	*Syringa vulgaris*
Medusahead wildrye	*Taeniatherum asperum*

Tamarisk	*Tamarix parviflora*
Tansy	*Tanacetum vulgare*
Dandelion	*Taraxacum officinale*
Pacific yew	*Taxus brevifolia*
Thelypodium	*Thelypodium laciniatum*
Arbor vitae	*Thuja occidentalis*
Western redcedar	*Thuja plicata*
Western poison ivy	*Toxicodendron radicans*
Goatsbeard	*Tragopogon dubuis*
Goatsbeard	*Tragopogon miscellus*
Puncture vine	*Tribulus terrestris*
Douglas'	*Trifolium douglasii*
Common wheat	*Triticum aestivum*
Western hemlock	*Tsuga heterophylla*
Mountain hemlock	*Tsuga mertensiana*
Narrowleaf cattail	*Typha angustifilia*
Cat-tail	*Typha latifolia*
Chinese elm	*Ulmus parvifolia*
Big stinging nettle	*Urtica dioica*
Slim nettle	*Urtica gracilus*
Cow soapwort	*Vaccaria segetalis*
Moth mullein	*Verbascum blattaria*
Flannel mullein	*Verbascum thapsus*
Bigbract verbena	*Verbena bracteata*
American speedwell	*Veronica americana*
Water speedwell	*Veronica anagallis*
Common speedwell	*Veronica arvensis*
Purslane speedwell	*Veronica peregrina*
Hairy vetch	*Vicia villosa*
Grapevine	*Vitis spp.*
Cocklebur	*Xanthium strumarium*
Common poolmat	*Zannichellia palustria*

Tributaries

Alpowa Creek

One of the earliest recorded observations of vegetation around Alpowa Creek dates back to October 1854, when the stream was described as being is from eight to ten yards wide and fifteen inches deep and bordered by willow, long-leaved cotton-wood, birch, sumac, cherry, white haw, honeysuckle and gooseberry. The left bank of the stream was described with "very good grass and an abundance of wood" (Brauner 1976). The native riparian vegetation of the area was characterized by shrubby thickets, patches of deciduous trees, and grass-dominated plant communities. Conifer trees, predominantly ponderosa pine and douglas fir, were historically more common than today. A broad scale analysis of the changes in wetland distribution by researchers at the University of Idaho indicates a 97% reduction in the Palouse Bioregion. Most of these wetlands were drained or filled to increase the land available for agricultural and ranching uses (Black *et al* 1997).

The predominant upland vegetation types were bluebunch wheatgrass communities on the drier sites, and shrub steppe communities of rabbitbrush, sagebrush, or antelope bitterbrush on the more mesic sites (Asherin and Claar, 1976). Significant alterations in the quality and quantity of upland habitats have occurred since European settlement. Habitats on more gentle topography have been converted to commercial agriculture, with the remaining areas used as pasture for domestic livestock. Some remnant shrub steppe communities can be found within the Alpowa Creek drainage but these are increasingly threatened by wildfire, and continued livestock grazing. Encroachment of noxious weeds has also degraded the quality of native plant communities within the uplands. Hironaka (1954) described bluebunch wheatgrass and Sandberg's bluegrass communities that had been invaded by St. John's wort. Cheatgrass and St. John's wort were early invaders but now yellow starthistle and other knapweeds are beginning to establish within the drainage.

Deadman Creek

The riparian vegetation within this basin was historically more extensive and diverse than what is present today (Black *et al*. 1997). In most areas, a mixture of mature trees, shrubs, and herbaceous plants covered the entire floodplain. However, as the width of area covered by dense trees and shrubs declined, so did the diversity and abundance of species. The Washington Department of Fish & Wildlife (WDFW) has developed recommendations on the width of the riparian zone that will help maintain high quality fish and wildlife habitat (Riparian Habitat Area-RHA) (Knutson and Naef 1997). Although the recommended RHA for Deadman Creek and its major tributaries is 150 feet, present conditions seldom meet this, contributing to a reduction in large woody debris recruitment potential and the watershed's ability to support fish and wildlife.

A large amount of cropland has been converted into the Conservation Reserve Program (CRP) since 1986. The CRP contract is for ten years and contracts that were signed in 1986 until 1990 have expired and a large portion of these were resigned under newer contracts.

Due to the economic conditions of agriculture over the last several years, the enrollment into the government programs continues to increase. The allotment of acres (25%) for CRP in Garfield County will undoubtedly be reached with another CRP signup period, which will set the limit on this type of upland conservation. However, the continuation of the continuous CRP and CREP programs will increase the number of acres along perennial and seasonal streams in the Deadman Watershed.

Fish and Wildlife Status

Fish

Reservoirs (Corps 1999)

Eighteen native species and 17 introduced fish comprise the current resident ichthyofauna of the reservoirs. A list of resident fish species compiled from several sources with common and scientific names is shown in Table 32. The white sturgeon is a state species of concern in Idaho. Bull trout are listed as a threatened species in the Snake River Basin.

Current information on the relative abundance of resident fish in the lower Snake River reservoirs suggests that fish community structure is generally similar among reservoirs (BPA 1995). Bennett *et al*. (1983) conducted seasonal sampling in each of the four lower

Snake River reservoirs and extensive sampling in Little Goose Reservoir in 1979 and 1980. Bridgelip sucker, redside shiner, largescale sucker, smallmouth bass, and northern pikeminnow were the age one and older fish in highest relative abundance, based on sampling with multiple gear types in Little Goose Reservoir (Table 32). These five species accounted for about 80% of all fish sampled in 1979 and 1980. All of these fish but smallmouth bass are native species in the Snake River. Species of lesser abundance were a mixture of native and introduced fish. Chiselmouth, another native cyprinid species, was moderately abundant in the lower Snake River reservoirs, while native peamouth, sculpins, and white sturgeon were less abundant. Introduced crappies, yellow perch, and some sunfish were highly abundant in off-channel habitats. Other introduced fish such as catfish and bullheads were present, but in lower abundance. Non-migratory salmonid fish were generally rare, seasonal in occurrence, and typically associated with a tributary confluence.

Relative abundance of fish varied among habitats sampled. In general, introduced centrarchid fish were more abundant in lentic backwater habitats while native suckers and redside shiners were more abundant in the more lotic up-reservoir stations (e.g., tailwater and upper shoal). For example, Bennett *et al*. (1983) reported that redside shiner and bridgelip sucker dominated the catch in the Lower Granite Dam tailwater of Little Goose Reservoir during 1980. These two species combined represented over 60% of the fish caught by multiple gear types. A tendency also existed to have higher abundance of selected species in the older downstream reservoirs. These species, all introduced, included channel catfish, largemouth bass, and carp. In contrast, non-native smallmouth bass, pumpkinseed, and white crappie were more abundant in upriver reservoirs.

Table 32. Composite resident fish species list and sources of data for the Lower Snake River (Corps 1999).

Common Name*	**Scientific Name**	**Bennett *et al*. (1983)**	**BRD-ODFW (1991)**	**SOR (1995)**
White sturgeon	*Acipenser transmontanus*	X	X	X
Rainbow trout	*Oncorhynchus mykiss*	X		X
Kokanee	*Oncorhynchus nerka*	X		X
Mountain whitefish	*Prosopium williamsoni*	X	X	X
Brown trout	Salmo trutta	X		X
Bull trout	*Salvelinus confluentus*		X	X
Chiselmouth	*Acrocheilus alutaceus*	X	X	X
Common carp	Cyprinus carpio	X	X	X
Peamouth	*Mylocheilus caurinus*	X	X	X
Northern pikeminnow	*Ptychocheilus oregonensis*	X	X	X
Longnose dace	*Rhinichthys cataractae*			X
Speckled dace	*Rhinichthys osculus*	X		X
Redside shiner	*Richardsonius balteatus*	X	X	X
Bridgelip sucker	*Castosmos columbianus*	X	X	X
Largescale sucker	*Catostomus macrocheilus*	X	X	X
Yellow bullhead	Ameiurus natalis	X		X
Brown bullhead	Ameiurus nebulosus	X	X	X
Channel catfish	Ictalurus punctatus	X	X	X
Tadpole madtom	Noturus hyrinus	X		X
Flathead catfish	Pylodictus olivaris	X		X

Common Name*	Scientific Name	Bennett *et al.* (1983)	BRD-ODFW (1991)	SOR (1995)
Mosquitofish	Gambusia affinis			X
Three-spine stickleback	*Gasterosteus aculeatus*		X**	
Sandroller	*Percopsis transmontana*		X	X
Pumpkinseed	Lepomis gibbosus	X	X	X
Warmouth	Lepomis gulosus	X		X
Bluegill	Lepomis macrochirus	X	X	X
Smallmouth bass	Micropterus dolomieui	X	X	X
Largemouth bass	Micropterus salmoides	X		X
White crappie	Pomoxis annularis	X	X	X
Black crappie	Pomoxis nigromaculatus	X	X	X
Yellow perch	Perca flavescens	X	X	X
Walleye	Stizostedion vitreum			X
Prickly sculpin	*Cottus asper*	X		X
Mottled sculpin	*Cottus bairdi*	X		X
Piute sculpin	*Cottus beldingi*	X		X

*Bold type indicates native species.
**Questionable record.
Note: Bennett *et al*. (1983) reflects sampling by multiple gear types in the four reservoirs. BRD-Oregon Department of Fish & Wildlife (ODFW) (1991) reflects sampling by electrofisher and includes sampling in the unimpounded Snake River above Asotin, Washington. SOR (1995) is a compilation of data from various sources, including the Snake River below Ice Harbor Dam.

Bennett *et al*. (1983) also showed variation in abundance among similar habitats in different reservoirs. For example, the abundance of chiselmouth and northern pikeminnow was considerably higher at an embayment station in Lower Monumental Reservoir than in embayment habitat in either Little Goose or Ice Harbor reservoirs. Also, the abundance of chiselmouth was higher at main channel stations on Lower Monumental and Lower Granite reservoirs than in Ice Harbor Reservoir (Table 33).

Table 33. Species composition of fish collected with multiple gear types in Lower Snake River reservoirs during 1979 to 1980 (Corps 1999).

Species	Lower Granite		Little Goose		Lower Monumental		Ice Harbor	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
White sturgeon	0	0.0	235	0.6	3	0.1	2	0.1
Mountain whitefish	2	0.1	39	0.1	2	0.0	10	0.3
Rainbow trout	4	0.1	172	0.4	22	0.5	6	0.2
Brown trout	0	0.0	1	0.0	0	0.0	0	0.0
Chiselmouth	310	10.0	1,456	3.6	408	8.7	99	2.6
Common carp	120	3.9	1,057	2.6	187	4.0	256	6.6
Peamouth	2	0.1	76	0.2	25	0.5	23	0.6
Northern pikeminnow	354	11.5	2,510	6.2	823	17.5	347	9.0
Speckled dace	0	0.0	4	0.0	0	0.0	0	0.0
Redside shiner	246	8.0	3,847	9.5	219	4.7	553	14.3
Bridgelip sucker	274	8.9	3,803	9.4	490	10.4	402	10.4
Largescale sucker	1,255	40.7	7,972	19.7	849	18.1	1,257	32.5
Yellow bullhead	15	0.5	240	0.6	22	0.5	1	0.0
Brown bullhead	36	1.2	629	1.6	31	0.7	20	0.5
Channel catfish	7	0.2	1,152	2.8	118	2.5	218	5.6
Tadpole madtom	0	0.0	72	0.2	1	0.0	1	0.0

Species	Lower Granite		Little Goose		Lower Monumental		Ice Harbor	
	Number	**Percent**	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Flathead catfish	0	0.0	0	0.0	0	0.0	2	0.1
Pumpkinseed	16	0.5	1,926	4.8	145	3.1	70	1.8
Warmouth	0	0.0	13	0.0	0	0.0	0	0.0
Bluegill	12	0.4	1,218	3.0	5	0.1	21	0.5
Smallmouth bass	218	7.1	2,104	5.2	301	6.4	106	2.7
Largemouth bass	0	0.0	61	0.2	0	0.0	31	0.8
White crappie	68	2.2	7,011	17.3	440	9.4	118	3.7
Black crappie	79	2.6	1,672	4.1	129	2.7	141	3.6
Yellow perch	68	2.2	3,046	7.5	396	8.4	145	3.7
Sculpins	0	0.0	201	0.5	80	1.7	38	1.0
Totals	3,086		40,517		4,696		3,867	
Source: Modified from Bennett *et al*. 1983.								

Although these differences in the fish community were apparent, overall similarities in relative abundance persisted as determined by correlation analysis (Table 34). The relative abundance of fish among reservoirs showed high similarities with correlations ranging from r = 0.74 (Lower Granite and Little Goose reservoirs) to r = 0.94 (Lower Granite and Ice Harbor reservoirs). This cursory analysis shows that from 54 to 87% of the variation in fish communities is accounted for by differences in reservoirs. These correlations are largely driven by the species in higher abundance among each of the reservoirs. A number of other fish were collected, but all were generally lower in abundance in each of the lower Snake River reservoirs. Because of the general similarities in fish community structure, we believe a more specific analysis by habitat best describes the fish within the lower Snake River reservoirs.

Table 34. Correlation coefficients of relative abundance among Snake River reservoir resident fish communities (Corps 1999).

	Little Goose	Lower Monumental	Ice Harbor
Lower Granite	0.74	0.80	0.94
Little Goose	1.00	0.81	0.78
Lower Monumental	0.81	1.00	0.76

Subsequent research has provided updated or refined estimates of relative abundance among reservoirs or among macrohabitat types for selected species deemed important in predator-prey relationships or sport fisheries. ODFW sampled fish with multiple gear types throughout the Lower Snake River in 1991 and 1994 to 1996 as part of an investigation of predator dynamics, distribution, and abundance (Zimmerman and Parker 1995; Ward and Zimmerman 1997; Zimmerman and Ward 1997). Reporting of results was limited to three piscivorous species. Smallmouth bass density (CPUE) in 1991 was reportedly highest in mid-reservoir and forebay reaches of Snake River reservoirs. Additionally, smallmouth bass relative abundance and density in Lower Granite Reservoir was more than twice that in other lower Snake River reservoirs, and density decreased in a downstream direction. Follow-up sampling in the upper reservoir reach of Lower Granite Reservoir showed a trend of decreasing abundance of smallmouth bass from 1994 to 1996, but other areas in

Lower Granite Reservoir or other reservoirs were not sampled from 1994 to 1996 for comparison.

Trends in channel catfish abundance and density were generally opposite those for smallmouth bass. The density and relative abundance of channel catfish in Ice Harbor Reservoir were more than twice that in any other reservoir, and catfish were least abundant in Lower Granite Reservoir. Further, the highest density of channel catfish among reservoir macrohabitats was in mid-reservoir and tailrace reaches, especially in tailrace BRZs.

Northern pikeminnow density among reservoir macrohabitats was highest in tailrace BRZs. Density was highest in tailrace BRZs of Little Goose and Lower Monumental reservoirs (i.e., below Lower Granite and Little Goose dams). Mid-reservoir densities were lower, but the overall abundance was higher due to the large size of mid-reservoir areas relative to other habitats. Comparable sampling during the 1994 to 1996 period in the tailraces of Lower Monumental and Little Goose reservoirs and upper reservoir habitats in Lower Granite Reservoir showed declines in abundance of northern pikeminnow greater than 250 millimeters (9.8 inches) due to operation of a sport reward program that paid bounties for removal of large-sized individuals by angling (Friesen and Ward 1997).

Qualitative assessments of distribution and abundance within reservoir macrohabitats for other Snake River fish sampled by electrofishing during 1991 are shown in (Table 35) (Tom Poe, U.S.G.S., B.R.D., unpublished data). Species such as chiselmouth, carp, northern pikeminnow, suckers, and smallmouth bass were widely distributed among reservoirs and habitats, and abundance of these species was reported as common in most locations. Only northern pikeminnow and suckers were recorded as abundant in some reservoir macrohabitats. Species either less abundant or more narrowly distributed included mountain whitefish, brown bullhead, pumpkinseed, bluegill, crappie, and yellow perch. Of these, all but mountain whitefish were most abundant in embayment or gulch habitats as reported in Bennett *et al*. (1983), which may illustrate the results of different sampling protocols or gear types.

Table 35. Qualitative relative abundance estimates of resident fish determined by electrofishing in macrohabitats of Lower Snake River reservoirs in 1991(Corps 1999).

Species	Ice Harbor			Lower Monumental			Little Goose			Lower Granite			Snake R. Arm	Clearwater R. Arm	Free-Flowing Snake R.
	F	M	T	F	M	T	F	M	T	F	M	T			
White sturgeon			C						R				R		
Bull trout															R
Mountain whitefish	R			R	R	R			R	R		R	C	C	C
Chiselmouth	R	R	C	C	C	C	R	C	C	C	R	C	C	C	C
Common carp	C	C	C	C	C	C	C	C	C	C	R	C	C	R	C
Peamouth	R	C	C	C	C	C						R		R	
Northern pikeminnow	R	C	C	C	C	C	C	C	A	C	R	C	C	C	C
Redside shiner								R						R	
Suckers	C	C	A	C	C	C	C	C	C	C	C	C	A	A	A
Brown bullhead		R		R	R	C	C	R			R				
Channel catfish	R	C	R	R	C	C		C					R		

Sandroller					R										
Three-spine											R*				
stickleback	R	C	R	R	C			R			R	R		R	
Pumpkinseed	C				R										
Bluegill	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Smallmouth bass	C	C	R	R	C	C	R	C	R	R	R	R			
Crappies	R	R	C	R	C	C	R	C	C					R	
Yellow Perch														R	
Sculpins															

A=abundant (>25 individuals per collection
C=common (>2-25 individuals per collection
R=rare (1-2 individuals per collection)
*Questionable record
F=forebay; M=mid-reservoir; T=tailrace; U=upper reservoir
Source: USGS, Biological Resources Division, Cook, Washington

Several species were mostly reported as rare (one or two individuals per collection) in 1991 samples. These included redside shiner, sandroller, bull trout, and sculpins. Bull trout was only reported above the reservoir influence in the mid-Snake river, but are also infrequently reported passing the dams. Sculpins and sandrollers are occasionally seen in stomach samples of reservoir predators, rather than in standard fisheries collections (David H. Bennett, University of Idaho, personal communication). Mosquitofish are only found in levee ponds in Lewiston (David H. Bennett, University of Idaho, personal communication).

More recently, the spatial trends in catch and catch rates among reservoirs determined by 1997 sport fishing surveys (Normandeau Associates *et al*. 1998a) corroborated trends in species density and abundance estimates for major Snake River predators as portrayed by Zimmerman and Parker (1995). For example, the highest smallmouth bass sport angling catches and catch rates occurred in Lower Granite Reservoir, whereas sport angling catch, harvest, and catch and harvest rates for channel catfish were highest in Ice Harbor Reservoir. The catch and catch rates of northern pikeminnow by anglers were highest in Lower Granite Reservoir, particularly in the more lotic Snake River arm of the upper reservoir.

Recent sport fishing catches may also illustrate recent spatial trends in distribution among reservoirs for several other species not targeted by specific management studies or activities. Sport catch and harvest of crappie were substantially higher in Little Goose Reservoir than in other reservoirs, especially in Ice Harbor Reservoir where crappie catch was nearly two orders of magnitude lower than in Little Goose Reservoir (Normandeau Associates *et al*. 1998a). Similarly, the white sturgeon sport catch was highest in Little Goose Reservoir. Yellow perch and sunfish (Lepomis spp.) sport catches were substantially higher in the downstream reservoirs, especially in Ice Harbor Reservoir. The sport catch of bullheads was highest in Lower Granite Reservoir.

In summary, recent documentation of the status of Lower Snake River reservoir resident fish communities has focused primarily on a small group of species, mostly non-native, and that information on the current status of most native species (other than northern pikeminnow and white sturgeon) is lacking. Thus, the work by Bennett *et al*. (1983) shortly after the last reservoir was completed in 1975 represents the only quantitative information available on most resident fish that likely remain quite abundant and widely distributed. These species include largescale and bridgelip suckers, redside shiner, and other native cyprinids and cottids.

In spite of the recent information on the relatively high-profile species, the overall similarities in community composition and relatively limited information on specific fish abundance of most species in each reservoir suggest that the four lower Snake River reservoirs should be treated as one reservoir system with an analysis of the fish community inhabiting each of the principal macrohabitats in the reservoirs. Our analysis of expected impacts will be based on examination of the characteristic fish communities in the forebay, tailrace, mid-reservoir, and specific backwater/embayment habitats common to all reservoirs in the system. This type of analysis will facilitate subsequent descriptions of expected impacts to reservoir fish communities for the various alternatives under consideration.

Six species or congeners have been identified for individual treatment as ecologically key, or important, species. The native northern pikeminnow, for example, is important in predator-prey dynamics of the reservoirs (Ward *et al*. 1995) and is the focus of population reduction efforts via a sport reward program that pays bounties for removal of large individuals (Friesen and Ward 1997). Largescale and bridgelip suckers are native species that were highly abundant throughout the reservoirs during comprehensive sampling efforts in 1979 and 1980 (Bennett *et al*. 1983). White and black crappie, smallmouth bass, and channel catfish represent introduced species that are highly sought by sport anglers throughout the reservoir system (Normandeau Associates *et al*. 1998a). Smallmouth bass and channel catfish also have been the focus of predator-prey investigations (Zimmerman and Parker 1995; Ward and Zimmerman 1997), along with northern pikeminnow. White sturgeon is a native species that has declined in abundance due to continued harvest and isolation and loss of flowing water habitats by dams. White sturgeon is a Species of Concern in Idaho (BPA 1995).

Smallmouth bass

Smallmouth bass is one of the more abundant and widely distributed species in the lower Snake River reservoirs (Bennett *et al*. 1997) and an important sport fish (Normandeau Associates *et al*. 1998a). However, limited research has been conducted on the life history of smallmouth bass in the Lower Snake River.

Two known estimates of the absolute abundance of smallmouth bass have been conducted in lower Snake River reservoirs. Anglea (1997) conducted multiple-census estimates during 1994 in Lower Granite Reservoir and reported 20, 911 bass greater than 174 millimeters (6.8 inches) (95% CI -17,092 to 26,197). Using an estimate of 0.47% survival, Anglea (1997) estimated that the population abundance of smallmouth bass greater than 70 millimeters (2.8 inches) in Lower Granite Reservoir was 65,400 (95% CI -61,023 to 71,166). Standing crop was estimated at 0.75 kilogram/hectare (0.44 lb/acre) for bass greater than 199 millimeters (7.8 inches), and density was 3.4 smallmouth bass/hectare

(1.4 bass/acre) throughout the entire reservoir. More recently, Naughton (1998) estimated the absolute abundance of smallmouth bass in the Lower Granite Dam tailwater (Little Goose Reservoir), the forebay, Clearwater River, and Snake River arms of Lower Granite Reservoir. He found that densities were highest for smallmouth bass greater than 174 millimeters (6.8 inches) in the forebay of Lower Granite Reservoir (12.7 bass/hectare), followed by the Clearwater River Arm (12.5 bass/hectare [5.1 bass/acre]). His estimates of standing crop compared closely to those of Anglea (1997).

Although absolute abundance has not been estimated for Lower Monumental and Ice Harbor reservoirs, studies by Zimmerman and Parker (1995) have shown that Lower Granite Reservoir supports the highest density and relative abundance of smallmouth bass among Snake River reservoirs. However, these estimates of abundance of smallmouth bass are generally lower than those reported by investigators for other geographical areas. For example, Paragamian (1991) reported densities of 2 to 911 smallmouth bass/ha (0.8 to 369 bass/acre) for 22 waters throughout Iowa, and Carlander (1977) reported densities no less than 16 smallmouth bass/ha (6.5 bass/acre). These findings demonstrate that smallmouth bass are comparatively low in abundance in lower Snake River reservoirs compared to other waters throughout their range.

The spawning season of smallmouth bass in lower Snake River reservoirs is generally later than reported elsewhere. Bratovich (1983) reported on the reproductive cycle of smallmouth bass from examination of gonads in Little Goose Reservoir in 1979 and 1980. The largest ovaries were measured in April, and the reported time of spawning based on ovarian condition was in May, June, and July. In contrast, Pflieger (1975) reported smallmouth bass spawning in Missouri as early as the first of April. Henderson and Foster (1957) observed smallmouth spawning in the Columbia River until the latter part of July. Bennett *et al*. (1983) suggested a spawning period of longer than 60 days, similar to that reported for Missouri (Pflieger 1975). Other observations suggest spawning largely occurs in June and July, based on attainment of suitable water temperatures of about 15.9°C (60.6°F) (Coble, 1975). Bennett *et al*. (1983) observed spawning to occur over a range of temperatures from 14 to 19.6°C (57 to 67°F), within the full range of water temperatures reported in the literature (12.8 to 26.7°C [55 to 80°F]); Henderson and Foster 1957; Reynolds 1965) for smallmouth bass. Others have reported spawning temperatures of 15 to 18.3°C (59 to 65°F) (Turner and McCrimmon 1970; Coble, 1975; Pflieger 1975; Coutant 1975).

Habitat used for spawning is largely gravel substrate, highly abundant along the shorelines of the lower Snake River reservoirs. Substrate used by smallmouth bass for spawning in Little Goose Reservoir was similar to that reported in the literature (Bennett *et al*., 1983). All observed smallmouth bass spawning activity in Little Goose Reservoir was on low-gradient shorelines of sand and/or gravel, with 85% of spawning nests on gravel 6 to 50 millimeters (0.25 to 2.0 inches) in diameter. Spawning areas in Little Goose Reservoir were frequently found in gulch and embayment habitats in the lower reservoir. The areas were generally protected from direct wind and wave action with little to no perceptible current. In the upper reservoir, smallmouth bass nests were more commonly observed in shoal areas that were usually exposed to wind and wave action and/or higher water

velocities. Differences in habitats used were attributed to the paucity of gulch and embayment habitats in the upper reservoir (Bennett *et al*., 1983).
Bennett and Shrier (1986) reported that smallmouth spawning nests were located in Lower Granite Reservoir from the confluence of the Snake and Clearwater rivers downstream nearly to Lower Granite Dam. Highest nest abundance was in the lower part of the reservoir where water velocities were lowest.

Fluctuating water levels and water temperatures may adversely affect smallmouth bass in Lower Granite Reservoir. Bennett *et al*. (1994) suggested from their research that cold upstream water releases from Dworshak Reservoir in 1991 and 1992 probably had only a minimal effect on smallmouth bass growth and survival and, consequently, year-class strength. However, operational water level fluctuations up to 1.5 meters (5 feet) in Little Goose Reservoir may affect the vertical distribution of spawning activity by smallmouth bass. Most spawning activity of smallmouth bass (and other centrarchid fish) occurs in water of 2 meters (6.6 feet) or less (Bennett 1976). Most bass nests have been reported in water from 0.3 to 2 meters (1 to 6.6 feet) (Scott and Crossman 1979; Coble 1975), although smallmouth have been reported to spawn at depths of 6.7 meters (22 feet) in clear water (Trautman 1981). The deepest smallmouth bass nests reported for Little Goose Reservoir were 5.3 meters (17.4 feet) (relative to full pool), although 84% were located at depths of 2 meters (6.6 feet) or less. In 1980, Bennett *et al.* (1983) found that 27% of all nests located were desiccated by fluctuating water levels in Little Goose Reservoir, although 75% of all spawning nests were located within the 1.5-meter (5-foot) fluctuation zone. Bennett *et al*. (1983) suggested that periods of high, stable water levels during the spawning season, followed by pronounced reduction in water levels, may have deleterious effects on the spawning success of smallmouth bass in Little Goose Reservoir. Vertical fluctuations of similar magnitude can also occur in Lower Granite Reservoir, whereas those in Lower Monumental and Ice Harbor reservoirs are about 0.5 meter (1.6 feet) lower (i.e., limited to about 0.9 meters [3 feet]). Spawning of smallmouth bass in the latter reservoirs has not been investigated.

Food items of smallmouth bass have been intensively examined in Little Goose and Lower Granite reservoirs. Bennett *et al.* (1983) found that smallmouth bass (n=484) consumed crayfish, fish, and terrestrial and aquatic insects in decreasing order of importance in Little Goose Reservoir during 1979 and 1980. Crayfish accounted for 72% by volume of the food items eaten and appeared in 64% of all bass stomachs. Fish consumed accounted for 25.4% by volume and were found in 32% of the smallmouth bass stomachs that contained food. Fish eaten were sculpin, white crappie, redside shiner, northern pikeminnow, catfish, bluegill, yellow perch, chinook salmon, bridgelip sucker, and pumpkinseed.

Anglea (1997) examined food items from over 4,000 smallmouth bass in Lower Granite Reservoir. Crayfish were consistently the dominant food item in Lower Granite Reservoir in 1995, although salmonids and other fish accounted for nearly 50% of the diet in the spring. He found that fish were the most important food item, by weight, from April to June 1994 and 1995, whereas crustaceans and insects increased in abundance after June. As others have reported, larger smallmouth bass consumed a higher proportion of fish. Crayfish were the most abundant food item by weight for smallmouth bass from 175 to

249 millimeters (6.9 to 9.8 inches), while finfish and crayfish were equally important for bass from 250 to 389 millimeters (9.8 to 15.3 inches). Fish were the dominant food item of smallmouths greater than 389 millimeters (15.3 inches).

Bennett and Naughton (1998) examined greater than 8,500 smallmouth bass stomachs from the tailwater, forebay, and Snake and Clearwater River arms of Lower Granite Reservoir in 1996 and 1997. They found that non-salmonid fish were the most abundant prey item by weight in the tailrace (46.9%), tailrace BRZ (71.6%), forebay BRZ (51.5%), and Clearwater River arm in 1996. In contrast, during 1997, crayfish were clearly the dominant food item by weight in the tailrace (73.4%), tailrace BR (60.8%), forebay (58.8%), and Snake River arm (50.3%). Monthly differences in food items were low within study sites. From these findings, it is obvious that smallmouth bass in Lower Granite, Little Goose, and probably other lower Snake River reservoirs consume a large number of crayfish, similar to that reported in the literature for other river and lake systems.

The 1997 sport fishing catch (kept and released) of smallmouth bass was highest in Lower Granite (greater than 10,000 fish) and Little Goose (greater than 8,000 fish) reservoirs, while the sport harvest (kept only) of smallmouth bass varied more than fourfold among reservoirs. Lower Monumental and Little Goose reservoirs yielded the largest smallmouth bass harvests (2,802 and 2,762 bass, respectively), whereas anglers in Ice Harbor Reservoir harvested less than 700 fish (Table 36).

Table 36. Estimated sport fishing harvest of selected fish in Lower Snake River reservoirs from April to November 1997 (Corps 1999).

	Lower Granite	Little Goose	Lower Monumental	Ice Harbor
Smallmouth bass	897	2,762	2,802	691
Crappie spp.	1,634	15,523	4,952	204
Channel catfish	228	5,654	1,789	5,607
Northern pikeminnow	1,512	161	256	102
Source: Normandeau Associates *et al*. 1998a				

Crappie

Black crappie and white crappie are two of the more important sport fish in backwater habitats in the lower Snake River reservoirs (Knox 1982; Normandeau Associates *et al.* 1998a). They are highly habitat-specific in the reservoirs and are chiefly limited to embayment areas off the main channel. The species co-occur throughout the reservoir system, but only in Little Goose Reservoir was there apparent dominance by white crappie (Bennett *et al*. 1983). The white crappie is more tolerant of turbidity and siltation than other centrarchid fish, although it is less competitive in clear waters (Carlander 1977). Limited life history information has been collected on crappie, primarily in Little Goose Reservoir (Bennett *et al.* 1983).

Relative abundance of crappie has been determined for each of the lower Snake River reservoirs, and absolute abundance was determined for Deadman Bay in Little Goose Reservoir. Crappie ranged from about 20% of the fish community in Little Goose Reservoir to about 5% in Lower Granite Reservoir. Their relative abundance is directly related to habitats sampled during the abundance surveys. Crappie attains highest abundance in backwaters and, therefore, attained highest relative abundance in Little Goose Reservoir.

Bennett *et al*. (1983) conducted the only known population dynamics studies on crappie in lower Snake River reservoirs. A multiple-census population estimate in Deadman Bay found that white crappie was the most numerous species (Table 37). Density and biomass estimates for white crappie ranged from 158 to 200 fish/hectare (64 to 81 fish/acre) and 26.7 to 33.8 kilogram/hectare (23.8 to 30.2 lb/acre), respectively, while those for black crappie were about 85% less. Catches of black crappie were higher in the main channel areas of Little Goose Reservoir, while catches were higher for white crappie in backwaters.

Table 37. Estimates of population density (Number/Area) and standing crop (Biomass/Area) for selected centrarchid fish in Deadman Bay, Little Goose Reservoir (Corps 1999).

Species	Minimum Size (mm)	High Pool Level		Low Pool Level	
		Population Density (fish/ha)	Standing Crop (kg/ha)	Population Density (fish/ha)	Standing Crop (kg/ha)
White crappie	200.0	158.0	26.70	200.0	33.80
Black crappie	200.0	21.0	4.20	27.0	5.30
Pumpkinseed	100.0	13.0	0.51	17.0	0.64
Bluegill	100.0	11.0	0.72	13.0	0.92

Growth increments and condition factors of crappie from the lower Snake River reservoirs were similar or better than those for comparable geographical areas (Bennett *et al.* 1983). Growth increments were not significantly different among reservoirs, although growth of black crappie was slightly slower than that of white crappie. Differences in growth between white and black crappie were attributed to higher water temperatures in backwaters where white crappie predominate, as well as the greater consumption of fish by white crappie.

Food of white crappie in the lower Snake River reservoirs was similar to that reported in the literature. Cladocerans were the dominant food item of white crappie in the summer, and fish became more important in the fall in Little Goose and other lower Snake River reservoirs (Bennett *et al.* 1983). Dietary items of black crappie were similar to those of white crappie.

Time of spawning for crappie is typically later in the north than in the south (Hardy 1978). Bratovich (1983) found white crappie in the lower Snake River reservoirs in spawning condition from June into August, similar to Nelson *et al.* (1967), who found the white crappie spawning season extended from mid-May through mid-July in Lewis and Clark Lake, Missouri River, on the Nebraska-South Dakota border. Hjort *et al*. (1981) reported white crappie spawning ranged from late May to late July in John Day Reservoir on the Columbia River. From late May to late July, water temperatures in the lower Snake River reservoirs ranged from 15.8 to 20.4°C (60 to 69°F) (Bennett *et al.* 1983). Published reports generally consider 16 to 21°C (61 to 70°F) optimal for white crappie spawning (Nelson *et al.* 1967; Siefert 1968). Spawning times for black crappie in the lower Snake River reservoirs were June and July, compared to early May to mid-July in John Day Reservoir (Hjort *et al*. 1981). Water temperatures in the lower Snake River reservoirs during the time when black crappie were in spawning condition ranged from 15.8 to 19.6°C (60 to 67°F). These water temperatures were a little cooler than those generally reported suitable for black crappie spawning (19 to 20°C [66 to 68°F]); Scott and Crossman 1979).

The most recent sport harvest data for crappie varied among reservoirs by more than two orders of magnitude. The largest harvest was in Little Goose Reservoir (15,523 fish), compared to an estimated 204 crappie harvested from Ice Harbor Reservoir.

Suckers

Suckers are the most abundant fish in the lower Snake River reservoirs (Bennett *et al*. 1983; 1987; 1990). Largescale suckers are about two times more abundant than bridgelip suckers in Little Goose and Lower Monumental reservoirs and two orders of magnitude higher in Lower Granite and Ice Harbor reservoirs. The high abundance of suckers throughout the reservoirs suggests that both species are habitat generalists. The greater overall abundance of largescale sucker relative to bridgelip sucker suggests that habitat requirements for bridgelip sucker might be somewhat narrower than for largescale sucker. Bridgelip sucker was classified as a mesotherm, with narrower temperature requirements than largescale sucker, although their generalized distribution within a river continuum was similar (Li *et al*. 1987).

The seasonal distribution of suckers in Lower Granite Reservoir can be inferred from data presented by Bennett *et al*. (1993), although spring catches are dissimilar with findings in Little Goose Reservoir (Bennett *et al*. 1983). Both species were primarily sampled in shallow waters in Lower Granite Reservoir during the spring of 1990. In 1980, however, captures of bridgelip sucker were highest in deepwater areas of Lower Granite Reservoir in the spring, while largescale suckers were more evenly distributed among deepwater areas and shallower shoal and gulch habitat. Both species were widely distributed throughout the water column in summer and fall based on gill net captures at deepwater stations. Bennett *et al*. (1983) also showed a tendency of both bridgelip and largescale suckers to move to the tailwaters of Lower Granite, Little Goose and Lower Monumental dams in the fall.

Bennett *et al*. (1983) conducted the only known estimates of absolute abundance of suckers in the lower Snake River reservoirs. They estimated about 9,000 largescale suckers in Deadman Bay of Little Goose Reservoir in 1980, with a density of 172 fish/ha (70 fish/acre) and estimated standing crop about 156 kilograms/hectare (139 lb/acre).

Little information is available on the spawning of bridgelip or largescale suckers in the northwest. Dauble (1980) found that bridgelip suckers spawn from March to June, with most spawning in the Columbia River occurring during April. Water temperatures in the lower Snake River reservoirs that coincided with the presence of ripe bridgelip suckers ranged from 10.2 to 12.2°C (50.4 to 54°F) (Bennett *et al*. 1983). Dauble (1980) reported spawning from 6 to 13°C (43 to 55°F) in the Columbia River.

Bennett *et al.* (1983) found largescale suckers in spawning condition in May and June, similar to that reported by Scott and Crossman (1979) for British Columbia. MacPhee (1960) reported that largescale suckers spawn in the North Fork Payette River, Idaho, in mid-to late June, whereas Hjort *et al*. (1981) reported largescale sucker spawning from early May to early August in the lower Columbia River. Water temperatures in the lower Snake River reservoirs were 12.2 to 15.8°C (54 to 60°F) compared to 7.8 to 8.9°C (46 to 48°F) for stream-spawning largescale suckers in British Columbia (Scott and Crossman 1979).

Food of suckers has been reported to be primary producers such as diatoms and filamentous green algae and benthic invertebrates (Carlander 1977; Li *et al*. 1987). Bennett *et al*. (1983) conducted stomach analyses of bridgelip and largescale suckers and found predominantly diatoms and green and blue-green algae in the stomachs of each species. Macroinvertebrates were relatively minor food items. Few seasonal differences were found, although detritus and blue-green algae increased in abundance from spring to winter.

Anglers usually catch suckers only incidentally while fishing for other species. A few anglers, more typically in the mid-Snake River upstream of Asotin, catch suckers for bait for white sturgeon (Normandeau Associates *et al.* 1998b).

Northern Pikeminnow

The northern pikeminnow is a species of great interest in the Columbia River basin because of its predatory habits pertaining to downstream migrating juvenile salmonids (Poe *et al.* 1991). There has been substantial recent work detailing the food habits (Zimmerman and Ward 1997), predatory role (Zimmerman and Ward 1997), exploitation rates (Friesen and Ward 1997), and population and growth parameters (Parker *et al*. 1995; Knutsen and Ward 1997) for this important species in Snake River reservoirs. However, limited life history information exists relative to spawning and reproduction. Smith (1996) recently completed an analysis of the incidence of chiselmouth x northern pikeminnow hybrids in the Lower Snake River. F1 hybrids are present in the system, with 33% of the hybrids having chiselmouth maternity and 67% having northern pikeminnow maternity. His work demonstrated how morphological characteristics could be used to assess accurate species identification.

The northern pikeminnow spawns from mid-May to late June in lower Snake River reservoirs (Bennett *et al.* 1983), somewhat earlier than reported by Hjort *et al.* (1981) for John Day Reservoir, Columbia River (June to August). In other areas, northern pikeminnow reportedly spawn from May to early July (Carl *et al*. 1959), both in lakes and tributary streams (Jeppson and Platts 1959; Patten and Rodman 1969). In Cascade Reservoir, central Idaho, Casey (1962) reported that northern pikeminnow spawn during June, with peak spawning activity in the latter part of June. Water temperatures at the time of spawning in Snake River reservoirs ranged from 14.0 to 20.4°C (57.2 to 68.7°F), similar to those reported by Casey (1962, 14.5 to 16.7°C [58.1 to 62°F]) and Stewart (1966, 18.0°C [64.4°F]).

Other than the time of spawning, little other information is available on spawning habits of northern pikeminnow in any of the Snake River reservoirs. Bennett *et al*. (1994) and Cichosz (1997) have emphasized the importance of the early rearing period to year-class strength and recruitment. Cichosz (1997) examined what factors limit the abundance of northern pikeminnow in Lower Granite Reservoir. He found that their abundance is probably determined in the egg-through-larval stage, although juvenile mortality is also important. Density independent factors were most important in controlling egg-through-juvenile survival. Timing of water temperature conditions was most important in predicting survival of northern pikeminnow. Survival was also positively related to growth.

Dresser (1996) examined the influence of habitat factors on fish assemblages in Lower Granite Reservoir. Through the use of multivariate analysis, he reported that the northern pikeminnow selected shallow, vegetated habitats with substrate sized less than 2.0 millimeters (0.08 inches). These findings were considerably different from those of Dupont (1994) who found that the northern pikeminnow in the Pend Oreille River, Idaho, selected rocky shorelines with deeper depths and higher water velocities. Dresser (1996) believed differences in selected habitats could be attributed to interactions with other species, particularly smallmouth bass. Smallmouth bass are not present in the Pend Oreille River. Habitat types occupied by the northern pikeminnow in the Pend Oreille River are occupied by smallmouth bass in Lower Granite Reservoir. Further, some evidence supports the hypothesis that predation on northern pikeminnow by smallmouth bass may account for differences in habitat use. Werner *et al*. (1997) reported that predation on small size classes may result in habitat segregation. Pollard (Idaho Department of Fish and Game, retired, personal communication, Portland, Oregon) observed that the abundance of northern pikeminnow decreased following the introduction of smallmouth bass into Anderson Ranch Reservoir, Idaho. He further suggested that similar habitats inhabited by the northern pikeminnow in Brownlee Reservoir, Idaho, were void of them following the introduction of smallmouth bass. Since most northern pikeminnow collected by Dresser (1996) were 120 to 250 millimeters (4.7 to 9.8 inches), and the smallmouth bass ranged in length from 100 to 520 millimeters (3.9 to 20.5 inches), his explanation seems plausible.

The influence that northern pikeminnow have on downstream migrating salmonids has been a concern for over a decade in the Columbia River system. A number of studies have been conducted to investigate northern pikeminnow predation in the lower Snake River reservoirs. Chandler (1993) provided the initial quantification of actual predation on downstream migrating salmonids in Lower Granite Reservoir. Chandler (1993) found that salmonids were the most abundant food item (by weight) consumed by northern pikeminnow during spring from 1987 to 1991. Crayfish were second in importance. Year-to-year variation in salmonid consumption was high. Ward *et al*. (1995) found that northern pikeminnow abundance and consumption of salmonids were higher in the lower Columbia River than in the Snake River. Among Snake River habitats sampled, the consumption index was higher in the Lower Granite Reservoir forebay and in tailwaters of Ice Harbor, Lower Monumental, and Little Goose reservoirs. Ward *et al*. (1995) correlated biological characteristics of northern pikeminnow populations and found a significant correlation only of density with relative fecundity, implying that northern pikeminnow populations were not limited by density.

Sport anglers pursue northern pikeminnow largely in Lower Granite Reservoir, mostly due to the bounty paid by the sport reward program (Freisen and Ward 1997). Harvest in Lower Granite Reservoir was approximately 1,500 fish (although most were in the Snake River arm), and less than 260 fish in the other reservoirs.

White Sturgeon

Limited information exists on the white sturgeon in the lower Snake River system. No known information exists on spawning activities of white sturgeon in the lower Snake River reservoirs. However, Parsley and Beckman (1994) quantified spawning habitat in three of the lower Columbia River reservoirs by using a geographic information system. They showed that spawning habitat was available downstream of each of the dams, although the quantity of available habitat was affected by flow variability. Rearing habitat for age 0 and juvenile white sturgeon was also quantified and found to be more available in the impounded river than in the unimpounded reach below Bonneville Dam.

Samples of numerous juvenile white sturgeon (less than 16 centimeters [6.3 inches]) suggest that juvenile rearing habitat is probably highly abundant in Lower Granite Reservoir (Bennett *et al.* 1993). Additionally, Bennett *et al.* (1994) concluded that the flowing water section of the Snake River above Lower Granite Reservoir may provide spawning habitat and ultimately could be a recruitment source for downstream reservoirs. Data collected in 1992 before and after the test drawdown indicated white sturgeon moved from Lower Granite Reservoir to the upstream portion of Little Goose Reservoir. However, Bennett *et al.* (1994) could not determine whether this movement was stimulated by the drawdown or occurred following the drawdown.

Rearing habitat for white sturgeon seems to be linked to water velocity. Apperson (1990) suggested that white sturgeon in the Kootenai River, Idaho, were found at water velocities between 0.05 and 0.56 meters/second (0.2 and 1.8 feet/second). Velocities in this range were found exclusively in the upper portion of Lower Granite Reservoir, the reach with the highest abundance of white sturgeon. Deep, slack water in Lower Granite Reservoir, and probably in other lower Snake River reservoirs, did not provide suitable habitat, and captures have been consistently low.

Lepla (1994) conducted the most comprehensive study on white sturgeon in the lower Snake River reservoirs on Lower Granite Reservoir, including the only known population estimate among the reservoirs. He estimated that 1,524 (95% CI -1,155 to 2,240) white sturgeon greater than 40 centimeters (15.7 inches) (fork length) inhabited Lower Granite Reservoir. White sturgeon density was estimated at 0.38 fish/hectare (0.15 fish/acre), or 12 to 45 sturgeon/rkm (19 to 73 sturgeon/rm). The density estimate was generally similar to that of Lukens (1985; 24 sturgeon/rkm 39 sturgeon/rkm) but lower than those of Coon *et al*. (1977) who reported 35 to 53 sturgeon/rkm (56 to 85 sturgeon/rm) between Lower Granite and Hells Canyon dams.

Lepla (1994) sampled nearly 1,000 white sturgeon and examined habitat use. He found that 94% of the white sturgeon in Lower Granite Reservoir were less than 125 centimeters (49 inches) total length (TL) with the majority in the 0 to 8 age group. Lepla (1994) developed a stepwise discriminate model to explain white sturgeon distribution but could account for only 26% of the variation in distribution using habitat data. However, he found 56% of all fish sampled were from a 5.5-kilometer (3.4-mile) reach near Clarkston, Washington, (Port of Wilma to Red Wolf Crossing) in upper Lower Granite Reservoir. Catches in the mid-to-lower reservoir were consistently low.

Coon (1975) also suggested the importance of moving water to white sturgeon, based on tracking fish with sonic tags. Implanted white sturgeon moved to the upstream portion of Lower Granite Reservoir during the impoundment process and resided in the same area near Clarkston, Washington, as the majority of fish sampled by Lepla (1994). Crayfish relative abundance has been quantified in Lower Granite Reservoir and its distribution appears very similar to that of white sturgeon (Bennett *et al*. 1993; Lepla, 1994). Crayfish are reportedly an important food item of white sturgeon in the Snake River (Coon *et al.* 1977; Cochanuer 1983). Bennett *et al*. (1993) could not ascertain whether higher crayfish abundance in up-reservoir areas was responsible for the upstream abundance of white sturgeon, or whether both species had similar habitat preferences.

The sport harvest of white sturgeon is largely restricted to Little Goose Reservoir (Normandeau Associates *et al*. 1998a). Nearly 600 were caught, but estimated harvest was 40 individuals.

Channel Catfish

Reasonably good information exists on the relative abundance of channel catfish in the lower Snake River reservoirs, although absolute abundance is unknown. Bennett *et al*. (1983) recorded the first known estimates of abundance from samples collected in 1979 and 1980. Their study indicated that channel catfish attained highest relative abundance in Ice Harbor Reservoir (5.8%), followed by Little Goose (2.8%) and Lower Monumental (2.5%) reservoirs. Abundance in Lower Granite Reservoir was considerably lower than in the other three reservoirs. The abundance of channel catfish in Little Goose Reservoir was significantly correlated with the abundance of several other species. The highest correlation of channel catfish abundance was with brown bullhead and bluegill, suggesting its abundance in backwater habitats is highest where these other species attain high abundance.

Bennett *et al.* (1983) reported seasonal differences in the relative abundance of channel catfish. In the spring, 71% of the channel catfish in Little Goose Reservoir were collected from the Lower Granite Dam tailwater, whereas in the summer and fall, channel catfish were more highly abundant in lower embayment and gulch habitats. In general, the smallest catfish were collected from embayment habitats whereas the largest individuals were captured in the tailwater of Lower Granite Dam. Channel catfish distribution was not greatly different among habitats in Lower Granite (n = 8), Lower Monumental (n = 227), and Ice Harbor (n = 467) reservoirs from spring to fall, although seasonal differences may have obscured any habitat preferences.

Growth of channel catfish in Little Goose Reservoir was deemed comparatively rapid (Bennett *et al*. 1983). Growth was more rapid during the first 6 years of life than in subsequent years. Bennett *et al*. (1983) suggested that growth increments increased since 1969, possibly a result of higher vulnerability of salmonid smolts downstream of Lower Granite Dam. Growth increments of channel catfish were significantly smaller in Ice Harbor Reservoir than either Lower Monumental or Little Goose reservoirs. The growth increments reported were similar to those for channel catfish in the midwestern United States, which was surprising because of below optimum Snake River water temperatures. Kilambi *et al*. (1970) reported 32°C (89.6°F) as the optimum temperature for growth, whereas the highest water temperatures in the lower Snake River reservoirs are typically 5-

10°C (9 to 18°F) lower. These temperatures were taken in slack water areas and are higher than average high temperatures in the main reservoirs.

Food of 452 channel catfish (92 to 649 mm [3.6 to 25.6 inches]) was also examined by Bennett *et al*. (1983). They found that fish, aquatic insects, crayfish, wheat, and cladocerans were the more important food items. Food items varied with sampling location. Seasonally, fish was the predominant food item in the spring. Predation on downstream migrating juvenile steelhead and chinook salmon was high in the spring, especially in samples taken from the Lower Granite tailwater. In the summer, crayfish, cladoceran zooplankton, and aquatic insects were important food items.

More recently, Bennett *et al.* (1988) examined food items of channel catfish in Lower Granite Reservoir. They found that fish constituted 42% by weight of the food items during spring 1987. Rainbow trout, presumably juvenile steelhead, comprised 38% of the weight of fish consumed and juvenile chinook salmon about 1%. Chironomidae comprised about 29% of the remaining items of the diet in spring and 60 and 85%, respectively, of the channel catfish diet in the summer and fall. Juvenile salmonids comprised about 1% of all food items in the fall.

The highest sport harvests of channel catfish in 1997 occurred in Little Goose (5,654 fish) and Ice Harbor (5,607 fish) reservoirs. In contrast, the harvest in Lower Granite Reservoir was estimated at only 228 fish.

Bull Trout

Several subpopulations of bull trout occur upstream of the reservoir influence of Lower Granite Dam. Representatives from these subpopulations have the capability of freely moving to and from Lower Granite Reservoir. These groups include fish from Asotin Creek, and the Grande Ronde, Imnaha and Salmon rivers. There is little evidence to suggest these populations use habitat associated with the reservoirs in the Lower Snake River. Radio tracking data from Elle *et al*. (1994) and Elle (1995) showed that adult migrants from the Rapid River subpopulation typically overwinter in the main stem Salmon River as far downstream as Whitebird, but a few may move as far as Mahoney Creek. None of these fish have been observed in the Snake River. Buchanan *et al*. (1997) suggested that some migrants from the Grande Ronde still utilize the Snake River. Recent observations of radio-tagged bull trout from the Grande Ronde River verified the use of the Snake River by those fish as far down as RM 146, just upstream from Asotin, WA (Shappart, ODFW, personal communication, 2000). Underwood *et al*. (1995) suspected that radio tagged fish migrated from the Tucannon River to the Snake River, but they could not locate the fish in the reservoir. In the lower reaches of the Imnaha River, large migrant sized bull trout are incidentally caught by steelhead anglers each year, and ODFW believes these fish are migrants that use the Snake River seasonally (Knox, ODFW, personal communication, 2000). The most compelling evidence is data from the Idaho Fish and Game smolt trap at Lewiston. It indicates the capture of an occasional bull trout (Basham, in litt. 2000), but the catch rates have been no more than one bull trout annually.

Other Fishes

Several species of fish in the Snake River reservoirs occur in lower relative abundance than the key species. Some of these are native fish, while many others were introduced into the Snake River. The native fish are largely from two fish families: Cyprinidae and Cottidae. Of the cyprinids, chiselmouth and redside shiners are the most abundant. From limited sampling, chiselmouth seem to be equally abundant between Little Goose and Ice Harbor and between Lower Granite and Lower Monumental reservoirs, although differences in relative abundance may be more related to habitats sampled (Bennett *et al.* 1983). In Lower Granite Reservoir, Bennett and Shrier (1986) reported that chiselmouth were collected in highest abundance at the confluence of the Snake and Clearwater rivers and immediately downstream of the riverine portion of the Clearwater River. Data presented by Bennett *et al*. (1993) and Bennett *et al*. (1988) suggest that chiselmouth movements occur throughout the year. In the spring, abundance is higher at shallow water locations, whereas in the winter they are found in deeper waters. Time of spawning is similar to northern pikeminnow, based on the presence of hybrids (Smith 1996).

Redside shiners are about equally abundant in the upper three reservoirs compared to their higher relative abundance in Ice Harbor Reservoir. Redside shiners have been sampled in highest abundance in the spring in the impounded portion of the Clearwater River arm (Bennett and Shrier 1986) and in shallow water stations in Lower Granite Reservoir (Bennett *et al*. 1988). Few were collected in the summer through the fall. The common carp is an introduced species and most abundant in Little Goose Reservoir, probably because of the extensive backwater habitats. Peamouth and speckled dace, both native cyprinids, have consistently been collected in low abundance in the lower Snake River reservoirs.

Limited information exists on the species composition and relative abundance of various species of cottids in the lower Snake River reservoirs. Bennett *et al*. (1983) listed three species of cottids. Prickly sculpin, Piute sculpin and mottled sculpin were all identified, although all were treated as an assemblage throughout their work. No other known information has been collected on sculpins, especially their species composition and relative abundance in the lower Snake River reservoirs. Little life history information exists on these species in the lower Snake River reservoirs, although general life history information is available on each of these species from other systems (Simpson and Wallace 1978; Blair *et al.* 1968).

The species complex of introduced ictalurids, other than channel catfish, has been consistently low (less than 1% of the total fish community) in relative abundance in the lower Snake River reservoirs (Bennett *et al*. 1983). Brown, black, and yellow bullheads have been found along with tadpole madtoms and a low number of flathead catfish. Brown bullheads have been the most abundant of the bullheads in Lower Granite Reservoir, although they comprise only 10 to 20% of the catch of channel catfish (Bennett *et al*. 1988, 1993). Tadpole madtom is a common species to the middle Snake River reservoirs above Hells Canyon (Dunsmoor 1990). They consumed similar food items as juvenile smallmouth bass in Brownlee Reservoir, Snake River, Idaho, with the bulk of their energy coming from cyclopoid microcrustaceans and freshwater shrimp. Species comprising the

Snake River ictalurid complex are generally late-spring or summer spawners in areas out of the current with adequate bottom cover (Bratovich 1985).

The centrarchid and percid assemblage consists of all introduced fish in the Lower Snake River. Centrarchid fish are largely found in backwater areas out of the current. A general characteristic of this habitat is finer substrate and the presence of aquatic vegetation. The exception to this generalization is smallmouth bass, which is common throughout the reservoirs. Pumpkinseed is the most abundant "sunfish" other than crappies and smallmouth bass.

Yellow perch are included in this complex because of their use of similar habitat as the centrarchid fish. Yellow perch are almost exclusively found in conjunction with aquatic macrophytes in the lower Snake River reservoirs (Bennett *et al.* 1983). They have consistently been found in relatively low abundance and only achieve higher abundance in backwater habitats that characteristically have finer substrates, low velocity, and aquatic macrophytes.

All of the centrarchid and percid fish are spring and summer spawners in shallower water on substrates that are protected from the current. Yellow perch in the lower Snake River reservoirs are the earliest spawners, and some of the centrarchids are the latest (Bratovich 1985). Sunfish (bluegill and pumpkinseed) and yellow perch were important components of the sport harvest only in Ice Harbor Reservoir. More than 10,000 yellow perch and more than 4,800 sunfish were harvested from Ice Harbor Reservoir in 1997 (Normandeau Associates *et al.* 1998a). These data suggest that as the lower Snake River reservoirs have aged, habitat for the centrarchid and percid fish, except smallmouth bass, has increased.

River lamprey, margined sculpins, Umatilla dace, and leopard dace may exist in the Snake River mainstem, or some of the tributaries to the Snake River. These species are listed as State Candidate or Sensitive Species in Washington, but they have not been verified in the Snake River.

Anadromous Fish

Salmon populations in the Snake River have been listed under provisions of the U.S. Endangered Species Act (ESA). The pertinent listed species are Snake River sockeye salmon (Oncorhynchus nerka, listed as endangered in 1991), Snake River spring/summer and fall chinook salmon (O. tshawytscha, both listed as threatened in 1992), and Snake River steelhead (O. mykiss, listed as threatened in 1998). Because of these listings, there is a need to consider management options that might mitigate the threats to these populations and assist in their recovery.

The Snake River historically was and presently is one of the most important drainages in the Columbia River System for producing salmon. More broadly, salmon in the entire Columbia River system at one time numbered between 10 and 16 million fish; this drainage once contained the largest chinook salmon population in the world. Estimating specific historical population levels and trends of particular stocks of salmon in the Snake River Subbasin of the Columbia River is more difficult. But it is clear that all salmonid stocks in the Snake River were much more abundant at the end of the nineteenth century than they are now and that these stocks have undergone major fluctuations.

Declines in Columbia River salmon populations began at the end of the last century as a result of overfishing; by early in the 20th century, however, environmental degradation from mining, grazing, logging, and agriculture caused further declines. Before construction of the first mainstem hydroelectric dams on the lower Columbia River (Bonneville Dam was completed in 1938), aggregate pounds of chinook salmon caught in the Columbia River had declined by approximately 40% since the beginning of the century (Netboy 1974).

More recent historical decreases in Snake River stocks coincided with an intensive period of change from 1953 to 1975 in the middle and Lower Snake River and the lower Columbia River. In addition to construction of the impassible Hells Canyon complex of dams, four dams which allowed varying degrees of passage were built in the Lower Snake River and three in the lower Columbia River. The completion years during this period were 1954 (McNary Dam), 1957 (The Dalles Dam), 1958 (Brownlee Dam), 1961 (Ice Harbor and Oxbow Dams), 1967 (Hells Canyon Dam), 1968 (John Day Dam), 1969 (Lower Monumental Dam), 1970 (Little Goose Dam), and 1975 (Lower Granite Dam). The seven new dams on the Lower Snake and Columbia rivers inundated 227 and 294 kilometers (141 and 182 miles) of mainstem habitat, respectively. This changed the lower mainstem river from a mostly free-flowing body into a series of reservoirs covering about 70% of the distance between Lewiston, Idaho, and the Pacific Ocean. The slow-moving reservoirs decreased the rate of downstream travel for juvenile fish and increased the amount of habitat favorable to occupation by exotic and predator species. The construction of new dams was one of a suite of major changes in the Columbia Basin ecosystem. Other major changes that had potentially significant impacts on salmonid populations included: the emergence of industrial-scale hatchery production, the introduction of exotic species, major shifts in oceanic conditions, and dramatic seasonal shifts in water storage and flow regulation (National Research Council 1996b).

Spring/Summer Chinook

This species was listed as threatened in 1992. Spring and summer Chinook migrate through the mainstem Snake River, but no spawning or rearing is known to occur there or in any of the minor tributaries in this subbasin, except the Tucannon River where an endemic stock persists. (see Tucannon subbasin summary).

No spring chinook fishery has occurred in the Snake River since a jack fishery was terminated in the mid-1980’s.

Fall Chinook

Fall chinook salmon were listed as threatened under the Endangered Species Act in 1992. Fall chinook salmon are unique in that they spend the entire freshwater portion of their life cycle in main-stem habitats. Historically, the majority of Snake River fall chinook salmon apparently spawned in the mainstem near Marsing, Idaho (Haas 1965; Irving and Bjornn 1981).

Construction of the Hells Canyon complex (1958-1967) and the Lower Snake River Dams (1961-1975) eliminated or severely degraded 530 miles of spawning and rearing habitat for fall chinook in the Snake River (Mendel 1998). Historically, fall chinook salmon runs averaged 72,000 fish between 1938-1949, with highs of up to 120,000 (Irving and Bjornn 1981). By the 1950s these runs had decreased to an average of 29,000. Fall chinook continued to decline, and by the late 1960s and 1970s the average run was only 5,100 fish at Ice Harbor Dam. The average annual runs have remained at 4,700-5,500 fish in the 1980s and the 1990s. Spawning escapement in the Snake River is probably lower than Ice Harbor Dam counts would indicate. A radio telemetry study in the early 1990s found that a high percentage of fall Chinook that cross Ice Harbor Dam apparently “dip into” the Snake River and return to the Columbia or Yakima rivers to spawn (Mendel and Milks 1997). Today, spawning is restricted to the Hells Canyon Reach and to the tail-races of Lower Snake River dams (Dauble *et al*. 1999) and in the Clearwater River, Idaho.

Juvenile fall chinook salmon rear along mainstem shorelines for 2-4 months before migrating seaward in the summer. Juvenile fall chinook salmon use the Lower Snake River as a migration corridor and begin passing Lower Granite Dam in June, peak passage occurs in July, and the migration is protracted into September. Many juveniles are transported, primarily by trucks, from Lower Granite, Little Goose, and Lower Monumental dams to below Bonneville Dam where they are released. The migrant population of fall chinook salmon is composed of natural fish produced in the Hells Canyon Reach and hatchery fish released from Lyons Ferry Hatchery.

Fall chinook fisheries have been closed for many years in the Snake River. Lower Columbia River fisheries have targeted upriver bright fall chinook destined primarily for the Hanford Reach of the Columbia River. However, these mixed stock fisheries have harvested Snake River fall chinook at high rates during many years, especially prior to ESA listing in 1992.

Coho

Wild coho are extinct in the Snake River basin since the early to mid 1980s.
Hatchery coho are being reintroduced in the Clearwater River by the NPT. Also, there may be stray coho from the Umatilla, and possibly the Yakima reintroduction efforts in the Snake River. Some of these fish are recovered at Lyons Ferry Hatchery or in the Tucannon River since about 1997.

Steelhead

Information on Snake River steelhead is limited because it is difficult to develop stock-specific estimates of abundance and survival. Additionally, it is nearly impossible to obtain accurate redd counts for Snake River steelhead because of their spawning locations and timing. The result of these limitations is a more qualitative than quantitative analysis. Nonetheless, some insight regarding hydrosystem options and the future prospect for survival and recovery of steelhead is possible from comparisons to spring/summer chinook salmon (noting both similarities and contrasts). In particular, to the extent that steelhead respond like spring/summer chinook salmon, the limited quantitative data for steelhead can be supplemented with the spring/summer chinook salmon PATH analyses and inferences. There are, of course, extrapolation limitations from spring/summer chinook salmon to steelhead.

Biologically, steelhead are divided into two basic run-types based on the state of sexual maturity at the time of river entry and duration of spawning migration (Burgner *et al*. 1992). The stream-maturing type, or summer steelhead, enters fresh water in a sexually immature condition and requires several months in fresh water to mature and spawn. The ocean-maturing type, or winter steelhead, enters fresh water with well-developed gonads and spawns shortly after river entry (Barnhart 1986). Snake River steelhead are all classified as summer steelhead. Inland steelhead of the Columbia River Basin, especially the Snake River Subbasin, are commonly referred to as either A-run or B-run. These designations are based on observation of a bimodal migration of adult steelhead at Bonneville Dam and differences in age (1-ocean versus 2-ocean) and adult size among Snake River steelhead. Adult A-run steelhead enter fresh water from June to August; as defined, the A-run passes Bonneville Dam before 25 August (Columbia Basin Fish & Wildlfife Authority, CBFWA 1990; Idaho Department of Fish & Game, IDFG 1994). Adult B-run steelhead enter fresh water from late August to October, passing Bonneville Dam after 25 August (CBFWA 1990; IDFG 1994). Above Bonneville Dam, run-timing separation is not observed, and the groups are separated based on ocean age and body size (IDFG 1994). A-run steelhead are defined as predominately age-1-ocean, while B-run steelhead are defined as age-2-ocean (IDFG 1994). Adult B-run steelhead are also, on average, 7.5-10 cm larger than A-run steelhead of the same age; this difference is attributed to their longer average residence in salt water (Bjornn 1978; CBFWA, 1990; Columbia River Fisheries Management Plan Technical Advisory Committee 1991). It is unclear, however, if the life history and body size differences observed upstream are correlated with the groups forming the bimodal migration observed at Bonneville Dam. Furthermore, the relationship between patterns observed at the dams and the distribution of adults in spawning areas throughout the Snake River Basin is not well understood.

Unlike Pacific salmon, steelhead can spawn multiple times before death. However, it is rare for steelhead to spawn more than twice before dying; most that do so are females (Nickelson *et al*. 1992). Prior to construction of most lower Columbia River and Lower Snake River dams, the proportion of repeat-spawning summer steelhead in the Snake and Columbia rivers was less than 5% (3.4% (Long and Griffin 1937); 1.6% (Whitt 1954)). The current proportion is unknown, but is assumed near zero.

The Snake River Evolutionarily Significant Unit generally matures after 1 year in the ocean. Based on data from purse seine catches, juvenile steelhead tend to migrate directly offshore during their first summer from whatever point they enter the ocean, rather than migrating along the coastal shelf as do salmon. During fall and winter, juveniles move southward and eastward (Hartt and Dell 1986). Oregon steelhead tend to be north-migrating (Nicholas and Hankin 1988; Pearcy *et al.* 1990; Pearcy 1992).

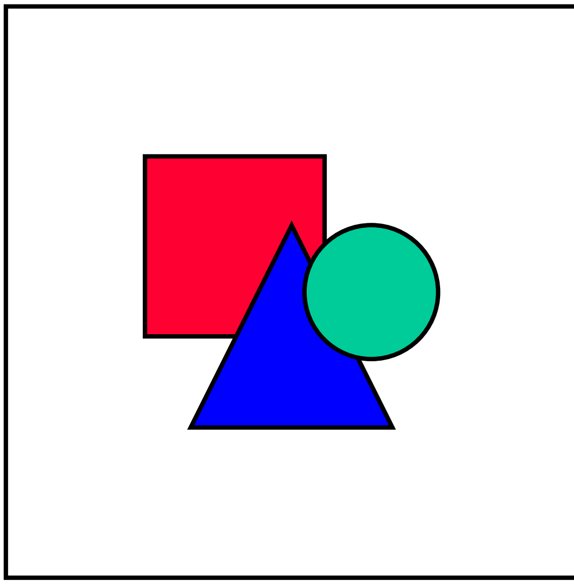
The average return of wild steelhead to the Snake River Basin declined from approximately 30,000 to 80,000 adults in the 1960s through mid-1970s to 7,000 to 30,000 in recent years. Average returns during 1990 through 1991 and for the 1995 and 1996 return years was 11,465 fish. The general pattern has included a sharp decline in abundance in the early 1970s, a modest increasing trend from the mid-1970s through the early 1980s, and another decline during the 1990s. The sharp decline in steelhead numbers during the early 1970s parallels the similar sharp decline in spring/summer chinook salmon populations during the same time period. However, whereas the wild steelhead population in the Snake River doubled from 1975 (13,000) to 1985 (27,000), the spring/summer chinook salmon did not show an increase. In addition, much of the initial steelhead decline in the 1970s may be attributed to the construction of Dworshak Dam in 1973. This dam cut off access to the North Fork of the Clearwater River, which was an important spawning and rearing area for B-run steelhead.

Some natural production of steelhead occurs in minor tributaries such as Alpowa Creek, Alkali Flat Creek, Almota Creek, Steptoe Creek., Deadman and Meadow creeks, etc. Steelhead are also produced from the Tucannon River (see Tucannon subbasin). Spawning and rearing by steelhead is limited in the mainstem because of the Snake River Dams and reservoirs. Most tributaries that maintain summer water flows and do not have barriers are suspected of being used by steelhead.

The mainstem Snake River provides some of the largest steelhead harvests in Washington (Table 38). Wild or naturally produced (not fin clipped) steelhead must be released and only hatchery fish can be retained. Many anglers fish for hatchery produced steelhead near dams or at the mouth of the Tucannon River.

Table 38. Steelhead harvest estimates from catch cards for the Snake River from its mouth to Clarkston, WA (WDFW harvest data).

Run Year	Harvest
1999-2000	3,107
1998-1999	2,658
1997-1998	4,504
1996-1997	3,387
1995-1996	3,253



American Shad

Although American shad are an anadromous fish in the Snake River, their abundance may indirectly affect resident predatory fish. Other than estimates of abundance from passage counts at dams, little American shad life history information exists in the Columbia River basin. American shad in the Snake River are most abundant in the lower reservoirs, while few adults are observed upstream of Lower Granite Dam (Bennett *et al*. 1988). Some biologists have hypothesized that American shad may assist in maintaining fish predator populations at artificially high levels. Research is needed to determine if this hypothesis has merit.

Where juvenile American shad are most abundant, such as in lower Columbia River reservoirs, they may constitute a protein source for predators that enables them to maintain higher population levels than could occur without shad. However, their role as prey is insignificant in Lower Granite Reservoir for smallmouth bass (Curet 1994; Anglea 1997; Naughton 1998) and northern pikeminnow (Chandler 1993). Further, it is unlikely that juvenile shad currently constitute a major prey item in predator diets in the lowermost Snake River reservoirs, based on recent passage estimates of 5,000 to 14,000 adults at Ice Harbor Dam during 1996 to 1998 (Corps data).

Tributaries

Steelhead

Some natural production of steelhead occurs in minor tributaries such as Alpowa Creek, Alkali Flat Creek, Almota Creek, Steptoe Creek., Deadman and Meadow creeks, etc. Steelhead are also produced from the Tucannon River (see Tucannon subbasin). Most minor tributaries of the mainstem Snake River that maintain summer water flows and do not have barriers are suspected of being used by steelhead.

Alpowa Creek

Steelhead trout presently use Alpowa Creek, although spawning is probably limited to the upper reaches. A survey of the stream on April 29, 1999, confirmed the presence of three steelhead spawning redds within the upper watershed and numerous juvenile steelhead/rainbow trout were observed during surveys in 1981 (Mendel and Taylor 1981) and 1998 (Mendel 1999).

Deadman Creek

Steelhead trout are known to have used Deadman Creek, although spawning was probably limited to the upper reaches. Anecdotal information from local residents suggest that steelhead still spawn in this stream system. Habitat in the upper reaches of the South Deadman are ideal for spawning and rearing and angler reports suggest steelhead were caught at the Deadman Creek Bridge at the base of Wildhorse Hill.

Area on northside of Snake River in Whitman County and the Small Area North of Tucannon and Pataha Creek in Columbia County

It is assumed that at populations of Steelhead have been present in the past.

Whitefish

Juvenile whitefish were observed during the fall of 1998 in the lower reach (approximately Wilson Banner Ranch) of Alpowa Creek (Table 39). Juveniles are thought to move from the Snake River into Alpowa Creek where they may overwinter (Mendel 1999).

Alpowa Creek

Sculpins and crayfish are abundant in the upper Alpowa watershed where dace are also found, though relatively uncommon. Further downstream (from about one mile above Highway 12 to near the mouth), sculpins, speckled dace and longnose dace, and crayfish exist. Just below Clayton Gulch and downstream are bridgelip suckers, in addition to the above species. Northern pikeminnow and chiselmouth are found in the lower reach of Alpowa Creek (Mendel 1999).

Table 39. Salmonid densities (#/100 m^2) in Alpowa Creek, September and October 1998. Sites are listed in order from upstream to downstream (Mendel 1999).

				Densities (#/100m^2)						
				Rainbow/steelhead				Whitefish		
				Age/size				Age/size		
Site code	Site length (m)	Mean width (m)	Area (m^2)	0+	1+	≥ 8 in	Total	0+	1+	≥ 8 in
AL-1	51.2	4.1	209.9	7.1	12.4	1.0	20.5			
AL-2	46.3	2.8	129.6	9.3[b]	18.5	0.0	27.8			
AL-3	30.5	2.7	82.4	7.3	20.6	2.4	30.3			
AL-4	34.5	2.5	86.3	5.8[b]	18.5	0.0	24.3			
AL-5	34.5	3.6	124.2	0.8	12.1	0.8	12.9			
AL-6	31.7	4.1	129.9	6.9	6.2	0.0	13.1			
AL-7	41.2	4.9	201.9	2.0[b]	4.5	0.5[c]	7.0			
AL-8	54.9	3.5	192.2	9.4	6.8	0.5	16.7			
AL-9	37.2	4.4	163.6	0.6	0.6	0.0	1.2	7.3[b]	0.0	0.0

[b]Calculated using the sum of the passes because of poor reduction between passes, minimum estimates only

[c]Trout of hatchery origin

Wildlife

The subbasin contains large and small mammals, passerines, waterfowl, upland birds, raptors, reptiles, and amphibians (Table 40). Population status varies by area and species. Some species are doing well, while others are listed as state threatened, candidate, or species of concern (Table 41). Big game, upland birds, diversity species, furbearers, and waterfowl are managed by state and federal agencies. Mule deer are the primary big game species within the subbasin.

Table 40. Wildlife species found in the Lower Snake River subbasin.

Common Name	Scientific Name
FROGS AND TOADS	
Tailed Frog	*Ascaphus truei*
Tailed Frog	Ascaphus truei
Western Boreal toad	Bufo boreas boreas
Western Boreal toad	*Bufo boreas boreas*
Woodhouse's Rocky Mountain toad	*Bufo woodhousei woodhousei*
Pacific treefrog	*Hyla regilla*
Boreal chorus frog	*Pseudacris triseriate maculata*
Bullfrog	*Rana catesbeiana*
Western leopard frog	*Rana pipiens brachycephala*
Leopard frog	*Rana pipiens pipiens*
Spotted frog	*Rana pretiosa*
Great Basin spadefoot toad	*Scaphiopu intermontanus*
SALAMANDERS AND NEWTS	
Northern long-toed salamander	*Abystoma macrodactylum karusel*
Blotched tiger salamander	*Abystoma tigrinum melanostrictum*
Northern rough-skinned newt	*Taricha granulosa granulosa*
LIZARDS	
Western Great Basin whiptail	*Cnemidophorus tigris tigris*
Long-nosed leopard lizard	*Crotaphytus wislizenii wislizenii*
Collared lizard	*Crotaphytus collaris*
Western skink	*Eumes skiltonianus skiltonianus*
Western Great Basin skink	*Eumes skiltonianus utahensis*
Northern Alligator lizard	*Cerrhenotus corcrulens principis*
Short-horned pygmy lizard	*Phrynosoma douglassi douglassi*
Northern desert horned lizard	*Phrynosoma platyrhinos platyrhinos*
Northern sagebrush lizard	*Sceloporous gracious graciosus*
Northern Great Basin fence lizard	*Sceloporous occidentalis biseriatus*
Northern side-blotched lizard	*Uta stansburiana stansburiana*
SNAKES	
Rocky Mountain rubber boa	*Charina bottae utahensis*
Western yellow-bellied racer	*Coluber constrictor mormon*
Western Northern Pacific rattlesnake	*Crotalus viridis oreganus*
Northwestern ringneck	*Diadophis punctatus occidentalis*
Desert night	*Hypsiglena torquata deserticola*
Great Basin gopher snake	*Pituopis melanoleucus deserticola*
Western ground snake	*Sonora semiannulata*

Western terrestrial wandering snake	*Thamnophis elegans vagrans*
Common valley garter	*Thamnophis sirtalis fitchi*
TURTLE	
Western Painted turtle	*Ghrysemys picta*
LOONS	
Common loon	*Gavia immer*
GREBES	
Western grebe	*Aechmophorus occidentalis*
Horned grebe	*Podiceps auritus*
Earned grebe	*Podiceps caspicus*
Pied-billed grebe	*Podilymbus podiceps*
PELICAN AND ALLIES	
Double crested cormorant	*Phalacrocorax auritus*
WATERFOWL	
Wood duck	*Aix sponsa*
Pintail	*Anas acuta*
Common teal	*Anas crecca*
Green-winged teal	*Anas carolinensis*
Blue-winged teal	*Anas discors*
Mallard	*Anas platyrhynchos*
Gadwall	*Anas strepera*
White-fronted goose	*Anser albifrous*
Lesser scaup	*Aythya affinis*
Redhead	*Aythya americana*
Ring-necked duck	*Aythya collaris*
Greater scaup	*Aythya marila*
Canvasback	*Aythya valisineria*
Canada goose	*Branta canadensis*
Bufflehead	*Bucephala albeola*
Common goldeneye	*Bucephala clangula*
Barrows goldeneye	Bucephala *islandica*
Snow goose	*Chen hyperborea*
Ross' goose	*Chen rossil*
Hooded merganser	
American widgeon	*Mareca Americana*
European widgeon	*Mareca penelope*
Common merganser	*Mergus merganser*
Red-breasted merganser	*Mergus serrator*
Whistling swan	*Olor columianus*
Ruddy duck	*Oxyura jamaicensis*
Shoveler	*Spatula clypeata*
HAWKS, FALCONS, EAGLES	
Cooper's hawk	*Accipiter cooperii*
Goshawk	*Accipiter gentilis*
Sharp-shinned hawk	*Accipiter striatus*
Golden eagle	*Aguila chrysaetos*
Red-tailed hawk	*Buteo jamaicensis*
Rough-legged hawk	*Buteo lagopus*
Ferruginous hawk	*Buteo regalis*
Swainson's hawk	*Buteo swainsoni*

Turkey vulture	*Carthartes aura*
Marsh hawk	*Circus cyaneus*
Pigeon hawk	*Falco columbarius*
Prairie falcon	*Falco mexicanus*
Peregrine falcon	*Falco peregrinus*
American kestral	*Falco sparverius*
Bald eagle	*Haliaeetus leucocephalus*
Osprey	*Pandion haliaetus*
GALLINACEOUS BIRDS	
Chukar	*Alectoris graeca*
Ruffed grouse	*Bonasa umbellus*
California quail	*Loportyx californicus*
Grey partridge	*Perdix perdix*
Ring-necked pheasant	*Phasianus colchicus*
HERONS, CRANES & ALLIES	
Great Blue heron	*Ardea herodias*
American coot	*Fulica americana*
Sora rail	*Porzana carolina*
SHOREBIRDS & GULLS	
Spotted sandpiper	*Actitis macularia*
Semi-palmated plover	*Charadrius semipalmatus*
Killdeer	*Charadrius vociferus*
Sanderling	*Crocethia alba*
Common snipe	*Capella galinago*
Western sandpiper	*Ereunetes mauri*
Caspian tern	*Hydroprogne caspia*
Herring gull	*Larus argentatus*
California gull	*Larus californicus*
Ring-billed gull	*Larus delawarensis*
Long-billed curlew	*Numenius americanus*
American avocet	*Recurvirostra americana*
Wilson’s phalarope	*Steganopus tricolor*
Forster’s tern	*Sterna forsteri*
Common tern	*Sterna hirundo*
Greater yellowlegs	*Totanus melanoleucus*
PIGEONS & DOVES	
Rock dove	*Columba livia*
Morning dove	Z*enaidura macroura*
OWLS	
Short-eared owl	*Asio flammeus*
Long-eared owl	*Asio otus*
Great horned owl	*Bubo virginianus*
Burrowing owl	*Spectyto cunicularia*
Barn owl	*Tyto alba*
GOATSUCKERS	
Common nighthawk	*Chordeiles minor*
SWIFTS	
Vaux’s swift	*Chaetura vauxi*

CORACIIFORMES

Belted kingfisher	*Megaceryle alcyon*

WOODPECKERS

Common flicker	*Colaptes auratus*
Downy woodpecker	*Dendrocopos pubescens*
Hairy woodpecker	*Dendrocopos villosus*

PASSERINES

White-throated swift	*Aeronautes saxatlis*
Red-winged blackbird	*Agelaius phoeniceus*
Grasshopper sparrow	A*mmodramus savannarum*
Cedar waxwing	*Bombycilla cedrorium*
House sparrow	*Carpodacus mexicanus*
Purple finch	*Carpodacus purpureus*
Canyon wren	*Catherpes mexicanus*
Lark sparrow	*Chodestes grammacus*
Western wood pewee	*Contropus sordidulus*
Common crow	*Corvus brachyrhynchos*
Common raven	*Corvus corax*
Yellow- rumped warbler	*Dendroica coronata*
Yellow warbler	*Dendroica petechia*
Townsend’s warbler	*Dendroica townsendi*
Willow flycatcher	*Empidonax trailli*
Horned lark	*Eremophila alpestris*
Brewer’s blackbird	*Euphagus cyanocephalus*
Common yellowthroat	*Geothlypis trichas*
Evening grosbeak	*Hesperiphona vespertina*
Barn swallow	*Hirundo rustica*
Hermit thrush	*Hylocichla guttata*
Yellow-breasted chat	*Icteria virens*
Northern oriole	*Icterus galbula bullockii*
Tree swallow	*Iriduprocne bicolor*
Varied thrush	*Ixoreus naevius*
Dark-eyed junco	*Junco hyemalis*
Northern shrike	*Lanius excubitor*
Loggerhead shrike	*Lanius ludovicianus*
Gray crowned rosy finch	L*eucosticte arctoa tephrocotis*
Lincoln’s sparrow	*Melospiza lincolnii*
Song sparrow	*Melospiza melodia*
Brown-headed cowbird	*Molothrus ater*
Townsend’s solitaire	*Myadestes townsendii*
Macgillivary’s warbler	*Oporornis tolmiei*
Black-capped chickadee	*Parus atricapillus*
House sparrow	*Passer domesticus*
Savannah sparrow	*Passerculus sandwichensis*
Fox sparrow	*Passerella iliaca*
Lazulli bunting	*Passerina amoena*
Cliff swallow	P*etrochelidon pyrrhonota*
Black-headed grosbeak	*Pheucticus melanocephalus*
Black-billed magpie	*Pica pica*
Pine grosbeak	*Pinicola enucleator*
Western tanager	*Piranga ludoviciana*
Ruby-crowned kinglet	*Regulus calendula*
Golden-crowned kinglet	*Regulus satrapa*
Bank swallow	*Riparia riparia*

Rock wren	*Salpinctes obsoletus*
Say's phoebe	*Sayornia saya*
Pine siskin	*Spinus pinus*
American goldfinch	*Spinus tristis*
Tree sparrow	*Spizella arborea*
Chipping sparrow	*Spizella passerina*
Rough-winged swallow	*Stelgidopteryx ruficollis*
Western meadowlark	*Sturnella neglecta*
Starling	*Sturnus vulgaris*
Long-billed marsh wren	*Telmatodytes palustris*
Bewick's wren	*Thryomanes bewickii*
House wren	*Troglodytes aedon*
Winter wren	*Troglodytes troglodytes*
American robin	*Turdus migratorius*
Eastern kingbird	*Tyrannus tyrannus*
Western kingbird	*Tyrannus verticalis*
Solitary vireo	*Vireo solitarius*
Wilson's warbler	*Wilsonia pusilla*
Yellow headed blackbird	*Xanthocephalus xanthocephalus*
White-crowned sparrow	*Zonotrichia leucophrys*
SHREWS & MOLES	
Vagrant shrew	*Sorex vagrans*
BATS	
Pallid bat	*Antrozous pallidus*
Big brown bat	*Eptesicus fuscus*
Silver-haired bat	*Lasionycteris noctivagans*
California bat	*Myotis californicus*
Long-eared bat	M*yotis evotis*
Little brown bat	*Myotis lucifugus*
Small-footed bat	*Myotis subulatus*
Fringed bat	*Myotis thysanodes*
Long-legged bat	*Myotis volans*
Yuma bat	*Myotis yumanensis*
Western pipistrel	*Pipistrellus hesperus*
Western big-eared bat	*Plecotus townsendi*
GNAWING ANIMALS	
Beaver	*Castor candensis*
Ord's kangaroo rat	*Dipodomys ordi*
Porcupine	*Erthizon dorsatum*
Yellow-bellied marmot	*Marmota flavivententris*
Long-tailed meadow vole	*Microtus longicaudus*
Mountain meadow vole	*Microtus montanus*
House mouse	*Mus musculus*
Bushy-tailed rat	*Neotoma cinerea*
Muskrat	*Ondatra zibethica*
Northern grasshopper mouse	*Onychomys leucogaster*
Great Basin pocket mouse	*Perognathus parvus*
Deer mouse	*Peromyscus maniculatus*
Norway brown rat	
Western harvest mouse	*Reithrodontomys megalotis*
Fox tree squirrel	*Sciurus niger*
Golden-mantled ground squirrel	*Spermophilus lateralis*

Townsend's ground squirrel — *Spermophilus townsendii*
Red tree squirrel — *Tamiasciurus hudsonicus*
Northern pocket gopher — *Thomomys talpoides*

HARES & RABBITS
Black-tailed jackrabbit — *Leous californicus*
White-tailed jackrabbit — *Lepus idahoensis*
Nuttall's cottontail rabbit — *Sylvilagus nuttali*

UNGULATES
Elk — *Cervus canadensis*
Mule deer — O*docoileus hermionus*
White-tailed deer — *Odicoileus virginianus*

PREDITORS
Coyote — *Canis latrans*
River otter — *Lutra canadensis*
Bobcat — *Lynx rufus*
Striped skunk — *Mephitis mephitis*
Long-tailed weasel — *Mustela frenata*
Mink — *Mustela vison*
Raccoon — *Procyon lotor*
Badger — *Taxidea taxus*
Black bear — *Ursa americanus*
Red fox — *Vulpes fulva*

Table 41. Status of Priority Habitat Species (PHS) within the Lower Snake River sub-basin (WDFW data).

Species	Status	Population
Ferruginous hawk	T	5 nesting pairs ?
Prairie Falcon	PHS	13 eyries*
Peregrine Falcon	E & PHS	none
Ringneck pheasant	G	declining
Whitetailed jackrabbit	SC	unknown
Washington ground squirrel	SC	unknown
Mule Deer	G	MO
Burrowing owl	C	5 nesting pairs
Ringneck pheasant	G	declining
Sharptail Grouse	T	extirpated
Whitetailed jackrabbit	C	unknown
Blacktailed Jackrabbit	C	low
Mule Deer	G	MO lowlands
Whitetail deer	G	increasing
Northern grasshopper mouse		unknown
Sagebrush Vole		unknown
Washington ground squirrel	C	low
Upland sandpiper	E	unknown
Long-billed curlew		low
Loggerhead shrike	C SC	unknown
Sage sparrow	C	unknown
Sabebrush lizard	SC	unknown
Sage thrasher	C	unknown
Bald eagle	T	wintering

Species	Status	Population
Striped whipsnake	C	unknown
Kangaroo rat		unknown

* 1988 survey
State Status: E = endangered, C = candidate, T = threatened, SC = species of concern, G = game species. PHS = Priority Habitat Species

Ferruginous Hawk

Ferruginous hawks exist in low number in shrubsteppe and grassland regions of several eastern Washington counties. The state population is estimated at between 50 and 60 nesting pairs (WDFW 1996). The Lower Snake River Subbasin contains portions of the north and central Ferruginous hawk recovery zones (WDFW 1996). Isolated rock outcrops, and other platforms that provide unobstructed views are used as nest sites by these hawks. Their diet consists primarily of small to medium-sized mammals, such as pocket gophers, mice, and ground squirrels, but often includes birds, reptiles, and insects. Persecution by early settlers reduced the number of ferruginous hawks in the West. Recent pressures are frequently related to land-use practices. Conversion of shrub-steppe for agriculture or grazing has broadened the influence of human activity, reduced nesting opportunities, and lowered the diversity and abundance of prey species.

Burrowing Owl

Once widespread across grasslands and shrub steppe of North America, the burrowing owl is declining throughout much of its range in the Western States and Canada (Sheffield 1997). Burrowing owls depend on burrows excavated by other animals such as marmots, ground squirrels, and badgers. Agriculture and other land conversion has reduced available habitat by eliminating burrows used by these owls, and also by eliminating habitat for mammals that create burrows.

Prairie Falcon

Prairie falcons use the basalt cliffs along the Lower Snake River for nesting. A survey conducted by the WDFW in 1988 located 13 active eyries along the Snake River.

Peregrine Falcon

Historically, peregrine falcons nested along the Lower Snake River, but no active nests have been reported recently. One active nest site was documented 6 miles upstream from Asotin, Washington in 1992, and remains active today.

Bald Eagle

Bald eagle populations use the Lower Snake River subbasin primarily for winter habitat and foraging, depending on the severity of the winter weather. Although no nesting has been recorded in this subbasin it is anticipated in the future. Maintaining high quality habitat for prey species, fish, and waterfowl and protecting potential nesting and winter roost sites are critical to encourage and perpetuate eagle use of the area.

Golden Eagle

Golden eagles nest in limited numbers in this subbasin. Usually the golden eagles are found in proximity of shrub-steppe habitat and feed on rabbits, ground squirrels and marmots. The Golden eagles are not tied so closely to the riparian areas of the subbasin as are bald eagles.

Waterfowl

Waterfowl are seasonally abundant in the Lower Snake River subbasin. Nesting, staging, and pair formation all take place in the streams and lakes of this area and in the temporary ponds, vernal pools and permanent lakes of the Channeled Scablands (WDFW 1999). Agricultural lands are important food sources for these birds especially during the fall and winter. Protection of wetlands habitat is critically important in this subbasin if waterfowl production is to remain at an acceptable level (WDFW 198?). WDFW has protected, enhanced and created waterfowl habitat in this area with funds from the Washington State Duck Stamp program each biennium on WDFW lands, other public lands (BLM, DNR) and on private acreage.

Neo-tropical Migratory Birds

Neo-tropical migratory birds are dependent on wetlands, grassland (shrub-steppe), riparian, and timbered habitats in this subbasin. The distribution and abundance of these songbirds is determined by the mosaic of the landscape. Agricultural lands have had a huge impact on native migratory species in this area. Any habitat enhancements to wetlands, riparian-floodplain, timber, and agriculture lands of the Lower Snake River subbasin will benefit migratory and resident Neo-tropical migrants. The WDFW continues to study these species using the area search and point-count methods of survey.

Riparian vegetation is the limiting factor on many Snake River tributaries for passerines and neo-tropical migrant species. During the breeding season, 15 or more species of birds will use the Lower Snake River subbasin and during migration 75 to 80 species will stop, rest, feed and stage in these types of habitats.

Wetland Dependants/ Shorebirds

Loss of wetlands, spring creeks and ephemeral waters to agriculture and cattle grazing and resting has impacted all shorebirds and wetland dependant species (e.g., Avocets, Black-necked Stilts, Sandpipers, and Marsh Wren) in the Lower Snake River subbasin

Ringneck Pheasant

The ringneck pheasant is the primary upland game bird species in southeast Washington. The annual pheasant harvest peaked in Walla Walla, Columbia, Garfield, Asotin, and Whitman counties at approximately 108,000 during the early 1980’s, but had declined 66% by 1999 to approximately 36,800 birds (WDFW 1999). A number of factors can impact the pheasant harvest. First and foremost is the abundance of the pheasant population, hunter participation, and weather during the hunting season. The dramatic decline in the pheasant harvest is a direct reflection of pheasant abundance. Hunter numbers decline and effort increases as pheasant populations decline. Inundation of riparian habitat along the Snake

River and the loss of shrub steppe/grassland habitat has resulted in a tremendous decline in the pheasant population within the subbasin.

Columbian Sharp-tailed Grouse

Historically the Columbian Sharp-tailed grouse was found in the Snake River subbasin until as recently as the 1940's and 1950's. The Columbian Sharp-tailed grouse is declining throughout most of its range and is highly vulnerable to extirpation in Washington. Two populations remain in the eastern Washington. One of these is in central Lincoln County and the other is in Douglas/Okanagan counties. The Lincoln County population is estimated at only 250-350 individuals. As a result, the Columbian Sharp-tailed grouse has been listed as endangered by Washington State.

Whitetail Jackrabbit

The whitetail jackrabbit is listed as a PHS and state candidate species. Historically, whitetail and blacktail jackrabbit populations were quite high. The loss of shrub steppe habitat has contributed to the dramatic decline in jackrabbit populations. Agricultural development and livestock grazing have modified and destroyed much of the shrub steppe habitat on which the whitetail jackrabbit was dependent.

Washington Ground Squirrel

The Washington ground squirrel is PHS and state candidate species. The loss of shrub steppe and grassland habitats to agricultural development and livestock grazing has resulted in the loss of Washington ground squirrel colonies. Historical colonies were surveyed in 1997, but no ground squirrels were observed.

Rocky Mountain Mule Deer

Rocky mountain mule deer are a PHS and primary big game species within the subbasin. Portions of game management units 142, 145, and portions of units 149 lie within the subbasin. Mule deer populations in the subbasin have increased significantly over the last 15 years. Whitetail deer in the subbasin are susceptible to EHD, and outbreaks occur with varying severity every four to five years. A severe outbreak in 1998 resulted in a significant decline in whitetail deer numbers. Surveys in COE habitat areas along the Snake River revealed as many as 15-20 dead whitetail deer within a 20-40 acre plot. Due to the susceptibility of whitetail deer to EHD and periodic die-offs, inter-specific competition between whitetail deer and mule deer may be insignificant within the subbasin.

Elk

Elk were undoubtedly present in the shrub steppe habitats of eastern Washington prior to the arrival of settlers (McCorquodale 1985; Dixon and Lyman 1996; L. Lyman personal communication., G. Cleveland, personal communication). The current Selkirk elk population in the Snake River came from natural immigration from north central Idaho. Elk of the Selkirk herd farther north developed from the reintroduction of 100 Rocky Mountain elk from Yellowstone National Park before 1920. The Selkirk Elk Herd is among the top three herds, in terms of harvest, identified in Washington State. The

Hangman sub- herd is an important resource that provides significant recreational, aesthetic and economic benefit to the people and is the southern portion of the Selkirk herd. This herd ranges over several thousand acres in portions of Lincoln, Whitman and south Spokane counties. The breaks of the Snake River in Whitman County have provided elk habitat for this population in small numbers since the 1970's and only recently have we seen an increase and change in distribution in south Whitman County (WDFW 1999). Recently the herds have emigrated to agriculture lands along the river as well as the fields near the breaks on top of the Snake River in Whitman county. During the 2000 hunting season, at least 7 bulls and one cow were harvested by hunters (Morgan Grant, wildlife officer, WDFW, personal communication).

Management of this subherd is complicated by a lack of public lands in the subbasin to allow habitat improvement. It is difficult to manage a public resource on private lands in this subbasin (WDFW, 1999).

Bats

Ten species of bats are found in this area (H Ferguson, WDFW, personal communication,). Basalt cliffs and talus slopes provide both maternity and hibernaculum opportunities. The crepuscular feeding habit of the bats is most common near riparian areas and waterways.

Habitat Areas and Quality

Fish

Reservoirs (Corps 1999)

The Snake River reservoirs conform to a typical longitudinal impoundment gradient composed of three macrohabitat types, or reaches (Hjort *et al.* 1981). The tailwater is the section immediately below a dam and is the most riverine in nature. The uppermost portion of Lower Granite Reservoir is also more riverine, but is not a tailwater since there is no impoundment immediately upstream. Impoundment of Lower Granite Reservoir is considered to end near Asotin in the Snake River arm and near the Potlatch Corporation in the Clearwater River arm. A mid-reservoir reach represents the largest section of each impoundment and is a transition area from the lotic (riverine) character of the tailwater to the more lake-like (lentic or lacustrine) conditions nearer the dam. The reach immediately above a dam is the forebay. A sampling protocol described by Zimmerman and Parker (1995) assigned reach lengths of 6 kilometers (3.73 miles) each to a tailwater or forebay, but the length was likely a result of sampling considerations as opposed to defined differences in habitat. So designated, lower Snake River tailwaters and the upper reach of Lower Granite Reservoir comprised 5-15% of total reservoir area. Forebays formed a more uniform 13-18% of total reservoir area, and the remaining 67-72% is mid-reservoir (Zimmerman and Parker 1995). Each macrohabitat reach can contain up to several habitat types. The sampling scheme developed by Bennett *et al.* (1983) recognized six individual habitat classifications, or mesohabitats, that are described below. Six limnological characteristics of each mesohabitat in Little Goose Reservoir were summarized by Bennett *et al*. (1983) and are shown in Table 42. These attributes would be generally applicable for the respective habitats in all of the Lower Snake River.

Tailwater-The highest water velocities in a reservoir up to 23 ft/sec were always found in the tailwater immediately below the dam. The uppermost area of a tailwater adjacent to the dam is the boat restricted zone (BRZ), which is variable in size but typically less than 0.6 miles long (Ward *et al*. 1995). Also included in a tailwater are protected areas with little or no current behind the lock chamber walls (most prominently below Lower Granite Dam) or adjacent to the earthen portion of a dam (e.g., below Little Goose Dam). Water current is typically negligible in these areas unless induced by spill. For example, under certain spill conditions, reverse eddy flows can occur below the earthen portion of Little Goose Dam. The bottom slope in a tailwater is moderate with relatively little littoral area and no macrophyte growth.

Upper shoal-Moderately sloped areas in the upper portion of a reservoir, but located below a tailwater. Upper shoal habitats have slower velocities and a greater littoral area than in a tailwater due to slightly shallower bottom slopes. As a result of slower velocities, these areas generally accumulate sediment by deposition. In Little Goose Reservoir, water velocities in spring were lower than 3.3 ft/second, but higher than 1.0 ft/second, and intermediate between tailwater velocities and those of more downstream habitats (Bennett *et al*. 1983).

Lower shoal-Moderately sloped areas up to 33 feet deep at 200 feet offshore, with water velocity less than 1.0 ft/second. Macrophyte growth was sparse, averaging about 3.3% of sampled areas.

Lower Embayment-Relatively large, shallow (up to 13 feet deep) areas off the main river channel, and typically separated from the main reservoir by a road or railroad berm. No measurable water current occurs, and macrophyte growth can be extensive. In Little Goose Reservoir, the embayment sampled averaged 3.7% macrophyte coverage. Increased siltation from small tributaries and reservoir maturity likely has led to more substantial macrophyte growth in recent years. Examples of embayments include Deadman Bay in Little Goose Reservoir and Dalton and Emma lakes in Ice Harbor Reservoir.

Gulch-Small to medium-sized, shallow (up to13 feet deep), off-channel areas with no measurable current. These areas may also be thought of as coves, as they are not cut off from the main reservoir body by a berm. Macrophytes are typically present, and the littoral areas of gulch habitats are typically extensive due to shallow bottom slopes.

Deepwater-Steep sloped areas with little or no littoral zone, intermediate to no current (less than 1.0 ft/second) and up to 98 feet deep (as measured in Little Goose Reservoir by Bennett *et al*. 1983). Macrophytes are absent due to a negligible littoral zone.

Comprehensive fisheries sampling conducted by the ODFW in 1991 and 1994 to 1996 in the lower Snake River reservoirs throughout the three macrohabitat reaches identified habitats only as "nearshore" and "offshore" (Zimmerman and Parker 1995; Parker *et al*. 1995). Nearshore habitats were defined as those less than 40 feet deep within 150 feet of shore.

Table 42. Limnological characteristics at major sampling stations on Little Goose Reservoir, Washington (Corps 1999).

Limnological Characteristics	Lower Embayment	Lower Gulch	Deepwater	Lower Shoal	Upper Shoal	Tailwater
Maximum water depth (m)[a]	4.0	4.0	30.0	10.0	8.0	10.0
Littoral reach (m)[b]	29.0	42.0	3.0	10.0	12.0	6.0
Average slope of bottom (°)	4.0	4.0	27.0	9.0	8.0	12.0
Water velocity (m/second)	0.0	0.0	0-0.03	0-0.3	0-0.9	0-1.7
Aquatic macrophyte coverage (%)	3.7	11.8	0.0	3.3	9.7	0.0
Mean water transparency						
Spring	0.7	1.1	1.2	1.2	1.1	1.1
Summer	1.0	2.1	2.2	2.2	2.0	1.9
Fall	1.4	2.8	3.1	3.1	2.5	2.4

[a]Mean water depth 61 meters from shoreline
[b]Distance which the littoral zone (<2 meters depth) extended in a perpendicular direction from the shoreline
Source: Bennett *et al.* 1983

Bennett *et al*. (1983) listed all habitats other than deepwater as having mean depths less than or equal to 33 feet within 200 feet of shore. Thus, the range of mesohabitats less than 33 feet deep sampled by Bennett *et al*. (1983) is represented within the nearshore habitats sampled more recently by ODFW.

Within the nearshore reservoir habitats, Bennett *et al*. (1983) defined the littoral area as 6.6 feet deep. Subsequent research in Lower Granite Reservoir redefined the littoral depth as 16 to 20 feet, approximately the maximum depth of light penetration (David H. Bennett, UI, personal communication).

Snake River embayments between river kilometers RM 59-90 in Lower Monumental and Little Goose reservoirs were surveyed by Corps biologists in 1988 and 1989 (Kenney *et al*. 1989). Most of the 37 embayments surveyed were canyons and gulches cut off by railroad relocation when Little Goose Reservoir was filled. Most of these embayments remained connected to the main reservoirs by culverts. Others maintained a direct channel opening to the reservoir. The embayments ranged in area from less than 0.1 acre to 11.6 acres, and were generally steep-sided. More than half of the embayments surveyed were greater than 20 feet deep, and 11 were 30 feet or deeper. Aquatic vegetation was generally sparse due to the steep slopes. Shallower embayments with more moderate slopes supported pondweed, cattails, and rushes. Although this survey documented these habitats for a 31-mile portion of the reservoirs, similar embayments occur throughout the impounded reach.

The proportion of shoreline distance represented by the six mesohabitats in Little Goose Reservoir, as listed in Bennett *et al.* (1983), was as follows: deepwater equals 47.8%; upper shoal = 14.8%; lower shoal = 11.9%; embayment = 9.4%; tailwater = 8.6%; gulch = 7.4%. Based on surface area estimates for the various macrohabitat reaches in Zimmerman and Parker (1995), proportionately more tailwater or upper reservoir (in Lower Granite Reservoir) habitat exists in each Snake River reservoir other than Little Goose. Similarly, Lower Monumental Reservoir had proportionately more deepwater habitat than Little Goose Reservoir, whereas Lower Granite and Ice Harbor reservoirs had proportionately less deepwater habitat. Relative to Little Goose Reservoir, both Ice Harbor and Lower Monumental reservoirs likely have more shallow water embayment and/or gulch habitat, whereas Lower Granite Reservoir has less.

Reservoir Substrates

Several studies have described the substrata in the lower Snake River reservoirs. Bennett and Shrier (1986) conducted the first known substrate analyses in Lower Granite Reservoir. They used a Ponar dredge to characterize the substrate at six stations. Substrate sizes were significantly different between shallow and deep waters, although silt was the predominant substrate class at each of the six study locations. Clay content of the substrate generally increased with distance downstream. Organic content was less than 5%.

In 1987, Bennett *et al*. (1988) surveyed the substrata in five shallow water areas of Lower Granite Reservoir by both systematic diving and Ponar dredge. Larger substrata were found near Wawawai (RM 109) in the lower portion of the reservoir than at other up-reservoir locations. A high degree of embeddedness was found for substrates less than 6 inches in diameter. Organic content ranged from 5.2% to 8.8% and overlapping confidence intervals suggested little difference in organic content among shallow water stations throughout Lower Granite Reservoir.

Dredge samples taken from various depths within the littoral zones of Lower Granite and Little Goose reservoirs were analyzed and summarized in Bennett *et al*. (1998). Although the samples were taken from "largely shallow shoreline areas," they were not keyed to specific mesohabitats as identified above. Due to their shallow nature, however, sampled areas likely were shoal or embayment/gulch type habitats that had moderate to shallow bottom slopes.

Littoral substrata in Lower Granite Reservoir were classified as sand, sand-cobble, sand-talus, or rip-rap (Curet 1994). Sampled areas on the north shoreline tended to be comprised of bottom particles greater than 1 inch in diameter. Most of the larger substrates were likely associated with rip-rap placed during parallel road and public access construction. South shore habitats tended to be comprised more of finer sands and silts. The south shore habitats are in reservoir areas less disturbed by anthropogenic activity. Shallow habitats in Little Goose Reservoir were classified as sand, cobble, talus, or rip-rap (Bennett *et al*. 1998). The north shoreline is largely rip-rap due to placement along the relocated parallel railroad. Finer grained sand and gravel habitats tended to occur more often along the south shore.

Dauble and Geist (1992) described substrata within the Snake River arm of Lower Granite Reservoir (upper reservoir) and the tailwater below Lower Granite Dam in Little Goose Reservoir during the 1992 experimental drawdown. Cobble substrate was highly embedded with sand and fines based on visual observations of exposed shoreline areas in upper Lower Granite Reservoir. Measured substrate composition at 16 shoreline transects in the upper 3 miles of Little Goose Reservoir was estimated at boulder-13.5%; cobble-40.3%; gravel-24.5%; sand-15.9%; and silt-5.9%. Cobble substrates were highly embedded except for the upper 0.5 miles of the tailwater in the BRZ immediately below Lower Granite Dam. A trend toward greater deposition of sand and fines was noted with distance below Lower Granite Dam. Gravel/cobble substrates on mid-channel islands 2.5 and 3.0 miles below Lower Granite Dam were also highly embedded.

Additional investigations by Dauble *et al*. (1996) reported large substrata in the cobble to boulder size in the tailwaters of Lower Granite and Little Goose dams on the Lower Snake River. Gravel was generally free of sediments in the tailwaters, which the authors attributed to hydraulic events (e.g., spills and power releases).

Bennett *et al.* (1998) recently completed the most comprehensive survey of substrata in three of the lower Snake River reservoirs. Eighty-one Van Veen dredge samples were collected in total, three each at shallow, mid-depth, and deep locations in each of three sites in Lower Granite, Little Goose, and Lower Monumental reservoirs. Generally, the percentages of fine sediments (silts, clay, and organic material) increased from upstream to downstream in each of the reservoirs. Upstream sample locations were generally higher in sands, although coarse and fine gravels were collected from a shallow water site at RM 117 in Lower Granite Reservoir. Substrata from the three depths were generally similar throughout the three reservoirs. Silt and sand accounted for most of the substrate composition.

Substrates were not otherwise classified in Lower Monumental or Ice Harbor reservoirs. Tailwater substrata, including the degree of embeddedness, are likely similar in composition to the more upstream tailwaters. Greater occurrence of fines, especially in down-reservoir areas such as gulch and embayment habitat, would be expected due to greater age and depositional history of these impoundments.

Tributaries
Many of the small tributaries to the Snake River with adequate water are used by steelhead for spawning and rearing. Habitat conditions in these small streams are affected by roads, livestock grazing, farming and other land use activities. Sediment deposition, low water flows and marginal water temperatures are common habitat limiting factors in these tributaries. Riparian vegetation is often absent or degraded along portions or the full length of these streams (G. Mendel, WDFW, personal communication, Jan. 2001).

Alpowa Creek

A survey in 1980 divided the creek length into three reaches: lower, middle, and upper. Five to six sampling segments were used to characterize riparian and channel conditions. There was evidence during the 1980 survey of high peak flows and channelization along some stretches of this lower reach. Grazing was described as “heavy” within the riparian zone on 83% of the streambanks, resulting in poor herbaceous vegetation quality and quantity on 83% of the banks, poor shrubby vegetation on 67% of the banks and missing on 33%, and poor to fair condition of trees. The trees were described as “relicts” and of little reproductive value. Active erosion was noted on 8% of the banks. Substrate was characterized as a mix of boulder, rubble, and gravel; however, 46% of this substrate was considered embedded with fine particles. This sediment was thought to be the result of gullies draining adjacent upland cropland, and secondarily from bank erosion. Poor riparian conditions, high stream temperatures, and low flows were noted as limiting the value of this portion of Alpowa Creek to salmonids from late spring through the Fall (Soil Conservation Service 1981).

Livestock grazing and some cultivation bounded the middle reach. Similar to the downstream reach, a few stretches appeared channelized. Again grazing was described as “heavy” on 83% of the streambanks and “moderate” on just 17% of the banks. Herbaceous, shrubby, and tree vegetation was characterized as either “poor” or “lacking” throughout this portion. One exception occurred along stream segment eight where trees were described in “good” condition despite evidence of heavy grazing in the past. It was suggested that this segment could serve as a model of the potential for riparian condition recovery provided the removal of disturbance (Soil Conservation Service 1981). This is near a site described in the 1998 survey as containing a “good riparian buffer with large trees and no grazing” (Mendel 1999). Grazing is heavy and riparian vegetation is missing just upstream of this site (upstream of Robinson Gulch).

An estimated 22% of the streambanks were actively eroding along the middle reach of Alpowa Creek. The channel along this portion was characterized as combined boulder, rubble, and gravel suitable for spawning and rearing of salmonids except that an estimated 50% of the course substrate was embedded with fine particles. Similar to the lower portion, gully contribution from adjacent cropland as well as bank erosion accounted for this sedimentation of fines (Soil Conservation Service 1981).

The Washington Department of Game estimated 70% of the stream was in poor condition and considered high stream temperatures, low flows, lack of streamside vegetative cover (primarily caused by overgrazing), lack of instream cover and bank instability (Mendel 1981) and sedimentation (Mendel and Taylor 1981).

The majority of Alpowa Creek streamflow originates from springs in the headwaters. Upstream of the final sampling segment, the stream flows only during the spring. Livestock grazing is the primary land use here and was evident during the 1980 and 1998 surveys. Consequently, riparian vegetation is minimal and stream habitat lacks complexity along this reach (Mendel 1999). Herbaceous and shrubby streambank vegetation was either in poor condition or completely lacking in 1981. Trees were in fair condition on 60%, and poor on 40% of the streambanks. This reach contained streambanks that were significantly more vegetated and stable (76%) than the middle reach, with 7percent of the streambanks actively eroding. Channel substrate was boulder, rubble, and gravel, and less embedded in the lower and middle reaches. Because of this relatively low embeddedness, the upper reach is considered as suitable for spawning and rearing salmonids in areas that sustain enough streamflow to maintain cool water temperatures through the summer. Given the minimal or complete lack of shade provided by riparian vegetative cover, it may be the influence of the headwater springs that allows salmonids to use the upper reaches of Alpowa Creek (Soil Conservation Service 1981).

The 1980 survey identified a major sediment source between segments 13 and 14 where a cropland terrace system flowed into a failed sediment retaining dam. The failed dam created a 10 to 20 foot deep gully, which apparently transported a large amount of rock and sediment delivering the material to the channel and creating a temporary dam in the stream. Although the retaining dam failure prior to the survey, considerable debris was still present found in the channel and for a distance downstream.

In summary, nine percent of the streambanks were identified as having erosion problems, which contribute an estimated 2,988 tons of soil annually to Alpowa Creek. Areas that lack vegetation and bends in the stream harbored the most severe stream channel erosion. The poor condition of the riparian vegetation is attributed to livestock grazing along the banks and either mechanical or chemical removal of vegetation (Soil Conservation Service 1981).

The reach from the confluence with the Snake River to the Highway 12 bridge is characterized by limited overhead riparian vegetation cover with grass as the predominant bank and riparian cover type. The channel contains some cobbles and small boulders embedded with a thick silt layer and covered in many places by thick attached algae. Some woody debris appears along this reach though it is mainly strewn outside of the channel, probably remnants of an extreme flood event. Glides and riffles dominate the instream habitat. Dry side channel(s) appear to be old channels as evidenced by adjacent riparian trees and shrubs.

The valley broadens in the reach above the Highway 12 bridge crossing with cattle grazing and orchards as the primary land uses (location of Wilson Banner Ranch). The riparian vegetative buffer is thin and the channel straightened in sections along this reach. There appear to be dikes formed along much of this reach by heaping dredged dirt upon the stream banks. Also located in this reach are concrete blocks placed in the channel during the irrigation season (probably sometime in May through the summer) forming the only potential obstruction to fish migration in Alpowa Creek. The effectiveness in blocking the ascent of adult steelhead into the upper watershed is unknown, though it is thought to be minimal (G. Mendel, WDFW, personal communication 1999). Presently there is an effort to completely remove this barrier by pumping in-channel water for irrigation purposes to an off-channel location (D. Bartels, PCD, personal communication 1999). Details of this barrier are described in the Migration Barriers section.

A relatively intact riparian vegetative zone occurs where Pow Wah Kee Gulch joins Alpowa Creek. However, there is evidence of grazing within this riparian area. Approximately one mile upstream from the Pow Wah Kee Gulch confluence the streambanks appear more severely degraded from grazing. At 2.8 miles upstream of Pow Wah Kee Gulch a vast grass field supports cattle and vegetation is non-existent along the creek. Just upstream of this section riparian vegetation reappears though grazing still occurs at lower densities.

The next reach is defined roughly where Stember Creek joins Alpowa Creek (Alpowa Creek Road and Highway. 12). The lower section of Stember Creek exemplifies poor grazing practices that leave no vegetation whatsoever along the banks and riparian zone. The banks of Stember Creek are exposed and appear highly erosive, and the channel is very shallow, with cobble bars embedded with silt causing a braiding pattern in places.

Approximately one mile above the confluence of Stember and Alpowa Creeks, large cottonwoods and other tree and shrub species provide some structure to the channel and substantial solar cover. However, there is little to no recruitment of LWD to the channel along this section. Larger boulders may provide some instream cover in some places in this reach.

At 1.65 miles upstream of the Stember Creek confluence the channel splits and there is considerable evidence of livestock grazing along the streambanks and cattle were observed standing in the stream. Although some large cottonwoods exist, the riparian buffer is thin and degraded along this section. A persistent riffle-glide dominates the channel habitat and adequate pools are infrequent as is characteristic of most of the mainstem Alpowa. Any side channels that exist along Alpowa Creek may be important pool or slow water sources for salmonids, especially during high flow events.

Two miles upstream of the Stember Creek confluence a small stockyard exists in the middle of the channel. No riparian woody vegetation exists in this location. At 2.5 miles upstream, the riparian vegetation consists of low grazed grasses. Large woody debris exists only out of the channel, possibly as remnants of abandoned channels.

Robinson Gulch joins into Alpowa at 3.5 miles upstream of the confluence with Stember Creek. Cattle grazing are evident in this area and cattle were observed nearby. Virtually no riparian woody vegetation exists and streambanks are heavily eroded.

Five miles from the Stember Creek confluence, grazing impacts the riparian zone and streambanks, and woody vegetation is sparse. The presence of LWD lodged in trees indicates the occurrence of a significant flood event. The channel is approximately 15 feet wide in this section, shallow with a cobble substrate, and dominated by riffle and glide habitat types. A sizeable remnant channel is evidence of a laterally mobile and dynamic channel through the floodplain. *Trichoptera, ephemeroptera,* and *Simulid* larvae were found attached to cobbles removed from the stream. A revisit to Alpowa Creek later in April found an abundance of pebble-cased caddis larvae *Trichoptera*.

Based on accounts of residents and evidence of the riparian and channel characteristics, Alpowa Creek appears to be a highly responsive stream to storm events. Snowpack melt is probably not a major contributor to stream flow thus, stream flow mainly reflects rainfall patterns within the watershed. High stream flow events probably have greater potential for negative impacts to juvenile fish than adults. The lack of side channel pocket habitats and pool areas where small fish can take refuge within the channel leaves young fish especially vulnerable to flood events. Incubating embryos and newly emerged fry are at least as vulnerable as larger juveniles. Larger resident fish and adult salmonids are probably less susceptible to flood events mainly due to their size and ability to hold. However, a powerful enough event can also displace these fish when the lack of protective side channel habitats provides little refuge during floods. Adult salmonids are probably most affected by the shifting of sediments and bed material in the channel, which potentially removes spawning areas.

The lack of side channels and large pools in Alpowa Creek is key to the survival of fish during high flows. Re-establishment of a meandering flood plain in areas that have been channelized and woody vegetation in the riparian zone may help develop these refuge habitats.

Concrete slabs are temporarily placed in the channel to divert water from the lower reach of Alpowa Creek just upstream of the Highway 12 overpass (Wilson-Banner Ranch). This is thought to normally occur after any adult steelhead have already passed into the upper reaches to spawn (probably at least May), and the structures remain through the irrigation season (September). The previously mentioned problem was corrected in 2000 by Wilson Banner Ranch in cooperation with the Pomeroy Conservation District by cost share funding received from the Salmon Recovery Funding Board. The barriers were removed and an irrigation intake and distribution system for irrigation of orchards and bottomland was installed. The previous barriers at this location are now non existent.

High water temperatures in the lower reaches (below Highway 12) of Alpowa Creek are thought to limit the movement of salmonids and any other cold water native species into the upper watershed during the summer months. Streamflow at times during the summer may also become low enough to limit movement into the watershed from the Snake River, although springs in the upper Alpowa usually maintain adequate flow even during this season. In 1998, salmonids were observed in Alpowa Creek downstream to the mouth during the late summer (Mendel 1999).

Deadman Creek

Livestock grazing and some cultivation bound the full length of the watershed. Herbaceous, shrubby, and tree vegetation was characterized as either “poor” or “lacking” throughout this portion.

The majority of Deadman Creek streamflow originates from headwater springs. The presence of low embeddedness, the upper reach was thought to be suitable for spawning and rearing salmonids at least in areas that sustain enough streamflow to maintain cool water temperatures through the summer. Given the minimal or complete lack of shade provided by riparian vegetative cover, it may be the influence of the headwater springs that allows salmonids to use the upper reaches of Deadman Creek.

Areas that lack vegetation and bends in the stream harbored the most severe stream channel erosion. The poor condition of the riparian vegetation is attributed to livestock grazing along the banks and either mechanical or chemical removal of vegetation (Soil Conservation Service 1981).

The Washington Department of Game identified low summer flows, high temperatures, lack of streamside vegetation, lack of instream cover and eroding banks as limiting factors for most of Deadman Creek and low flows, high temperatures, lack of streamside vegetation and eroding bank for Meadow Creek (Mendel 1981).

Based on accounts of residents and evidence of the riparian and channel characteristics, Deadman Creek appears to be a highly responsive stream to storm events. Snowpack melt is probably not a major contributor to stream flow, and therefore stream flow mainly reflects rainfall patterns within the watershed. High stream flow events probably have greater potential for negative impacts to juvenile fish than adults. The lack of side channel pocket habitats and pool areas where small fish can take refuge within the channel leaves young fish especially vulnerable to flood events. Incubating embryos and newly emerged fry are at least as vulnerable as larger juveniles. Larger resident fish and adult salmonids are probably less susceptible to flood events mainly due to their size and ability to hold. However, a powerful enough event can also displace these fish when the lack of protective side channel habitats provides little refuge during floods. Adult salmonids are probably most affected by the shifting of sediments and bed material in the channel, which potentially removes spawning areas.

Wildlife

Wildlife habitats within the subbasin consist of two types: riparian/floodplain, and shrub steppe/agricultural. The riparian/flood plain habitat lies along the Snake River and its tributaries. The shrub steppe/agricultural encompasses the sub-basin uplands and consists mostly of agricultural croplands, rangeland, Conservation Reserve Program lands (CRP), and some shrub steppe habitat. Vegetative associations are described by Daubenmire and Daubenmire (1968), Daubenmire (1970), and Franklyn and Dryness (1973). Native habitats within the subbasin have been altered by human development (e.g., agriculture, livestock grazing, and the invasion of noxious weeds).

Riparian/Flood Plain

Since the arrival of settlers in the early 1800's, 50%-90% of riparian habitat in Washington has been lost or modified. Riparian habitat is limited along the Snake River and was inundated when dams were established. The Corps of Engineers has created 3,197 acres of managed habitat units along the river in an effort to improve conditions after inundation; Ice Harbor pool – 1241 ac., Lower Monumental pool – 1035 ac., Little Goose pool – 1890 ac., - Lower Granite pool – 66 acres. Most of these sites were irrigated alfalfa-grass-forbe meadows and planted with a variety of trees and shrubs to provide a mosaic of habitats. In addition, an estimated 4,017 acres of dry land habitat plots exist, which have been enhanced with the addition of guzzlers, goose tubs, and bird boxes, the grassland habitat itself remains unchanged.

Shrub Steppe/Agriculture

Historically, shrub steppe habitat consisting of sagebrush, rabbitbrush, and various bunch grasses covered nearly all non-forested lands east of the Cascade Range in Washington, of which only 50% remains (Daubenmire 1970). Due to development, the lowland shrub steppe habitat component within the subbasin has suffered the same fate. Agricultural development results in rapid and extensive loss of vegetation, while livestock grazing results in a slower impact to the composition and structure of native vegetative communities (Dobler and Eby 1990). Species dependent on shrub steppe habitat have been extirpated or populations are severely depressed. In recent years, many acres have been removed from agricultural production in Whitman, Walla Walla, Columbia and Garfield counties (T. Johnson, personal communication 2000) and placed in the Conservation Reserve Program (CRP), which has benefited numerous species of wildlife within the subbasin by re-establishing grassland habitat.

Tributaries

Alpowa Creek

The Alpowa Creek watershed never supported large populations of grazing animals. Although white-tailed deer, mule deer, elk, and pronghorn antelope did occur, their numbers were small in comparison to those found on similar rich grasslands. The low rate of summer precipitation and hunting pressure probably kept grazing populations minimal. Many of the reports by early explorers comment on the scarcity of game in the area (Tisdale 1961). Later, the introduction of cheatgrass further complicated matters for native animals like the sharp-tailed grouse. This change in habitat favored introduced species such as the black-tailed rabbit that out-competed and have now replaced the indigenous white-tailed jackrabbit.

Watershed Assessment

Lower Snake River Compensation Plan 1976. Describes fish populations and their distributions and sets mitigation levels for fish and fishery losses caused by the four lower Snake River dams.

Bennett *et al*. 1983 - UI reservoir fishery evaluations describe fish distribution, abundance, and harvest levels for fish in the Snake River mainstem.

COE Draft Environmental Impact Statement (DEIS) Lower Snake River Juvenile Salmon Migration Feasibility Report. 1999. Describes four alternatives to try and improve juvenile survival for salmon and steelhead passing the Snake River dams. For more information about the environment see EISs for construction of Snake River dams and Biological Assessments for projects at those dams.

A cursory assessment of fish distribution, relative abundance and stream habitat conditions was conducted in Alpowa Creek in 1981 (Mendel and Taylor) and in 1998 (Mendel 1999). None of the other small tributaries have been surveyed in the past several decades.

Parkhurst, Z. Survey of the Columbia River and its tributaries. 1950. Part 6. Fish and Wildlife Service (FWS), Spec. Sci. Rep. Fish. 39p. Assessed the fish value of tributaries of the Snake River.

Fulton, L. 1970. Compiled the available information on spawning and rearing distribution and abundance of steelhead and salmon in the Columbia R. Basin.

Fishery Steering Committee of the Columbia Basin Interagency Committee. 1957. Inventory of streams and proposed improvements of the fishery resources of the upper Columbia River Basin.

Mains and Smith. 1955. Determination of the normal stream distribution, size, time and current preferences of downstream migrating salmon and steelhead trout in the Columbia and Snake Rivers.

Pirtle, R. 1957. Final Report to the US Army Corps of Engineers (USACE). Enumeration Study upper Columbia and Snake Rivers. IDFG. This report describes timing and size of adult runs of salmon and steelhead in the Snake River.

There have been no official watershed assessments completed in the Alpowa or Deadman watersheds or any of the other minor watersheds. A draft watershed characterization was completed by the Center for Environmental Education of WSU in 1999 and much of that information is contained in this summary for the Alpowa Watershed to be included in the Lower Snake Subbasin Summary.

Limiting Factors

Resident Fish

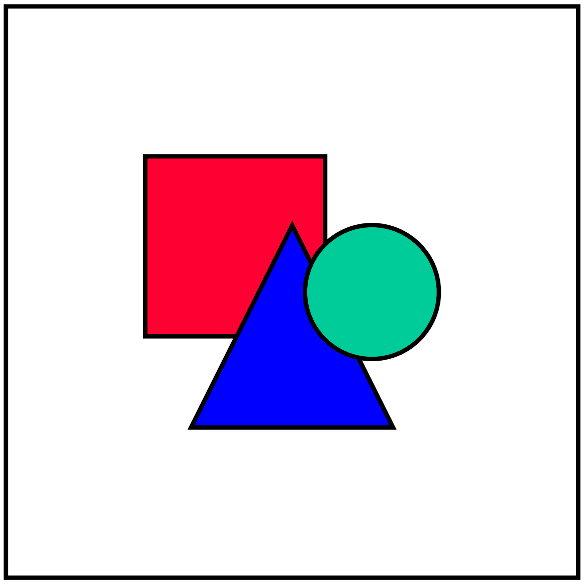
Reservoirs (Corps 1999)

Water Temperature

One of the key environmental variables that will serve as a limiting factor in the ability of the members of the resident fish community to successfully adapt to new riverine or impoundment conditions is water temperature. The seasonal Snake River hydrograph typically experiences peak flows in May and/or June from spring rains and snowmelt. Dry or wet springs or accelerated or delayed snow melt create highly variable inter-annual spring runoff, which in turn plays a major role in the overall timing of the water temperature regime and the summer thermal maxima experienced by lower Snake River fish. High temporal variability in water temperature may have a profound effect on the spawning success of lower Snake River resident fish.

The ranges of spawning temperatures and time frames for the resident are summarized in Table 43. Site-specific Snake River spawning temperatures are provided for 13 species, largely from the work of Bennett *et al*. (1983). White sturgeon spawning temperatures were those reported for the Lower Columbia River by Parsley *et al*. (1993). Spawning temperatures for the remaining species were derived from several literature sources. Sculpins, white sturgeon, and bridgelip sucker are the earliest spawning native species. Yellow perch generally spawn earliest among the introduced fish, in very early spring at 7 to 8°C (44 to 46°F). However, most non-native Snake River fish such as bass, sunfish, crappie, and, particularly, catfish spawn much later, usually at least after water temperatures have attained 15 to 18°C (59 to 64°F).

Water temperatures were monitored in Lower Granite Reservoir by recording thermographs for several years (Bennett *et al*. 1997; Connor *et al.* 1998). These data represent at least the lower two-thirds of the reservoir (Connor *et al*. 1998). For the 3 years depicted, 1994 represents a dry or low flow year, 1995 an "average" flow year, and 1997 a wet or high flow year. These data show typical seasonal water temperatures and trends experienced by lower Snake River resident fish. A major source of variability imposed on the spring-summer temperature regime experienced by resident fish in reproductive mode is the apparent cooling effect of augmentation flows released from upstream reservoirs (*e.g*., Dworshak Reservoir) to enhance juvenile salmonid smolt outmigration. Three episodes of rapidly declining water temperatures are evident in mid-May, mid-June, and nearly the entire month of July into August. Two similar episodes occurred in June 1995.



The release of upstream storage for flow augmentation, primarily to speed passage of salmonid smolts through reservoirs, can affect the spawning and growth of resident fish in several ways. The attainment of a suitable temperature to initiate spawning can be delayed substantially. If the delay were prolonged, as may have occurred in 1994, the effect on year-class production and/or growth due to persistent, lower-than-optimal temperatures can be severe (Bennett *et al*. 1991).

Delayed spawning followed by a short growing season may yield young-of-the-year too small to survive over-wintering. Spawning also can be interrupted, potentially several, by the steep temperature declines that can accompany release of augmentation flows, particularly during releases from Dworshak Reservoir. Such releases pose an additional stress on introduced resident fish that may already be exposed to sub-optimal thermal regimes in the Pacific Northwest (*e.g.*, smallmouth bass-Bennett *et al*. 1991).

The delay attaining certain critical spawning temperatures in some years can be substantial. For example, 18°C (64.4°F) is a critical temperature for initiation or continuation of spawning activities for many of the introduced sunfish and catfish. However, the date when 18°C (64.4°F) is attained can vary as much as 50 days from late May (1992) to mid-July (1993; Bennett *et al*. 1998). In addition, the attainment of peak summer temperatures may vary by a comparable time period. For example, the highest summer water temperature reached in Lower Granite Reservoir in 1995 was 20.4°C (68.8°F) on July 23, compared to a peak of 22.2°C (72°F) on September 5 in 1997, a difference of 44 days.

Table 43. Spawning temperatures of Snake River fish.

Species	Spawning Temperature and Timeframe		
	Temperature Range (°C)	**Month**	**Source**
Smallmouth bass	14-19.6	Mid-June to late July	1
White crappie	15.8-20.4	June-August	2
Black crappie	15.8-19.6	June-July	2
Largescale sucker	12.2-15.8	May-June	1
Bridgelip sucker	10.2-12.2	April-May	1

Northern pikeminnow	14.0-20.4	mid-May to late June	1
White sturgeon	10.0-18.0	April-July	7
Channel catfish	18.1-21.7	July-August	1
Redside shiner	18.1-20.4	July-August	1
Brown bullhead	20.4-21.7	June-August	1
Pumpkinseed	18.1-19.6	late June to early August	1
Bluegill	19.6-21.7	July-August	1
Yellow perch	12.2-13.6	April-May	1
Common carp	16.5-17.0	mid-June	1
Chiselmouth	17.0	May-June	3
Peamouth	12.2	May-June	3
Sculpins (3 spp.)	7.8-17.2	April- June	4
Flathead catfish	22.0-29.0	July-August	5
Sandroller	14.0-16.0	May-June	8
Yellow bullhead	20.0	June-July	4
Black bullhead	21.0	June-July	3
Warmouth	21.0-25.0	late June- July	6
Largemouth bass	16.0-24.0	June-July	6
Tadpole madtom	22.0-26.0	late June-August	3
Notes: Data are for resident, in-river spawners. Tributary spawners are not included. Native species are shown in bold type. Lower Snake River spawning temperature data are shown for underlined fishes.		Sources: Bennett *et al*. 1983 Bratovich 1985 Scott and Crossman 1979 Smith 1985 Turner and Summerfelt 1971 Carlander 1977 Parsley *et al.* 1993 Gray and Dauble 1979	

The effects of accelerated, delayed, or depressed spawning temperatures may be dramatic, but very difficult to isolate. Successful early spawning of some species may create a year-class with greater than average first-year growth, a recruitment advantage that may remain with that year class throughout its life. Conversely, delayed spawning may limit the growth of first-year fish, possibly to the extent that over-winter survival is poor, and the year-class may be virtually absent from the population as advanced juveniles or adults. While the above implications were evaluated for Snake River smallmouth bass (Bennett *et al*. 1991), similar effects on other resident, introduced fish not studied in such detail are likely. Further, for some species with relatively high spawning temperature requirements such as catfish, late warming may preclude attainment of optimum temperatures, seriously impacting reproductive success in that year.

Inundated Habitat

Available historical data does not suggest bull trout spawning/early-rearing habitat was inundated when the Lower Snake River dams were completed; all evidence suggests that the impounded areas were historically used as adult/subadult foraging and overwintering areas. This use continues today for these age groups. The transition from a riverine environment to a reservoir would likely eventually force the historic fluvial local populations to adapt to an adfluvial type life history. Provided the local populations adapt to the altered environment and sufficient forage is available throughout time in the reservoirs, the change to a reservoir system could have some positive effects on the bull trout as well. For example, adfluvial fish typically grow to larger sizes than fluvial migrants, and as a result can be more fecund (Goetz 1989). If sufficient spawning and early rearing habitat is available, a potential increase in individual fecundity may result in a larger, more robust local population. However, the available data does not indicate whether the reservoirs on the Lower Snake River have resulted in larger, more fecund bull trout. The data indicates some individuals use the reservoirs for adult and subadult rearing, so we assume that at least a portion of the local populations have adapted to the adfluvial migratory behavior. As a result, adverse effects associated with inundated habitat appear to be minimal, and may be offset by associated increased growth and fecundity.

Gas Supersaturation

Elevated levels of TDG are a common problem below dams during periods of high runoff and spill. High TDG can result in gas bubble disease (GBD) in fish. Bull trout that may be present in the tailraces below the Lower Snake River dams are subjected to high TDG levels, and as a result, could be adversely affected by GBD. Shrank *et al*. (1997) found that resident fish experienced a higher mortality rate from GBD than migratory fish moving through areas with high TDG concentrations.

For comparison purposes, we are including some data associated with Dworshak Dam on the Clearwater River. GBD was observed in 90 out of 8,842 individual fish sampled downstream of Dworshak Dam in the spring and summer of 1997 (Cochnauer and Putnam 1997). The occurrence of GBD in sampled fish ranged from 0.9 to 16.5%, and was most prominent following periods when TDG levels approached 120% saturation. The highest rate of incidence occurred in resident salmonid species sampled in the 1.5 miles long section immediately below the dam, but none of the 12 bull trout sampled in this section showed signs of GBD.

Total dissolved gas levels in the tailraces below the Lower Snake River dams are typically higher than those observed at Dworshak (Fish Passage Center 1997). During high spring runoff in 1997, TDG levels below these facilities were commonly at or above 130% saturation, and occasionally approached 140%. During late summer and early fall, when discharge was low, TDG levels were typically around 100%. Data collected near the Lower Snake facilities indicated occurrence of GBD in fishes in the Lower Snake River was less than the values Cochnauer and Putnam (1997) identified in the Dworshak Dam Tailrace. The data presented, however, appeared to focus on emigrating anadromous species. There are no documented GBD effects to bull trout in association with the Lower Snake River dams, but the potential for adverse effects is higher than that below Dworshak Dam as a result of higher TDG levels.

Passage/Entrainment

Based on fish counting schedules outlined in Corps reports (Corps 1997), adult fish enumerations are not conducted at the Lower Monumental, Little Goose, or Ice Harbor fish counting windows from November 1 - March 31. Unfortunately, this period coincides with adult bull trout movements into larger mainstem systems.

In the U.S Fish and Wildlife Service’s (USFWS or Service) Federal Columbia River Power System (FCRPS) Biological Opinion, the Service anticipated that the operation of the Lower Snake River dams is likely to result in variable levels of incidental take of bull trout. However, the Service is at this time unable to quantify the numbers of bull trout to be taken. Incidental take of bull trout will be difficult to quantify or detect for the following reasons:

1. The limited scope, timing, and sampling locations of existing monitoring programs which may detect predation of bull trout,
2. finding dead or impaired specimens is unlikely because of water depth and scavengers, and;
3. injuries or trauma caused by attempted predation or competition, which cause reduced survival of bull trout would be virtually undetectable.

The Service anticipates indeterminate levels of harassment, harm or killing of bull trout to occur in the Lower Snake River as described below:

> Harm and harassment to bull trout resulting from impediments to both upstream and downstream passage, potential entrainment of both adult and juvenile bull trout into turbine intakes, potential entrainment of adult bull trout into juvenile bypass systems, changes in pool water level elevations affecting food and habitat availability, elevated water temperatures resulting from impoundment, and gas supersaturation resulting from both voluntary and involuntary spill events are likely to continue to occur under the current water management scenario .

In the biological opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the species. Critical habitat has not been designated for bull trout, therefore, none will be affected.

The effects of entrainment can include physical injury, direct mortality, migration delays, and isolation from spawning areas. All these effects are likely to occur at all the Lower Snake River facilities at some unknown rate, but without appropriate monitoring and research it is impossible to estimate impacts to the population resulting from entrainment.

Operations that increase uncontrolled or controlled spill are likely to increase adverse affects from entrainment. System improvements that are focused on more effective diversion of juvenile fish away from the turbines may also effectively divert bull trout away from the turbines and thereby potentially decrease take below existing levels. However, short term disturbances from improvement construction may also adversely affect bull trout by preventing or discouraging use in the construction area, further impeding migration. Since the extent and timing of bull trout use of the four dam facilities is unknown, we cannot quantify the impacts to bull trout at this time.

Anadromous Fish

The maximum water temperature criteria established by Washington for the main-stem Snake River is 20°C, which is often exceeded during the warmest parts of the summer. The upper incipient lethal temperature for juvenile chinook salmon is 24°C (Brett 1952). Temperature affects swimming performance (Brett 1967), growth and energetics (Brett 1952; Elliott 1982), movement behavior (Bjornn 1971), physiological development (Ewing *et al*. 1979), disease susceptibility (Fryer and Pilcher 1974), and vulnerability of fish to predation (Sylvester 1972; Coutant 1973; Yocom and Edsall 1974; Deacutis 1978). The long-term consequences to fall chinook salmon of chronic exposures to sublethal temperatures that exist in the Snake River during the summer is unknown, but may manifest itself in high mortality at dams due to increased physical stress during passage. Studies have also shown that late-migrating juvenile Snake River fall chinook salmon exposed to high water temperatures have poorer survival than earlier migrants (Connor *et al*. 1998; Muir *et al*. 1998). Considering the life history of fall chinook salmon along with the environmental conditions that exist during their freshwater life cycle, high water temperatures may limit this population by reducing fish performance and long-term survival.

Flow and Migratory Conditions

The Snake River hydrosystem has increased the travel times of emigrating juvenile salmonids from those experienced historically. Spring and summer flows are currently augmented to reduce the travel times of in-river migrants to subsequently reduce exposure to such risks as predators, disease, and high summer temperatures. Although juvenile fall chinook travel time has been shown to be weakly related to river flow (Berggren and Filardo 1993; Giorgi *et al*. 1997; Tiffan *et al*. 2000), a clear flow-survival relationship has yet to be demonstrated and is the subject of considerable debate. The effects of flow on salmonid travel time and survival are often confounded with other behavioral, biological, and environmental factors. River flows is one of few variables that can be managed for juvenile salmonids, but much remains to be learned of its role as a limiting factor.

Passage

Using radio telemetry, Venditti *et al*. (2000) showed that most summer-migrating juvenile fall chinook salmon traveled fairly rapid through the upper and middle sections of Little Goose Reservoir, but 10-20% of the fish were delayed in the forebay for a week or more. This delay and inability to pass the dam quickly likely increases fall chinook salmon risk of predation and exposure to high summer water temperatures, which may decrease their survival.

Habitat Losses

Hydroelectric development has transformed most fast-moving main-stem riverine habitats into slow-moving reservoir impoundments. Construction of Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams from 1961 to 1975 inundated virtually all fall chinook salmon spawning habitat in the main-stem Lower Snake River. Recently, a very limited amount of fall chinook salmon spawning was documented in the tailraces of Lower Granite, Little Goose, Lower Monumental, and Ice Harbor dams, but did not contribute significantly to the production of fall chinook salmon in the Snake River (Dauble *et al*. 1999). Juvenile fall chinook salmon use main-stem shorelines for rearing, but the amount of available rearing habitat has not been quantified to date. The shoreline habitats available in lower Snake River reservoirs are predominantly rip-rapped, which juvenile fall chinook salmon avoid, and are often preferred by predators (USGS, unpublished data). These habitat-related limitations in main-stem reservoirs further reduce the production potential and survival of fall chinook salmon.

Food Webs

The transformation of the main-stem Snake River into a series of reservoirs has altered the food webs that support juvenile salmonids and resident fish (Bennett *et al*. 1988, 1990, 1991; Dorband 1980). Before impoundment, the benthic community of the now inundated Lower Granite Reservoir consisted of mainly ephemeropterans and thrichopterans (Edwards and Funk 1974). Today, the food of juvenile fall chinook salmon consists primarily of midges (Diptera), mayflies (Ephemeroptera), zooplankton (Cladocera), and larval fish in the upper portion of Lower Granite Reservoir (Curet 1993). However, Curet also observed an increase in terrestrial insects further downstream in Little Goose Reservoir. Similarly, Rondorf *et al*. (1990) found juvenile fall chinook salmon in McNary Reservoir consumed primarily midges, terrestrially-derived insects, and zooplankton. The limitation that altered reservoir food bases present is lower in-reservoir food production and an increased foraging cost to consume smaller, less energetically profitable zooplankton. The effect of this on the growth and survival of salmonids rearing and migrating in the Lower Snake River is unknown, but should be cause for concern.

Disease

The bacterium *Flexibacter columnaris* has been shown to be a significant pathogen to steelhead, and coho and chinook salmon (Holt *et al*. 1975; Becker and Fujihara 1978). The incidence of *Flexibacter columnaris* in the main-stem Snake River has not been rigorously monitored in recent history, but has been documented at Lower Granite and Lower Monumental dams (USGS, unpublished data). Its occurrence in juvenile fall chinook salmon has also been documented at Columbia River dams and may have contributed to the thermal-related mortalities observed at McNary Dam in 1994 and 1998. Little is known about the environmental and biological conditions that contribute to large-scale infections that could ultimately decrease fish performance and survival.

Tributaries

Alpowa and Deadman creeks

A limiting factors report will be completed by the Washington State Conservation Commission in 2001 for the Snake river basin from the mouth of the Tucannon River upstream in WRIA 35 within Washington. The following information was gathered by the Center for Environmental Education at WSU.

Sediment sources should also be considered in terms of the frequency of their impacts, as eventscale (short time-frame) vs. geoclimatic scale (long time-frame) affect aquatic habitat differently. Infrequent events such as landslides associated with major storms and flooding have obvious and recognizable impacts. Large storm events can totally restructure the stream channel by removing riparian vegetation and redistributing pools and riffles. Short interval events such as daily changes in flow and small amounts of precipitation can cause minor siltation or changes in the width and depth of the wetted channel. The seasonal increases associated with snowmelt and winter rains are not as dramatic, but still important contributors to the sediment load. Seasonal fluctuations can cause changes in the diversity of habitat units such as pools and riffles or increased instances of siltation during spring run-off (Swanston 1991). Spatial and temporal sediment sources control the distribution of sediment in the channel, which potentially impacts other important functions such as water quality, channel stability, and aquatic habitat in the Alpowa Creek watershed.

Once sediment enters the channel, much of it settles there until a large flood event moves it in the form of a sediment pulse. Low flows rework the deposited pulses during the times between flood events. The frequency of flooding partially determines the rate sediment moves through the stream system. For example, when intermittent creeks in the Alpowa watershed rapidly rise to flood stage, they can deliver large amounts of sediment to the larger channels in a short time period. However, no data currently exist specific enough to the Alpowa drainage to gage the contribution of individual tributaries to this process.

Water Temperature

High water temperatures occur mainly from June through September. This is not likely to affect adult steelhead that enter Alpowa Creek or Deadman Creek in late winter and early spring. However, it indirectly affects the success of spawning steelhead by reducing survival of juveniles that emerge from the substrate during the summer when temperatures are excessively high. High stream temperatures throughout the summer and sometimes into the early fall probably leave Alpowa Creek as marginal conditions for steelhead rearing and unsuitable for spawning adult chinook salmon and bull trout.

High water temperatures and sedimentation are directly related to the degraded condition of the riparian zone. In small streams, vegetative cover of the channel provides shade and can maintain cool water temperatures suitable for salmonids and other native fish species. A healthy vegetative community in the riparian zone also stabilizes streambanks and intercepts some upland sediments before they reach the channel, both of these function to reduce sediment delivery to the stream. Mature woody riparian vegetation also provides a source of woody debris to the stream channel, which is important in forming pools and creating complexity in stream habitats.

Rearing Habitat Conditions

Juvenile salmonid rearing is limited mainly to reaches upstream of Highway 12, although in 1998, salmonids were found as far downstream as the mouth late in the summer. A late summer rainfall may have allowed some fish to move that far downstream. Rearing conditions are marginally adequate in areas upstream of Highway 12 because the water is generally cooler, but conditions could be improved by improvement of the riparian vegetation and increases in channel complexity and cover. Further downstream, water temperature and the lack of pools makes these areas less tolerable to young fish.

Sediment Levels

Elevated sediment levels are one of the potential limiting factors to salmonid use in Alpowa Creek. Sediment is limiting for several reasons, including channel instability and habitat impairment. Brief field investigations in the spring of 1999 showed extensive areas of aggradation and channel incision in Alpowa Creek, both indicators of an altered sediment regime. The altered regime is of particular importance above the confluence of Stember Creek, where the only likely spawning habitat in the watershed occurs.

Elevated sediment levels are one of the potential limiting factors to salmonid use in Deadman Creek. Sediment is limiting for several reasons, including channel instability and habitat impairment. Brief field investigations in the spring of 1999 showed extensive areas of aggradation and channel incision in Deadman Creek, both indicators of an altered sediment regime.

Elevated sediment levels negatively impact aquatic habitat in many ways. Fine sediment and organic matter suspended in the water column impact the salmonid life cycle at several points, primarily in the first year of life. Fine sediment makes it difficult for adults to clean gravel nests (redds) for spawning, covers and suffocates eggs, and fills the interstitial space between larger gravel and cobbles where juveniles seek cover. Coarse sediment inputs can alter the morphology of channels that have evolved under specific sediment conditions, leading to pool filling, aggradation, and bed instability. A highly mobile streambed can scour and fill active redds.

Land use practices, topography, soils, geology, and climatic conditions in the watershed combine to produce sediment in streams. Sediment sources are areas or activities prone to producing sediment above natural levels. Sediment production can be broken into two phases: detachment and transport. Sediment detachment occurs from different sources and at different magnitudes throughout the Alpowa Creek watershed. For example, mass wasting rapidly contributes large amounts of both coarse and fine sediment, while surface erosion from overgrazing may contribute fine sediment at a slower rate to the creek. Wind and water constantly redistribute this sediment across the landscape. When sediment is deposited in areas sensitive to sedimentation such as spawning redds, then sediment becomes a problem. The spatial distribution of sediment sources, their transport mechanisms, and ways in which they contribute sediment to the channel are important factors in understanding the appropriate sediment regime for the watershed.

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Once sediment enters the channel, much of it settles there until a large flood event moves it in the form of a sediment pulse. Low flows rework the deposited pulses during the times between flood events. The frequency of flooding partially determines the rate sediment moves through the stream system. For example, when intermittent creeks in the Alpowa watershed rapidly rise to flood stage, they can deliver large amounts of sediment to the larger channels in a short time period. However, no data currently exist specific enough to the Alpowa drainage to gage the contribution of individual tributaries to this process.

Reference conditions help in the understanding of how the sediment regime changes as a result of different land use impacts. The reference conditions for Alpowa Creek were determined from historic descriptions of the density and species diversity of the vegetation; current observations of basin morphology, geology, and soils; current and historic climate data; and current and historic hydrologic data.

Historically, the major sediment sources in the Alpowa watershed included mass wasting, bank erosion, and surface erosion. All of these are naturally occurring phenomena. The primary factor involved in the distribution was probably slope, with higher slope areas being more likely to fail than lower slope areas. Although natural sediment sources fluctuated historically both in time and space, the watershed was able to return to a stable balance following disturbance events and adapt to climatic and geologic changes. Natural sediment production increased most dramatically during large precipitation events that triggered landslides and caused floods that scoured the riverbanks, eroded fluvial terraces, and moved sediment pulses through the stream system. After these events, the stream reworked the sediment, and the channel morphology adapted to the new sediment distribution.

In steep terrain where the hillslopes have weakened to the point at which they can no longer -resist gravity, catastrophic mass movements such as landslides result. Large precipitation events that saturate soils and increase interstitial pore pressure reduce resistance to gravity and contribute to shallow landslides on steep terrain. If the slide enters a flood-swollen stream, the flow becomes a slurry of sediment and water or a debris flow, which moves rapidly downstream and entrains material stored in the channel. Debris flow deposits were seen through9ut the -Alpowa watershed during the 1999 field reconnaissance and probably played an important role in channel development. Many of the larger tributaries to Alpowa Creek are lined with debris flow deposits, and first-order draws are often filled with stored colluvial material brought down from the steep hillsides. These types of mass wasting events probably dominated the reference sediment regime, with surface erosion providing comparatively little sediment to the aquatic ecosystem.

Surface erosion is limited when a watershed is in an undisturbed state. Accordingly, historic sources of surface erosion were most likely secondary to wide-scale disturbances such as fire or landslides that removed large portions of the vegetation from the soil surface. In places where soil was left exposed to the forces of wind, rain, and gravity, the soil was detached from its original position on the slope and transported to a new position down-slope. In places where no large-scale disturbance occurred, surface erosion was minimal. What erosion did occur was probably the result of the winnowing of fine-grained material from between the clumps of bunchgrass by wind and rainfall. Surface erosion probably did not deliver concentrated enough amounts of fine sediment to the stream to negatively impact the aquatic habitat until after the land use impacts from grazing and cultivation became prevalent in the region.

Agriculture practices over the last 135 years in the region are responsible for changes to vegetative cover that have increased surface erosion rates. These and other human land uses result in a loss of topsoil, reduced infiltration, lowered water retention, and escalated run-off (Bureau of Reclamation 1997). Soil erosion is most severe in winter and early spring when melting snow and rain occur at their maximum rates.

Highway 12 occupies Megginson Gulch for its entire length and the fill and rip-rap from the highway constrict the channel for much of the channel length. Megginson Creek has undercut the hillslope opposite Highway 12 and it is actively eroding in many places.

Area on northside of Snake River in Whitman County and the Small Area North of Tucannon and Pataha Creek in Columbia County

Sediment deposition and water temperature are assumed to be limiting factors in streams located in this combined watershed. Lack of riparian cover and sedimentation from cropland is presumed to be the main cause for these limiting factors.

Small Area North of Tucannon and Pataha Creek in Columbia County

The Columbia County Weed Board (Weed Board) visually surveyed approximately 48 miles of the Tucannon River, including private and public lands. Approximately 20% of the riparian areas are infested with yellow starthistle, Centaurea solstitialis, and knapweeds (Centaurea diffusa, Centaurea biebesteinii, Acroptilon repens). Eighty percent of rangelands are infested with yellow starthistle. The Weed Board found limited amounts of rush skeletonweed, Chondrilla juncea, and is attempting to contain leafy spurge, Euphorbia esula.

Yellow starthistle is a member of the Asteraceae family. It is a winter annual with yellow flowers. About 60% of the seeds produced by yellow starthistle survive dispersal (Sheley and Larson 1994) . Birds, wildlife, humans, domestic animals, whirlwinds, and vehicles may transport the seeds. A single plant may produce up to 150,000 seeds. Studies show that 90% of the seed falls within 2 feet of the parent plant (Roche 1991). Of these seeds, 95% are viable, and 10% can remain viable for 10 years (Callihan *et al.* 1993). Yellow starthistle can grow more rapidly than most perennial grasses. It is deep-rooted and will grow twice as fast as annual grasses (Sheley and Larson 1995) . Yellow starthistle displaces native plant communities and reduces plant diversity. It can accelerate soil erosion and surface runoff (Lacey *et al.* 1989). Yellow starthistle forms solid stands that drastically reduce forage production for wildlife.

Knapweeds are also members of the Asteraceae family. Spotted knapweed is a deep taprooted perennial that lives up to nine years (Boggs and Story 1987). Seed production ranges from 5,000 to 40,000/m^2 (Shirman 1981). Seeds can germinate in the spring and fall when moisture and temperature are suitable (Watson and Renney 1974). Spotted knapweed is able to extend lateral shoots below the soil surface that can form rosettes next to the parent plant (Watson and Renney 1974). Diffuse knapweed is a biennial that grows from a deep taproot. Seed production ranges from 11,200 to 48,000/m^2 (Shirman 1981). Knapweeds are spread by wind, animals, and vehicles. Diffuse knapweed reduces the biodiversity of plant population, increases soil erosion (Sheley *et al.* 1997), threatens Natural Area Preserves (Schuller 1992) and replaces wildlife forage on range and pasture. Spotted knapweed also reduces wildlife forage. Watson and Renney (1974) found that spotted knapweed infestations decreased bluebunch wheatgrass by 88%. Elk use was reduced by 98% on range dominated with spotted knapweed compared to bluebunch-dominated sites (Hakim 1979). Spotted knapweed also increases surface runoff and stream sediment (Lacey *et al.* 1989).

Rush skeletonweed is in the Asteraceae family. It can be a perennial, a biennial, or a short-lived perennial, depending on its location. Seed production ranges from 15,000 to 20,000 seeds. The seeds are adapted to wind dispersal but are also spread by water and animals. Rush skeletonweed can also spread by its roots. Rush skeletonweed reduces forage for wildlife. Its extensive root system enables it to compete for the moisture and nutrients that grasses need to flourish.

Leafy spurge is a perennial belonging to the Spurge family. The root system can penetrate the soil 8 to 10 feet. The plants will also produce horizontal roots that enable colonies to enlarge. The seeds are in a capsule and, when dry, the plant can project the seeds as far as 15 feet. Seeds may be viable in the soil up to 8 years. Leafy spurge is spread by vehicles, mammals, and birds. Leafy spurge root sap gives off a substance that inhibits the growth of grasses and reduces forage for wildlife. It also spreads by seed and root, which crowd out desirable forages.

Wildlife

Wildlife populations within the subbasin have been impacted by habitat loss due to agricultural development, hydropower development, livestock grazing, and the invasion of noxious weeds. Noxious weeds threaten mule deer winter range by decreasing both the volume and availability of palatable forage species. Agricultural development has altered or destroyed vast amounts of native shrub steppe habitat in the uplands, and increased herbicide/pesticide and sediment loads into streams.

Construction of Lower Granite Dam, the fourth and final of a series on the Lower Snake River, was completed in 1975 (Lewke 1975). The resulting reservoir caused a backup of waters flowing into the Snake from Alpowa Creek and flooded its lower reaches, inundating the surrounding riparian vegetation. Lewke (1975) estimated that the loss of riparian habitat caused by the impoundment of Lower Granite Dam resulted in a loss of habitat for 11,000 summer and 17,000 winter birds. There has of course been some recovery, but the carrying capacity for wildlife in the area has been undeniably lowered. Since impoundment, the recovery of riparian habitat has been slowed due to shallow soils along the current banks of the reservoir in comparison to soils formed in a natural riparian area.

The Lower Snake River, from the confluence of the Clearwater River to the confluence of the Snake River and the Columbia, provides a major transportation route by land and water. The railroad runs along the entire length of the Lower Snake corridor. The railroad presents a number of issues, which are limiting factors to wildlife. Direct loss of wildlife along the rail system is not avoidable. Fires set by the operation of the rail system is a common problem along the rail line. This can also lead to direct loss of wildlife. Indirect losses to wildlife due to the rail system is the permanent loss of riparian habitat due to rock rip rap along much of the rail system to reduce erosion from wave action along the reservoir, both man-made and natural. Barge traffic on the Lower Snake produces wave action throughout the length of the system. Along with barge traffic comes the continuous maintenance of the channel due to sedimentation deposit. Dredging is a continuous issue. Dredging activity and sediment deposit will always be a problem.

Alpowa and Deadman Creeks

Clean" farming practices (field burning, herbicide use, and roadbed-to-roadbed farming) have increased crop yields but negatively impacted habitat quality in the Alpowa Creek and Deadman Creek ecosystems. Wheat production in Garfield County increased from 20-30 bushels/acre in 1929 to 40-50 bushels/acre in 1992 (Black *et al*. 1997), but wildlife populations have declined. Cultivation is the main factor causing the disappearance of the Columbian sharp-tailed grouse (Lewke 1975). Even species well adapted to life on agricultural lands such as ring-necked pheasant have experienced recent population declines. Pheasant harvest in Washington fell from over 500,000 birds in 1981 to 70,000 in *1995*, most likely due to reductions in cover for nesting and protection and the effect of pesticides on breeding success. Ring-neck pheasants are currently the focus of a major habitat restoration program and the Alpowa and Deadman creek watersheds have been designated part of the high priority area (Ware and Tirhi 1999).

Erosion is also a major problem associated with agriculture in the area since much is practiced on the ridgetops. Soils in the watershed are fine and easily erodable. Runoff from storm events easily disturbs the soil particles, carrying them through the rangeland and into the streams. The -degraded quality of the vegetation in the ranges and riparian zone reduces the ability of these areas to trap sediments and prevent them from reaching the stream. The Southeast Washington Cooperative River Basin Study found that the croplands in the Alpowa Creek basin contributed more than 16,000 tons per year to the stream system (Soil Conservation Service *et al*. 1984).

Fertilizers and pesticides used to increase crop yields can be introduced to Alpowa Creek attached to sediment particles. Once in the stream, fertilizers encourage algal blooms and -aquatic plant growth due to their high nitrogen and phosphorus content (Bauer and Burton 1993). Pesticides can be toxic to wildlife, particularly amphibians and fish. Pesticides have been blamed for the drastic decline of many bat populations. Exposure to pesticides kills bats either directly through exposure or indirectly through ingestion of sprayed insects (Washington -Department of Fish and Wildlife 1998). Pesticides can also reduce reproductive success in birds, having been shown to lower chick production, chick viability, and cause degeneration of the nervous system in ring-necked pheasants (Ware and Tirhi 1999).

In addition to the cheatgrasses described above, a reconnaissance of the Alpowa Creek watershed in March of 1999 showed that yellow star thistle is among the most established introduced plant species in the drainage. This noxious weed reduces the diversity of the ecosystem by forming a canopy so dense that it shades out grasses and small herbs. Yellow star thistle can be fatal to cattle and wildlife if ingested (Stubbendieck *et al*. 1992). Its invasion of the watershed reduces available food, further increasing grazing pressures on the remaining forage and thus causing greater problems with erosion. These effects serve to limit the habitat and reduce essential requirements for aquatic species.

Precious Lands Project

Currently, the main limiting factors for wildlife populations within the Precious Lands project area are noxious weed infestations, effects of fire suppression, trespass livestock grazing, and altered hydrologic regimes.

A wide variety of invasive, non-native plant species currently occupy portions of the Precious Lands Wildlife Area. Species of particular concern are yellow starthistle and cheatgrass. Yellow starthistle is a very aggressive annual weed that invades after disturbance but once established can encroach upon seemingly pristine native bunchgrass communities. Cheatgrass is also a disturbance-adapted annual that can significantly alter plant community composition once it becomes established. In addition, cheatgrass can alter the fire regime of infested communities by providing fine, highly volatile fuels during the height of fire season. The long-term result of noxious weed invasion is a loss of biodiversity as exotic species out compete natives and replace diverse communities with monocultures or highly depauperate stands. Indirect affects to wildlife species can be a loss of food, cover, or nesting habitat.

Fire suppression efforts over the last 100 years have significantly altered natural fire return intervals within the canyon grassland systems of the Lower Snake River Basin. The result has been less frequent but more severe fires. Within the Precious Lands Area, old burn patterns are evident in the extent and composition of plant communities. The most recent natural fire event occurred in 1988 when part of the Teepee Butte Fire burned through the eastern portion of the project area. This was an intense stand-replacing fire event that resulted in conversion of several hundred acres of conifer forest to shrub fields. Under a more “natural” fire cycle perhaps this event may have been an underburn that maintained an open forest structure more common 100 years ago. Regardless of any speculation about this one fire event, it seems clear that current vegetation patterns are the result of lowered fire frequency. This has resulted in multi-layered conifer stands, high litter build-up, decadent bunchgrasses with poor forage values, and, in some areas, lower snag recruitment. The existence of noxious weeds like cheatgrass only acerbates concerns of altered fire regimes.

Livestock grazing is currently not permitted on the Precious Lands Wildlife Area, but some trespass grazing does occur from cattle moving into the area from adjoining ranches. Efforts are underway to establish fences where needed to limit livestock access to the property. The most noticeable impacts to wildlife habitat occur in the riparian corridors favored by grazing livestock. In these areas, herbaceous and shrub vegetation is directly removed through eating or trampling. Loss of understory vegetation can limit food, cover and nesting opportunities for riparian-dependant wildlife species. It can also mean a loss of shade to the stream, which may result in elevated water temperatures. In addition, cattle can transport noxious weed seeds in their feces, fur, or on their hooves, which can have long-term impacts to wildlife habitat even after livestock are removed from the area.

The Precious Lands Area is a low elevation site that largely encompasses the lower end of most streams crossing its boundaries. This lower elevation position means that area streams are impacted by upstream factors outside the management area and outside any management control of the Nez Perce Tribe (NPT). As such, the Wildlife Area is impacted by erosion, timber harvesting, livestock grazing, road construction, irrigation, and a host of other factors occurring in headwater areas. Sometimes these factors act to limit habitat values by direct degradation of habitat like increased water temperatures or turbidity. Other influences are more subtle and may act to alter in-stream flow patterns or acerbate the severity of flood events. Flood events in particular may impact wildlife habitat by removing overstory trees or otherwise impacting streamside vegetative structure. Such was the case of the 1996-97 flood events along Cottonwood, Buford, and Joseph Creeks which resulted in altered stream channels, and loss of overstory trees. Riparian systems are naturally dynamic but up-stream events may alter an areas ability to recover following a disturbance event.

Artificial Production

Artificial production occurs in the Lower Snake River (Figure 17) through the Lower Snake River Compensation Plan (LSRCP) and at Lyons Ferry Hatchery near the mouth of the Palouse River, and upriver mitigation programs funded by Idaho Power and others. Large numbers of hatchery steelhead and salmon from upriver in Idaho, Oregon or eastern Washington migrate through the area as adults or juveniles.

The LSRCP developed in 1976 to mitigate for fish and fishery losses caused by the four lower Snake River dams. Lyons Ferry Hatchery, funded by the USFWS and operated by WDGW, was built near the mouth of the Palouse River as part of the LSRCP. It is currently the only fall chinook hatchery program in the Snake River basin. The hatchery goal was to return 18,300 adult fall Chinook to the Snake River each year to mitigate as harvest augumentation and as an eggbank for the native Snake River stock of fall chinook (Bugert *et al* 1995, Mendel 1998). Snake River fall Chinook were trapped at Snake River dams to develop the broodstock for the Lyons Ferry Hatchery program. Juvenile fall chinook produced by Lyons Ferry Hatchery were barged downstream of Ice Harbor dam or released directly into the Snake River for several years (Bugert *et al* 1997) and are now released directly into the river at Lyons Ferry Hatchery (Table 45) or at three acclimation sites upstream of Lower Granite Dam (Mendel 1998). The priority for release is yearling fall chinook because of survival rates that are 4-10 times better than survivals of subyearling hatchery chinook (Bugert *et al*. 1997, Mendel 1998). Any production beyond 900,000 yearlings is released as subyearlings because of limited space at Lyons Ferry Hatchery.

FIGURE 17. Location of LSRCP hatcheries and satellite facilities.

Figure 17. Location of LSRCP Hatcheries and Satellite Facilities

Lyons Ferry Hatchery also releases steelhead (Table 46) at the hatchery site for harvest mitigation and to return Lyons Ferry broodstock for the hatchery program. Releases have been reduced in recent years. This stock of fish may be phased out in the future.

U.S. v Oregon agreements exist to try and minimize or stabilize the downriver harvest of naturally produced steelhead and fall chinook from the Snake River. The fisheries are currently controlled to protect these weak ESA listed stocks. Prior to ESA listings, Snake River hatchery and wild fall chinook were harvested at high rates in downriver fisheries.

Resident trout fisheries occur in many of the small impoundments along the Snake River that are stocked by Lyons Ferry Hatchery as mitigation for lost fishing opportunities along the Snake River due to the construction and operation of the Snake River dams. Several small tributaries were stocked until the 1990's however concerns for ESA listed steelhead resulted in the termination all stream stocking by the WDFW.

Table 45. Fall Chinook releases at Lyons Ferry Hatchery, 1990-2000.

Release Year	Age	Number of fish	Pounds of fish
2000	Yearling	456,401	48,699
	Subyearling	196,643	4,326
1999	Yearling	432,166	51,881
	Subyearling	204,194	4,171
1998	Yearling	418,992	41,484
1997	Yearling	456,776	49,168
1996	Yearling	407,503	38,996
	Subyearling(fry)	83,183	186
1995	Yearling	349,124	44,905
1994	Yearling	603,661	54,818
1993	Yearling	760,018	67,387
	Subyearling	206,775	3,390
1992	Yearling	689,601	81,677
1991	Subyearling	224,439	4,581
1990	Yearling	436,354	45,326
	Subyearling	3,812,068	54,658

Table 46. Steelhead releases near Lyons Ferry Hatchery from 1990-2000.

Year	Number released	Pounds released
2000		
1999	87,992	24,004
1998	93,842	19,059
1997	81,162	17,996
1996	71,942	13,833
1995	66,972	17,730
1994	119,039	31,087
1993	247,950	43,450
1992	66,688	18,460
1991	93,075	16,715
1990	43,479	7,730

Existing and Past Efforts

Reservoirs

Previous work has been referenced extensively throughout this summary.

Bonneville Power Administration funded a Fall Chinook Radio Telemetry study in the Snake River in 1991-1993. This study determined distribution, timing, fallback, and loss of fall Chinook in the Snake River (see Mendel and Milks, 1997).

COE juvenile migration study – 1999

COE LSRCP Mitigation Report 1975

Bennett’s warmwater fish or reservoir studies (U of I) – COE funded over many years

Fall Chinook juvenile telemetry – NPT & USGS

Fall Chinook passage and survival studies for juveniles – USGS & NPT

Sturgeon studies – NPT, WDFW, ODFW

Radio telemetry studies for steelhead and spring and fall Chinook and lamprey– UI/COE

Many past radio telemetry studies – UI and WDFW and NMFS

Fall Chinook spawning studies – USFWS, Battelle NW labs

Juvenile fall Chinook production studies

Predation studies – ODFW

Dredging studies – COE and UI

WDFW – fall chinook and steelhead annual reports for evaluation of the LSRCP in Washington

Tributaries

Alpowa Creek

Non-BPA-Funded Research, Monitoring and Evaluation Activities

Alpowa Creek Watershed Characterization

The Center for Environmental Education from WSU is currently involved in a characterization of the Alpowa Watershed. The CEE/WSU is also conducting a water quality monitoring program in the Alpowa along with the Pataha and Deadman Creeks. This information will be used in PCD's continued effort to obtain funding for watershed restoration.

Southeast Washington Fishery Enhancement Study

The COE funded the Washington Department of Game to assess the enhancement potential for several streams in southeast Washington, including Deadman and Alpowa creeks (Mendel 1981, Mendel and Taylor 1981).

Pataha and Alpowa Fish Assessment

The WDFW and PCD collaborated on a brief assessment of fish distribution and abundance during the summer and fall of 1998 (Mendel 1999).

Pataha and Alpowa Creek Water Quality Monitoring Project

The Pataha and Alpowa Creek Water Quality Monitoring project, a collaborative effort between PCD and WSU, was initiated in September 1998. The project aims to assess the success of agricultural management practices for Pataha Creek and Alpowa Creek. The monitoring effort's specific objectives include providing evidence of the effectiveness of

PCD efforts to address key water quality parameters and providing baseline data for assessing the creeks' water quality status.

Pataha and Alpowa Creek, both unclassified Washington State surface waters, are automatically classified as Class A streams. All sampling results were compared to Class A standards from the WDOE.

The monitoring protocol focuses on the most critical water quality parameters: sediments, temperature and coliform. Project staff sampled and analyzed these target parameters every two weeks. Nutrient sampling has been discontinued. In addition to water sampling, stream discharge is measured at three stations monthly. Benthic macroinvertebrate monitoring began in spring 1999.

Staff set up five monitoring stations on Pataha Creek starting below the confluence of Dry Hollow and Pataha Creek (Pataha 1), and extending upstream southeast of Columbia Center on Pataha Creek Road (Pataha 5). The Columbia Center station, located at the edge of the forest area where disturbances are minimal, will be used as a background site for evaluating water quality alteration along the lower reaches of the creek.

Three monitoring stations were established on Alpowa Creek beginning near Wilson Banner Ranch along SR 12 (Alpowa 1), and extending upstream near Landkammer's (Alpowa 3). The original Alpowa Site 2 has been changed to a different location 1/2 mile south of Flerchinger's Driveway, by the first Alpowa Bridge off Highway 12. Alpowa Site 2 is now called Alpowa Site 2A.

Staff monitored temperature, coliforms, and sediments twice each month at all eight sites (Pataha sites 1, 5, and Alpowa sites 1-3). Discharge was monitored once per month at three sites (Pataha sites 3, 5 and Alpowa site 1). Normally Pataha 1 is sampled twice a month for discharge levels to determine in greater detail the influence of Pataha Creek on the Tucannon River.

Watershed Scale Study on No-Till Farming Systems for Reducing Sediment Delivery
The first year of this project was focused on the development of a hydrologic and sediment transport model at a sub-watershed level, and the comparison of runoff, soil loss, and infiltration between conventional tillage wheat fields and wheat fields with no-tillage cropping system. The non-favorable weather situation and the conditions of the sub-watershed chosen for the hydrologic study impeded the collection of data required for modeling. Therefore, this objective will be delayed for the next year.

Runoff, soil loss and infiltration comparison between conventional tillage and no-till areas was positively achieved for the first year of the project. In this sense, a forest site was also used for comparison.

Activities for the first year of the project were very intensive. Adoption of techniques, installation, and the beginning of the measurements were the main tasks achieved. The development of these activities involved 25 trips to the areas of study, from October 1999 to April 2000. A summary of the main activities carried out is following.

Hydrological and Sediment Transport Modeling

A sub-watershed was selected in order to get data for the validation of a hydrologic and a sediment transport model. The sub-watershed land is owned by Mr. Gary Houser and involves approximately 183 hectares. Most of the sub-watershed is covered by wheat on fields with no-tillage as usual cropping practice. The sub-watershed drains to a main channel, which showed very small flow rates during the season and did not react at all when storms were happening.

Discharge of water in the main channel, sediments being transported and precipitation intensity were the main variables needed for the hydrologic and sediment transport model. In order to achieve those measurements, installation of some devices was required. An ultrasonic flow sensor was installed into a culvert through which water discharge passed by. The sensor was calibrated to measure the depth of flow, so the volumes may be determined through a Manning equation. As the objective of the models is to predict how the sub-watershed behaves with precipitation input, the important measurements were those implying flows over the basal volumes of water and peak flows. Sensor determinations were stored in a data-logger. Those determinations are continuous from January 2000. The lack of rainfall storm events of the last season and the standing stubble no-till condition of most of the area derived in the fact that the sub-watershed did not react to the precipitation input. The water discharges of the main channel barely were higher than the amounts the sensor could effectively detect. It is expected to have better conditions for next year so data can be collected. However, some modifications focused to determine variations of low flows will be achieved.

The low flows that happened last season and the conditions of the sub-watershed also determined very low transport of sediment in the main channel. Therefore, no data of sediment transport related to the hydrologic responses of the sub-watershed was collected.

Precipitation intensity data has been continuously collected from January 2000. A recording rain gage was installed in a Mr. Rouser's field, in the same sub-watershed and next to the main channel in which the flow sensor was placed. Recording chart is changed every week.

Runoff, Soil Loss and Infiltration Comparison

Seven fields around the city of Pomeroy were selected to the runoff, soil loss and infiltration comparison. Three of these fields were wheat seeded with conventional tillage practice. Three fields were wheat seeded with no-tillage practice and the remnant field was a forest. All the areas selected, with the exception of the forest site had slopes between six and eleven percent. The forest site had a slope of about fifteen percent. Fields were chosen in the way that comparison between conventional till and no-till systems could be done in areas with similar precipitation amounts.

WDOE

The WDOE is currently working in the area to setup a Total Maximum Daily Load (TMDL) baseline for many streams in the state.

Deadman Creek

The projects outlined in detail in Table 47-Table 56 are taken from full yearly reports on all the projects implemented in the Deadman Creek Watershed. The practices were funded outside BPA (Table 57). These practices are the main focus of the overall conservation plan to reduce the majority of the sediment entering the stream and to correct any migration problems into the watershed.

Table 47. Practices Implemented in Deadman Watershed in 1996 (Pomeroy Conservation District Jan. 2001) Includes Deadman Creek, Meadow Creek, New York Gulch, Lynn Gulch, and small tributaries of Snake River

Practice	Units	Tons Saved
Deep Fall Subsoiling	160 acres	800 tons
No-till Seeding	1,197 acres	11,319 tons
Sediment Basins	8,913 cubic yards	559 tons
Grass in Rotation	77 acres	980 tons
Grassed Waterways	15,526 feet	589 tons
Terraces	109,970 feet	17,364 tons
	Total tons saved	31,611 tons

Table 47. Practices Implemented in Deadman Watershed in 1997 (Pomeroy Conservation District Jan. 2001) Includes Deadman Creek, Meadow Creek, New York Gulch, Lynn Gulch, and small tributaries of the Snake River

Practice	Units	Tons Saved
Deep Fall Subsoiling	2,407 acres	10,499 tons
No-till Seeding	651 acres	3,642 tons
Sediment Basins	2,409 cubic yards	46 tons
Grassed Waterways	11,764 feet	458 tons
Strip Cropping	551 acres	3,428 tons
Terraces	34,498 feet	4,355 tons
	Total tons saved	22,428 tons

Table 48. Practices Implemented in Deadman Watershed in 1998 (Pomeroy Conservation District Jan. 2001) Includes Deadman Creek, Meadow Creek, New York Gulch, Lynn Gulch, and small tributaries of the Snake River

Practice	Units	Tons Saved
Deep Fall Subsoiling	3,888 acres	16,806 tons
No-till Seeding	977 acres	6,421 tons
2 pass seeding	1,116 acres	7,919 tons
Sediment Basins	27,010 cubic yards	1,867 tons
Grass in Rotation	25 acres	125 tons
Grassed Waterways	4,912 feet	254 tons
Strip cropping	582 acres	3,634 tons
Terraces	35,489 feet	1,651 tons
	Total tons saved	42,117 tons

Table 49. Practices Implemented in Deadman Watershed in 1999 (Pomeroy Conservation District Jan. 2001) Includes Deadman Creek, Meadow Creek, New York Gulch, Lynn Gulch, and small tributaries of the Snake River

Practice	Units	Tons Saved
Deep Fall Subsoiling	501 acres	501 tons
No-till Seeding	2,595 acres	11,989 tons
2 pass seeding	2,548 acres	7,936 tons
Sediment Basins	7,085 cubic yards	1,155 tons
Grassed Waterways	15,526 feet	589 tons
Pasture Planting	94 acres	659 tons
Strip Cropping	420 acres	2,323 tons
Terraces	18,699 feet	1,304 tons
	Total tons saved	26,068 tons

Table 50. Practices Implemented in Deadman Watershed in 2000 (Pomeroy Conservation District Jan. 2001) Includes Deadman Creek, Meadow Creek, New York Gulch, Lynn Gulch, and small tributaries of the Snake River

Practice	Units	Tons Saved
No-till Seeding	2,651 acres	14,181 tons
2 pass seeding	808 acres	3,354 tons
Sediment Basins	25,092 cubic yards	264 tons
Grass in Rotation	78 acres	544 tons
Grassed Waterways	7,012 feet	329 tons
Pasture Planting	79 acres	713 tons
Terraces	11,525 feet	100 tons
	Total tons saved	19,484 tons

Table 51. Practices Implemented in Alpowa Watershed in 1996 (Pomeroy Conservation District Jan. 2001)

Practice	Units	Tons Saved
No-till Seeding	333 acres	6,714 tons
Sediment Basins	3,808 cubic yards	521 tons
Grassed Waterways	10,825 feet	634 tons
Terraces	9,967 feet	1,260 tons
	Total tons saved	9,129 tons

Table 52. Practices Implemented in Alpowa Watershed in 1997 (Pomeroy Conservation District Jan. 2001)

Practice	Units	Tons Saved
No-till Seeding	183 acres	1,097 tons
Sediment Basins	41,803 cubic yards	2,207 tons
Upland Fencing	3,218 feet	500 tons
Terraces	34,281 feet	6,300 tons
	Total tons saved	10,753 tons

Table 53. Practices Implemented in Alpowa Watershed in 1998 (Pomeroy Conservation District Jan. 2001)

Practice	Units	Tons Saved
Deep Fall Subsoiling	244 acres	732 tons
No-till Seeding	494 acres	1,470 tons
Pasture Planting	56 acres	507 tons
Strip cropping	124 acres	248 tons
Terraces	10,277 feet	800 tons
	Total tons saved	5,551 tons

Table 54. Practices Implemented in Alpowa Watershed in 1999 (Pomeroy Conservation District Jan. 2001)

Practice	Units	Tons Saved
Deep Fall Subsoiling	205 acres	410 tons
No-till Seeding	455 acres	2,950 tons
2 pass seeding	461 acres	2,343 tons
Sediment Basin	566 cu. Yards	14 tons
Terraces	3,728 feet	174 tons
	Total tons saved	5,891 tons

Table 56. Practices Implemented in Alpowa Watershed in 2000 (Pomeroy Conservation District Jan. 2001)

Practice	Units	Tons Saved
No-till Seeding	182 acres	1,274 tons
Stream bank Projection	150 feet	48 tons
Terraces	1,650 feet	80 tons
Fish barrier removal	1 each	NA
	Total tons saved	1,402 tons

Table 57. Sources of Funding by Source and Year in Deadman Creek, Alpowa, Meadow Creek, New Work Gulch, and other small tributaries draining into the Snake River..

Source	1996	1997	1998	1999	2000
Conservation Commission Grant #95-47-IM	$ $43,053	$ $36,972			
Conservation Commission Grant #97-47-IM		$35,801	$44,199	$1,949	
Conservation Commission Grant #99-47-IM				$67,201	$9,778
Block Grant HB2496			$62,174	$34,057	
Salmon Recovery Funding Board					$67,730

The upland projects completed over the last five years are practices that reduce erosion from the cropland. No-till and Direct Seed farming's direct impact on soil erosion along with the economical aspects are being studied. Other practices such as terrace, waterway, sediment basin construction and the installation of strip systems is also taking place.

The past five years have been very productive for the Deadman Creek Watershed. All the upland practices that were implemented have helped to reduce erosion from the cropland. This has resulted in a reduction of sedimentation into the Deadman Creek and Snake River.

Wildlife

WDFW

1. Eastern Washington Mule Deer Study
2. The State of Washington issues harvest regulations annually for the general public for this subbasin (WDFW, 1998, 1999).
3. WDFW annual aerial and /or ground population surveys for mule deer and elk
4. Post Season Deer Count
5. Pre season Deer count for herd composition
6. Big Game Surveys (elk, winter deer)
7. Upland Game Bird Brood Counts
8. Waterfowl Pair and Brood Counts
9. Eagle Nest Surveys

Existing Plans, Policies, and Guidelines

Army Corps of Engineers

The COE is responsible for operating the lower Snake River dams and funding evaluation and mitigation for those dams and reservoirs. Table 57 provides a description of the wildlife mitigation sites idenified in Figure 18.

Figure 18. Location of the Wildlife Mitigation Lands for the Lower Snake River Dams

Table 57. Description of wildlife mitigation sites.

SITE HMU -Habitat Management Unit	**LOCATION**	**ACRES**
1. Mill Creek - FWWTR HMU	2 Miles East of Walla Walla, WA off Highway 12	611.5
2. Wallula HMU	12 Miles SE of Pasco, WA off Highway 12	1719
3. Big Flat HMU	16 Miles NE of Pasco, WA off Highway 124	832
4. Lost Island HMU	18 Miles NE of Pasco, WA off Highway 124	162
5. Hollebeke HMU	20 Miles NE of Pasco, WA off Highway 124	247
6. Skookum HMU	40 Miles NE of Pasco, WA off Highway 124	764
7. Fifty-Five Mile HMU	52 Miles NE of Pasco, WA off Highway 124	271
8. John Henley HMU	26 Miles N. of Dayton, WA off Highway 261	718
9. Ridpath HMU	28 Miles NE of Dayton, WA off Highway 261	64
10. New York Bar HMU	24 Miles NW of Pomeroy, WA off Highway 127	210
11. Central Ferry HMU	22 Miles NW of Pomeroy, WA off Highway 127	288
12. Willow Bar HMU	26 Miles NW of Clarkston, WA off Highway 127	191
13. Swift Bar HMU	24 Miles NE of Pomeroy, WA off Highway 127	344
14. Nisqually John HMU	14 Miles NW of Clarkston, WA off Highway 193	3070
15. Kelly Bar HMU	10 Miles NW of Clarkston, WA off Highway 12	368
16. Chief Timothy HMU	6 Miles W of Clarkston, WA off Highway 12	66
17. Asotin Creek	3 Miles W of Asotin, WA off Highway 129	13
18. Campbell Creek	4 Miles SW of Asotin, WA off Highway 129	529
19. Pintler Creek Unit	4 Miles SW of Asotin, WA off Highway 129	4261
20. Fisher Gulch Unit	5 Miles SE of Anatone, WA off Highway 129	1647
21. Shumaker Unit	4 Miles S. of Anatone, WA off Highway 129	2033
22. Hartsock Unit	16 Miles SE of Pomeroy, WA off Highway 126	2342
23. Windmill Ranch Unit	3 Miles NW of Mead, WA off Highway 17	1534
24. Bailie Ranch Unit	8 Miles NW of Mead, WA off Highway 17	3897
25. Revere Ranch Unit	12 Miles N of LaCrosse, WA off Highway 23	2291

SITE HMU -Habitat Management Unit	**LOCATION**	**ACRES**
26. 8 Mile Touchet River (Public Fishing Area	10 Miles NW of Walla Walla, WA off Highway 12	2.0
27. Swegle (Public Fishing Area)	4 Miles SW of Walla Walla, WA off Highway 12	114.80
28. McDonald Bridge (Public Fishing Area)	1.5 Miles E. of Lowden, WA off Highway 12	22.60
29. Couse Creek (Public Fishing Area)	12.3 Miles upstream of Asotin, WA on Snake River Road	3.0
30. Precious Lands Project	40 Miles N of Enterprise, OR off Highway 3	15,325

Natural Resources Conservation Service

The NRCS is obligated to assist Conservation Districts in the implementation of the District's short and long-term goals and objectives. All practices implemented by conservation districts meet NRCS standards and specifications.

The NRCS provides technical support to landowners and assists with funding projects designed to reduce soil erosion and provide streambank protection. The U.S. EPA is responsible for implementing the Clean Water Act, including ensuring that Total Maximum Daily Load (TMDL) plans are developed and implemented.

Fish and Wildlife Service

The USFWS budgets for and administers the operation, maintenance, and evaluation of the LSRCP spring and fall chinook, steelhead, and rainbow trout programs in the Snake River subbasin. The LSRCP was authorized by the Water Resources Development Act of 1976, Public Law 94-587, to offset losses caused by the four Lower Snake River dam and navigation lock projects (Corps 1975). The WDFW operates the LSRCP facilities (Lyons Ferry Hatchery) in the Tucannon River Basin and they are co-managers along with the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the NPT.

The USFWS also has permitting and oversight responsibilities to protect and enhance bull trout and other federally listed fish or wildlife within the subbasin under the Endangered Species Act (ESA).

USFWS assists Conservation Districts in meeting their goals for not causing any negative affect on listed species. The USFWS provides funding for habitat restoration projects and is the lead agency for administering the NSRP. The NSRP also has provisions for improving habitat and other measures to benefit native fish.

Columbia Fish & Wildlife Authority

The Columbia River Fish Management Plan (CRFMP) is an agreement among the tribal, state and federal parties with jurisdiction over Pacific salmon originating in the Columbia Basin that provides procedures whereby the parties co-manage anadromous fish harvest, production and habitat (Columbia River Inter-Tribal Fish Commission, CRITFC 1995). The CRFMP stems from the treaty fishing rights lawsuit, U.S. v Oregon. Although the CRFMP expired in 1999, the co-managers are working on developing another plan. The interim, short-term agreements on managing the fisheries have been entered into prior to execution of the specific fishery (spring or fall). The CRFMP, and further agreement, have all emphasized the importance of artificial propagation actions to accomplish the goals of rebuilding natural runs. Agreements struck in U.S. v Oregon forum often determine the number, purpose and location of fish released from various hatcheries. Management actions for the Tucannon artificial propagation program are often included in U.S. v Oregon agreements.

Tribal Government

A portion of the Snake River within this subbasin is within the lands ceded to the United States in the Treaty of 1855 by the Nez Perce, Confederated Tribes of the Umatilla (CTUIR) and the Yakama Tribe. The tribes reserved certain treaty fishing rights on these ceded lands as well as other usual and accustomed areas. They also retained the right to hunt and gather roots and berries on open and unclaimed land. Commensurate with the rights to hunt, fish and gather roots and berries, the tribes are responsible for protecting and enhancing these treaty resources and habitats for present and future generations. The tribes co-manage fish and wildlife with WDFW, specifically participating on review and implementation of the hatchery production activities in the subbasin.

The Wy-Kan-Ush-Mi Wa-Kish Wit: Spirit of the Salmon (CRITFC 1995)

CRITFC makes institutional and technical recommendations for the Columbia Basin and presents a subbasin plan calling for a number of administrative, instream flow and passage, watershed management and artificial production actions for the subbasin.

Washington Department of Fish & Wildlife

The WDFW is responsible for preserving, protecting, and perpetuating populations of fish and wildlife. Washington State laws, policies or guidance that WDFW uses to carry out its responsibilities include:

Hydraulic Code (RCW 75.20.100-160): This law requires that any person, organization, or government agency that conducts any construction activity in or near state waters must comply with the terms of a Hydraulic Project Approval permit issued by WDFW. State waters include all marine waters and fresh waters. The law’s purpose is to ensure that needed construction is done in a manner that prevents damage to the state’s fish, shellfish, and their associated habitat(s).

Strategy to Recover Salmon (part of *Extinction is not an Option*): The strategy is intended to be a guide, and it articulates the mission, goals, and objectives for salmon recovery. The goal is to restore salmon, steelhead, and trout populations to healthy harvestable levels and improve those habitats on which the fish rely. The early action plan identifies specific activities related to salmon recovery that state agencies will undertake in the 1999-2001 biennium and forms the first chapter in a long-term implementation plan currently under development. The early actions are driven by the goals and objectives of the Strategy.

Many of the expected outcomes from the early actions will directly benefit regional and local recovery efforts.

The *Bull Trout and Dolly Varden Management Plan*: Describes the goal, objectives and strategies to restore and maintain the health and diversity of self-sustaining bull trout and Dolly Varden stock and their habitats.

The *Wild Salmonid Policy for Washington* describes the direction the WDFW will take to protect and enhance native salmonid fish. The document includes proposed changes in hatchery management, general fish management, habitat management and regulation/enforcement.

The *Draft Steelhead Management Plan* describes the goals, objectives, policies and guidelines to be used to manage the steelhead resource.

The *Washington Priority Habitats and Species (PHS)* is a guide to management of fish and wildlife "critical areas" habitat on all State and private lands as they relate to the Growth Management Act of 1990. The recommendations address upland as well as riparian habitat and place emphasis on managing for the most critical species and its habitat.

The *Draft Snake River Wild Steelhead Recovery Plan* is an assessment of problems associated with the continuing decline in natural steelhead populations within the Snake River basin and includes recommendations to reverse the decline. The WDFW manages fisheries and fish populations to provide diverse recreational opportunity and conserve or enhance indigenous populations.

The *Lower Snake River Compensation Plan*: is funded by BPA and the USFWS through the LSRCP office, and the WDFW administers and implements the Washington portion of the program. The program mitigates for the loss of fish populations and recreational opportunities resulting from construction of the four lower Snake River dams. Specific mitigation goals include “in-place” and “in-kind” replacement of adult salmon and steelhead.

The WDFW *Fishery Management and Evaluation Plan* (FMEP): is required by NMFS for all fisheries in the Snake River and its tributaries in Washington. The plan is an assessment of fisheries effects on listed anadromous salmonids.

Enforcement measures to insure compliance with state fish passage and surface water diversion screening laws will be implemented consistent with multiple existing salmon recovery plans to ensure adequate steps are taken to provide greater protection to listed species.

Washington State Department of Natural Resources (WDNR)

The WDNR manages state land throughout the subbasin. These lands are generally located in sections 16 and 36 within each township. The main goal of the WDNR is to maximize monetary returns from state lands in order to fund school construction. This type of management often reduces the habitat value for wildlife on WDNR lands. The WDNR also enforces and monitors logging practices on private lands.

Washington Department of Ecology

The WDOE is charged with managing water resources to ensure that the waters of the state are protected and used for the greatest benefit. The WDOE allocates and regulates water use within the subbasin. Permits are required to divert surface water and ground water withdrawals in excess of 5,000 gallons per day. The WDOE also acts as trustee for instream trust water rights issued to the State of Washington and held in trust.

The WDOE regulates surface and ground water quality within the subbasin. The 1972 Federal Clean Water Act authorizes and requires states to establish water quality standards for specific pollutants. Every two years, the WDOE is required to list in Section 303(d) of the Clean Water Act those water bodies that do not meet surface water quality standards. The WDOE utilizes data collected by agency staff as well as data from tribal, state, local governments, and industries to determine whether or not a waterbody is listed on the 303(d) list. Total Maximum Daily Loads must be completed for every parameter that exceeds state water quality standards on listed water bodies.

The WDOE proposes several changes to surface water quality standards and the classification system. The revised standards must be applied so that they support the same uses covered under the current classification structure. Changes to the surface water quality standards will affect many programs, including monitoring, permits, TMDLs and the 303(d) list.

Garfield County Commission

The Garfield County Board of Commissioners has no known management program pertaining to fish and wildlife in Garfield County. The County works with the PCD, WDFW, and NRCS in meeting existing policies and guidelines.

Columbia County Commission

Columbia County Commissioners have adopted a county comprehensive management plan developed through the Growth Management Act (GMA) process. Columbia County ordinance #93-07 as amended and adopted January 18, 1994 and the Columbia County Shoreline Master Program, June 1975 and have a “draft” comprehensive flood hazard management plan, December 2000. Columbia County Commissioners have also designated Columbia Conservation District as the lead entity for watershed planning and implementation.

The Columbia Pomery Conservation Districts

The Districts are the counties’ designated lead agency for watershed planning and implementation. The Districts are responsible for the implementation and management of the Washington State Salmon Recovery Act within their respective counties.

The Columbia County Weed Board

The weed board conducts a cost share program with public and private landowners to control infestations of Washington State Class-A weeds. The program includes biological, chemical, and mechanical/hand control strategies. The weed board would like to expand cost share programs for more landowner involvement in rangeland and riparian protection and enhancement, as well as, restoration demonstration projects.

Lower Snake River Compensation Plan

The Lower Snake River Project was authorized by Congress on March 2, 1945 by Public Law 14, 79th Congress, First Session. The project was authorized under the Rivers and Harbors Act of 1945. It consists of Ice Harbor Dam, completed in 1962; Lower Monumental Dam, 1969; Little Goose Dam, 1970 and Lower Granite Dam, 1975. The project affected over 140 miles of the Snake River and tributaries from Pasco, Washington to upstream of Lewiston, Idaho. The authorized purposes of the project were primarily navigation and hydroelectric power production.

The Fish and Wildlife Coordination Act of 1958 (48 Stat. 401, 16 U.S.C. 661 et seq. as amended) requires an analysis of fish and wildlife impacts associated with federal water projects as well as compensation measures to avoid and/or mitigate for loss of or damage to wildlife resources (refer to Section 662 (b) of the Act). The original authorizing legislation for the project made no mention of fish and wildlife measures needed to avoid or otherwise compensate for the losses or damage to these important resources. Therefore, in order to be in compliance with the Coordination Act the U.S. Army Corps of Engineers (Corps) in 1975 wrote a report introducing t The first two items are commonly referred to as Land Acquisition Elements X (8,400 acres for upland bird hunting) and Y (15,000 acres for Chukar Partridge Hunting access). Wildlife mitigation measures in Idaho were not included in the Lower Snake River Fish and Wildlife Compensation Plan (LSRCP). Congress authorized the LSRCP as part of the Water Resources Development Act of 1976 (Public Law 94-587).

The wildlife compensation features of the original LSRCP included the following:

Acquisition of approximately 400 acres of riparian habitat in fee and 8,000 acres of farmland in perpetual easement surrounding these riparian lands to provide partial compensation for project-caused upland game bird hunting losses and additional hunting opportunity as a substitute for nongame species.

Acquisition of approximately 15,000 acres of land in perpetual easement to provide hunter access as partial compensation for project-caused losses to chukar partridge.

The Corps would enter into an agreement with the Washington Department of Game to provide 20,000 game birds per year for 20 years to stock project and acquired off project lands for compensation of lost hunter-day use and lost animals caused by the project construction.

There have been several changes made to the wildlife features of the original Plan since 1975. Development of wildlife habitat on project lands land surrounding the project reservoirs administered by the Corps received little emphasis in the LSRCP. However, subsequent studies identified habitat development potential on project lands and the LSRCP was amended to include development of selected areas.

In 1979 fifty-four management units were classified as wildlife lands. Ten Habitat Management Units (HMIJs) would be intensively developed (irrigation systems and plantings), 25 units moderately developed (dryland development with guzzlers, fencing, etc.) and the remaining 19 units were to remain undeveloped except for fencing (Corps 1979). A total of 4,254 acres of project land were identified for wildlife management purposes. Subsequently, the Corps entered into an agreement with WDFW to develop and maintain the identified wildlife management lands.

In 1983 the Corps was required to report to Congress on the status of the LSRCP and make recommendations of additional measures needed to complete compensation. It was recommended that LSRCP be changed to allow land acquisition by fee title or easement (prior to this change only 400 acres of riparian habitat was allowed to be purchased in fee title). In addition, it was recommended that the game bird production strategy using farm raised birds be redirected to developing a program of habitat development with private landowners (referred to as Game Farm Alternative). This latter change to the LSRCP was further refined in 1986 with a request to pay WDFW $2,125,000 to provide game birds by the alternative method of enlisting private landowners in southeastern Washington, by appropriate lease or other agreement, to provide and establish on their lands, upland gamebird habitats with public hunting". This program was funded ($2,571,512) in April of 1989 to be implemented for an 18-year period with WDFW crediting the Corps two years for game bird stocking conducted on project lands. These changes were authorized through the Water Resources Development Act of 1986 (P.L. 99-662).

Corps management actions to implement the LSRCP include the following:

Approximately 1,000 acres of land on 9 of the HMIJ s has been intensively developed using irrigation. This effort was started by the Corps and WDFW in 1980 and the maintenance of these areas was later contracted to a private company in 1987. Maintenance of these lands continues today. The LSRCP also included Land Acquisition Element Z which involved 700 acres in Washington and 50 acres in Idaho for fisherman access. To date, 64 acres have been acquired in Washington and 22 acres in Idaho. These features are being handled under other programs and will not be discussed further.

In 1986 a perpetual hunting easement was acquired on 3,986 acres of the Bailie Memorial Youth Ranch and portions were subsequently developed by WDFW for wildlife habitat through funding by the Corps (Element X).

In 1989 the Corps was authorized to pay WDFW a lump sum of $2,571,512 to initiate the Game Farm Alternative Program. The WDFW is currently implementing the program.

Wildlife compensation efforts in Idaho have been addressed separately. In 1978 Pengelly and McClelland reviewed mitigation needs in Idaho and provided recommendations. They recommended that a portion of Hells Gate State Park be managed for wildlife. A management plan was subsequently written and a Memorandum of Agreement signed between the Corps, IDFG, and Idaho Department of Parks and Recreation in 1983. The MOA created the Hells Gate HMU which it was agreed would be developed and maintained by the Corps in a similar manner to the HMTJ s in Washington. The Corps agreed to develop the HMU within 5 years following the lease amendment, dependent on sufficient funds. IDFG agreed that no further wildlife mitigation would be requested if Hells Gate HMU was developed according to the management plan (WDFW 1984). The Corps prepared specifications and design for an irrigation system in 1987 (Corps of Engineers 1987) and is currently awaiting funding to implement a development plan (C. Christensen, COE, pers. commun.). In addition to habitat development at Hells Gate, the Corps agreed to develop and maintain two goose pastures along the north bank of the Clear Water River.

Compensation Objectives and the 1989 Letter of Agreement (LOA)

The Plan establishes specific mechanisms (e.g. land acquisitions, project land development) whereby wildlife compensation objectives can be achieved. Compensation was defined as "... the maintenance of habitat and production of game animals which will sustain the hunting pressure, (and) appreciative use which would have occurred if the projects had not been constructed, and the maintenance of nongame animals at pre-project levels" (COE 1975a:8l). Since project-related wildlife losses were described in terms of animal numbers (COE 1975a) subsequent efforts to evaluate compensation progress were also measured in these terms (Mudd et. al. 1980). However, problems with this evaluation surfaced due to general disagreement between agencies as to the accuracy of the original loss estimates and differences in the size of the study areas to be used (Lutz, unpublished report).

During this period wildlife mitigation planning efforts throughout the country were beginning to shift from an animal number replacement basis to a habitat replacement emphasis. Two important reasons for this shift included (1) animal populations fluctuate seasonally and annually with several years of data necessary to establish baseline as well as population levels in subsequent years and (2) compensatory influences on animal populations not related to project-caused effects can significantly affect any measure of mitigation or compensation progress. Examples of this latter problem are harvest management regulations that influence population structure and numbers in the vicinity of a project area and land use changes that influence animal distribution in the general vicinity of the project area.

Recognizing the problem of using animal numbers to establish compensation goals and as a measure of compensation progress, the Corps and the Service began discussions in 1986 on defining compensation in terms of habitat. These discussions resulted in a Letter of Agreement (LOA) between the three agencies, which was signed in 1989. This LOA outlines the procedures whereby compensation is to be defined and measured on a habitat basis.

The LOA Has Four Purposes:

1. Determine the procedure for establishing measurable habitat-based compensation objectives.

2. Establish the criteria to be employed in a REP analysis for measuring progress toward compensation objectives from habitat development and/or land acquisition.

3. Establish the general procedure for crediting mitigation activities undertaken by the Corps towards compensation.

4. Implement modifications to the LSRCP resulting from PL 99-662.
   a) Authority to purchase all off-project lands in fee title and manage them in their entirety for wildlife purposes.
   b) Substitution of the Game Bird Farm Alternative Program (CFA) in lieu of game bird stocking. WDFW was paid a lump sum in 1989 to enter into lease agreements with southeast Washington landowners to establish and protect game bird type habitats and open their lands to public access. The program duration is 18 years.

Criteria

A modified HEP will be used in the implementation of the Plan.

Signatories agree to work as a HEP team to establish compensation objectives, coordinate mitigation recommendations, and evaluate mitigation actions.

Objectives for wildlife compensation under the LSRCP will be based on Habitat Units (HU s) derived from the HEP described in this report. HU s derived from the pre-project condition (based on 1958 aerial photography) will constitute the compensation objectives for the LSRCP. Compensation progress to date for on-project lands will similarly be determined using 1987 aerial photography.

Compensation will be met through present and future on-project habitat developments, acquisition of off-project lands and subsequent development, or riparian/wetland habitat protection.

Future expected HU s gained through development activities will be fully credited to the LSRCP immediately following the completion of habitat development. The signatories agree to focus acquisition on lands having minimal existing HU s, but good potential for habitat development. Off-project acquisitions will receive credit toward compensation for 50% of their existing HU s for evaluation species. If high quality riparian/wetland habitat on a given acquisition is potentially threatened by land use changes or practices, 100% of the existing HU s for evaluation species associated with riparian/wetland habitats will be credited toward compensation. This is a departure from standard mitigation policy for both WDFW and USF&WS and applies only to this agreement.

Each potential acquisition and/or habitat management action will be evaluated based on a cost/benefit comparison using potential HU s derived from the proposed action.

Habitat development progress will be monitored on each parcel to determine the HU s achieved to help guide future efforts.

"Interim" compensation will be fully satisfied through the implementation of the GFA program and through the perpetual easement purchase and development of the Bailie Memorial Youth Ranch. The RU s resulting from habitat developments on the Bailie Ranch will be credited toward compensation under the LSRCP.

Wildlife compensation measures implemented through the Plan will be accomplished within presently authorized acreage and cost levels.

A General Plan for the Lower Snake River Project will be prepared following completion of the HEP analysis.

Objectives

The objectives of this evaluation are to:

1. Quantify and describe wildlife habitat conditions prior to project construction.

2. Quantify and describe current wildlife habitat conditions.

3. Evaluate wildlife habitat contribution of the HMU s to current project conditions.

4. Define compensation goals in terms of habitat for the Lower Snake River Project.

This evaluation does not discuss wildlife compensation efforts in Idaho since they were addressed in separate negotiations from the LSRCP. The IDFG negotiated for about 50 acres of fishermen's access of which they obtained about 34 acres. It has been agreed between the USACOE and the IDFG to enhance several hundred acres of land surrounding Hells Gate State Park in Lewiston.

A total of 28,354.9 acres has been acquired by the USACOE to mitigate wildlife impacts under the LSRCP authorizations. A total of 21,140.9 acres were purchased out side of the Lower Snake River canyon as off site mitigation. The LSRCP originally called for 24,150 acres fishing access, riparian habitat w/ surrounding upland and upland chukar habitat. After the acreage goals were established, 750 acres of fishing access, 8400 acres of riparian and associated upland, and 15,000 acres of upland chukar habitat, the ACOE, USFWS, and WDFW proceeded to perform a HEP on all the land acquired under the LSRCP. It was found that the purchases made by the ACOE fell short of full mitigation using the HEP method of evaluation. The NPT requested the HU's short of full mitigation be amended into the Northwest Power Planning Council’s (NWPPC or Council) Program and be mitigated for under the Council’s Program. Once amended into the program the NPT entered into a contract with BPA to provide between 5,000 and 10,000 HUs as replacement for losses caused by the inundation of lands by the development of hydropower. The Tribe was eventually authorized to acquire up to 16,500 acres of land in NE Oregon and SE Washington.

Existing Goals, Objectives, and Strategies

Fish

Pacific Northwest Laboratory (PNL)

Goals

Protect, enhance, and restore anadromous and resident fish populations in the subbasin to viable levels that ensures they are not vulnerable to extinction, and to provide ecological, cultural, and sociological benefits.

Objective 1. Restore riverine ecosystem processes to key sections of the Lower Snake River.

Strategy Implement a research program to test hypotheses of restoring riverine ecosystem processes under current and future hydrosystem operational scenarios.

Objective 2. Increase the natural production of fall chinook salmon spawning in the Lower Snake River.

Strategy Determine carrying capacity of the Lower Snake River for producing fall chinook salmon under current and future hydrosystem operational scenarios.

Objective 3. Estimate the amount of Pacific lamprey spawning and rearing that occurs in the Lower Snake River, especially the tailraces of mainstem dams.

Strategy Implement a research program designed to evaluate the importance of mainstem habitats on the spawning and rearing of Pacific lampreys.

Objective 4. Restore abundance of white sturgeon populations throughout the Lower Snake River reservoirs.

Strategy Estimate potential levels of natural production under present conditions, the amount of additional natural production that could be achieved with modifications to flow and other environmental conditions, and additional increases, which could be, sustained with propagation and transportation measures.

Pomeroy Conservation District

Goal

The overall goal is to provide for healthy, sustainable populations of fish and wildlife that will provide ecological, economic, cultural, recreational, and aesthetic benefits to Alpowa Creek, Deadman Creek, and other minor tributaries of the Lower Snake River.

Objective 1. Reduce sediment delivery.

Strategy 1. To reduce sedimentation of the stream channel, soil conservation measures hould be integrated into upland cultivation practices. The implementation of long term no-till seeding programs coupled with the use of annual cropping and alternate crops will reduce sediments in area streams. The 1981 survey of Alpowa Creek (Soil Conservation Service 1981) recommended the use of terraces or storage structures such as dams to retain and settle out sediments prior to upland water transporting to the stream. This practice is recommended in conjunction with those implementing crop residue management practices in areas of high erodibility.

Strategy 2. Improve riparian habitat through the re-establishment of a healthy riparian vegetative community. This would help stabilize streambanks presently eroding or prone to future erosion.

Objective 2. Maintain cool water temperatures

Strategy 1. To maintain cool water temperatures through the critical summer season, riparian vegetative cover must be restored adequately to provide sufficient shading of the stream channel. This is only possible by excluding cattle grazing in many riparian areas to encourage re-growth of woody riparian species and by actively planting native shrub and tree species in these livestock excluded riparian areas. Re-establishment of a healthy riparian vegetative community would also help stabilize streambanks presently eroding or prone to future erosion. In addition to the instream cover provided to fish by roots and branches, mature woody riparian vegetation is also a source of LWD, which helps form pools and habitat complexity.

Strategy 2. Embedded substrate is another limitation to both spawning and juvenile rearing habitat for salmonids in Alpowa Creek. Riparian vegetation not only provides stabilization to streambanks, but also functions as a filter or interceptor of sediments draining from upland areas.

Given the present degraded condition of riparian vegetation that formerly provided some shade to Alpowa Creek and diminished streamflow during the summer months, it is likely that natural springs originating in the upper watershed are responsible for the remaining salmonid use of the stream. These springs provide cool water during the warmest months and the lowest stream discharge. Without this spring influence in Alpowa, perhaps no salmonids would find the stream supportive.

Objective 3. Reduce sediment delivery into Deadman Creek and its tributaries

Strategy 1. To reduce sedimentation of the stream channel, soil conservation measures should be integrated into upland cultivation practices. The implementation of long term no-till seeding programs coupled with the use of annual cropping and alternate crops will reduce sediments into Deadman Creek. It has been recommended the use of more terraces or storage structures such as dams to retain and settle out sediments prior to upland water transporting to the stream. This practice is recommended in conjunction with those implementing crop residue management practices in areas of high erodibility.

Strategy 2. Improve riparian habitat through the re-establishment of a healthy riparian vegetative community. This would help stabilize streambanks presently eroding or prone to future erosion.

Objective 4. Maintain cool water temperatures

Strategy 1. To maintain cool water temperatures through the critical summer season, riparian vegetative cover must be restored adequately to provide sufficient shading of the stream channel. This is only possible by excluding cattle grazing in many riparian areas to encourage re-growth of woody riparian species, and by actively planting native shrub and tree species in these livestock excluded riparian areas. Re-establishment of a healthy riparian vegetative community would also help stabilize streambanks presently eroding or prone to future erosion. In addition to the instream cover provided to fish by roots and branches, mature woody riparian vegetation is also a source of LWD, which helps form pools and habitat complexity.

Strategy 2. Embedded substrate is another limitation to both spawning and juvenile rearing habitat for salmonids in Alpowa Creek. Riparian vegetation not only provides stabilization to streambanks, but also functions as a filter or interceptor of sediments draining from upland areas.

Given the present degraded condition of riparian vegetation that formerly provided some shade to Deadman Creek and diminished streamflow during the summer months, it is likely that natural springs originating in the upper watershed are responsible for the remaining salmonid use of the stream. These springs provide cool water during the warmest months and the lowest stream discharge. Without this spring influence in the Deadman Watershed, perhaps no salmonids would find the stream supportive.

WDFW

Goals for the lower Snake River (not in order of priority)

- Protect, restore, and enhance the abundance and distribution of wild summer steelhead, spring and fall chinook salmon, bull trout and other indigenous fish in the subbasin to provide non-consumptive fish benefits including cultural or ecological values.
- Maintain, enhance or restore sustainable fishery and harvest opportunities for anadromous and resident fish.
- Maintain or enhance genetic and other biological characteristics of naturally and hatchery produced anadromous and resident fish.

Objectives (not in order of priority)

- Increase native fall chinook salmon to sustainable and harvestable levels. Meet the NMFS recovery goal of at least 2,500 adults at Lower Granite Dam and the LSRCP goal to return an average of 18,300 hatchery produced fall chinook to the Snake River annually.
- Increase native summer steelhead abundance and distribution to sustainable and harvestable levels. Determine the wild fish escapement goal and needs for each tributary in this subbasin.
- Restore and maintain the health and diversity of bull trout, sturgeon and other resident indigenous fishes to sustainable and harvestable levels. Determine the spawning escapement goal and population needs of resident fish.
- Maintain LSRCP mitigation program and fisheries for summer steelhead and resident trout in the Washington portion of the subbasin. Meet the LSRCP mitigation goal to return an average of 3,056 hatchery adult steelhead to the Snake River and its tributaries in Washington annually for harvest.
- Maintain warmwater and other fisheries as appropriate without conflicting with indigenous fish needs (WDFW).

Strategies

1. Protect, enhance or restore the abundance and distribution of indigenous fish.

   Action 1.1. Evaluate or refine methods to establish recovery goals, escapement goals and desired future conditions or other goals. Refine methods for determining carrying capacities for salmonids in streams within the basin to establish biologically sound restoration and target goals.

   Action 1.2. Establish wild/natural fish goals for recovery, escapement, desired future condition, and harvest implementation plans.

   Action 1.3. Provide protection for federal and state threatened and sensitive fish species in resource management plans.

   Action 1.4. Enforce federal, state, tribal and local land use regulations to protect fish habitats.

   Action 1.5. Increase enforcement of laws and fishing regulations pertaining to illegal take of fish (all life stages).

2. Protect, enhance or restore water quality to improve the survival, abundance and distribution of anadromous and resident fish.
   - Action 2.1. Reduce stream temperatures by restoring or enhancing riparian vegetation, floodplain function and increasing hypothetic and instream flows.
   - Action 2.2. Increase water quality monitoring and enforcement of existing regulations to maintain or enhance water quality. Use the Clean Water Act, Section 401, and the Washington Fish and Forests regulations to protect and restore water quality and fish habitat.
   - Action 2.3. Complete the Total Maximum Daily Load (TMDL) process and implement measures to remove streams from 303d listings under the Clean Water Act and improve water quality.
   - Action 2.4. Support timely updates and resource inventories related to local land use plans to prevent further development and degradation of floodplains, wetlands, riparian buffers and other sensitive areas.
   - Action 2.5. Properly maintain, relocate or eliminate forest, public and private roads in riparian or other sensitive areas.
   - Action 2.6. Implement the Conservation Reserve Enhancement Program (CREP), Continuous Conservation Reserve Program (CCRP), Wetland Reserve Program and other pertinent federal, state, tribal and local programs along riparian and other sensitive areas.
   - Action 2.7. Monitor and evaluate efforts to improve water quality and use the data to assist in management decisions.
   - Action 2.8. Use existing programs to reduce sediment delivery to stream channels from roads, agriculture, logging, and other land use activities.

3. Protect, enhance and restore instream and riparian habitat to improve the survival, abundance and distribution of anadromous and resident fish.
   - Action 3.1. Enforce federal, state, tribal and local land use regulations to protect fish habitats.
   - Action 3.2. In the short term, plant native vegetation, construct pools and place woody debris in streams to increase channel complexity, and provide pools and cover for fish.
   - Action 3.3. Over the long term, modify land use to improve stream sinuosity, channel stability, width/depth ratio, pool frequency, size and quality, and large woody debris recruitment in the stream to provide benefits to fish habitat quantity and quality.
   - Action 3.4. Reduce sediment deposition in area streams by reducing erosion and sediment delivery to waterways.

Action 3.5. Improve watershed conditions to reduce high water events and reduce instream substrate scour, deposition or movement.

Acton 3.6. Improve floodplain function to improve stream channel stability, hypothetic flows and instream habitat diversity.

Action 3.7. Improve or eliminate stream fords and other substrate disturbances.

Action 3.8. Monitor and evaluate the quantity and quality of fish habitat in the basin to provide baseline information and to assess the success of management strategies.

Action 3.9. Monitor and evaluate efforts to protect, enhance and restore instream and riparian habitats and utilize the data to assist in management decisions.

Action 3.10. Identify, prioritize and protect critical habitat to improve production and survival of indigenous fish.

4. Protect, enhance and restore instream flows to improve passage conditions and increase rearing habitat for anadromous and resident fish.

Action 4.1. Evaluate the location and timing of dewatered or flow limited stream reaches and prioritize them for instream water flow restoration, and enhancement activities.

Action 4.2 Refine and/or determine flows needed for salmonid migration and rearing.

Action 4.3. Increase stream flows by improving the efficiency of irrigation systems and conversion of conserved water to instream flows.

Action 4.4. Increase stream flows by lease and/or purchase of water rights.

Action 4.5. Increase monitoring of water use and instream flows. Use collaborative efforts or enforcement of existing regulations and water rights to increase available instream water.

Action 4.6. Modify state water laws to allow water users to transfer water for instream use and to provide adequate protection downstream.

Action 4.7. Evaluate efforts to protect, enhance and restore instream flows

5. Restore or enhance upstream or downstream passage for resident and anadromous fish.

Action 5.1. Identify and evaluate passage or screening needs within the basin and prioritize implementation of restoration.

Action 5.2. Modify or remove culverts, bridges, grade controls and water diversion structures as necessary to improve passage.

Action 5.3. Implement screening of all diversions (pump and gravity) to meet State and NMFS criteria. Achieve compliance with state screening and passage laws.

Action 5.4. Operate and maintain all fish passage facilities to ensure proper function and efficient passage of fish.

Action 5.5. Monitor river conditions and operation of passage facilities to ensure adequate fish passage.

6. Use artificial production, as necessary, to maintain, restore or enhance indigenous fish populations and harvest opportunities.

   Action 6.1. Evaluate the need for further hatchery supplementation or augmentation for bull trout, steelhead, spring chinook, resident trout, etc. Complete the artificial production Master Plan or HGMP for the subbasin before increasing hatchery production. Implement artificial production plans (Master Plan or HGMP).

   Action 6.2. Continue existing LSRCP hatchery production and releases for fall chinook and steelhead to restore endemic populations and provide harvest opportunities.

   Action 6.3. Modify LSRCP production programs as needed to minimize their potential effects on wild salmonid populations and to address ESA concerns.

   Action 6.4. Operate traps to reduce stray hatchery fish spawning, to enumerate and sample returning fish, and to collect fall chinook for holding and spawning at existing hatchery facilities.

   Action 6.5. Continue hatchery production and releases of rainbow trout in area ponds and lakes to provide harvest and recreational fishing opportunities.

7. Implement artificial production practices that minimize adverse effects on fish habitat and maintains the viability and stock characteristics of hatchery fish.

   Action 7.1. Monitor hatchery facility discharges to ensure they are within NPDES permit requirements.

   Action 7.2. Use IHOT genetics guidelines for broodstock selection, mating and rearing.

   Action 7.3. Monitor the health and disease status of hatchery fish.

8. Monitor and evaluate hatchery programs to ensure they are successful and minimize adverse effects on listed or other indigenous species.

   Action 8.1. Continue to monitor and evaluate the performance of the LSRCP spring chinook supplementation program.

   Action 8.2. Continue to monitor and evaluate the LSRCP captive brood program for spring chinook salmon.

   Action 8.3. Continue to monitor and evaluate the performance of the LSRCP steelhead program.

   Action 8.4. Continue to monitor and evaluate the recreational and tribal fisheries in the basin and the contribution by hatchery programs.

Action 8.5. Conduct baseline genetic monitoring and evaluation of hatchery populations in the subbasin.

9. Maintain or enhance fishery and harvest opportunities for anadromous and resident salmonids.
    - Action 9.1. Maintain the congressionally mandated Lower Snake River Compensation Plan (LSRCP) harvest mitigation for steelhead, fall chinook salmon and resident trout in the subbasin.
    - Action 9.2. Continue hatchery production and releases of Lyons Ferry Hatchery steelhead to provide harvest and recreational fishing opportunities and meet mitigation goals.
    - Action 9.3. Modify LSRCP production programs as needed to minimize their potential effects on wild salmonid populations. Continue to manage steelhead sport fisheries to maximize recreational opportunity within the basin through consumptive and non-consumptive fisheries, while protecting wild populations through regulations and sanctuary area closures.
    - Action 9.4. Continue hatchery production and releases of rainbow trout in area ponds and lakes to provide harvest and recreational fishing opportunities to provide mitigation for lost fishing opportunities.
    - Action 9.5. Continue efforts to develop and phase into use of a local steelhead stock in the subbasin and Tucannon River that will allow harvest augmentation (mitigation) and supplementation, as well as minimize adverse effects on indigenous steelhead, chinook, bull trout and other resident fish.
    - Action 9.6. Monitor the hatchery program to ensure it is successful and that it has minimal effects on indigenous species.
    - Action 9.7. Monitor and assess the effects of fishing seasons on the survival of indigenous species.

10. Maintain warmwater or other fisheries as appropriate without conflicting with indigenous fish needs.
    - Action 10.1. Assess distribution, abundance and biological characteristics of non-indigenous fish within the basin.
    - Action 10.2. Evaluate non-indigenous fisheries.
    - Action 10.3. Develop a fishery management plan for non-indigenous fish.
    - Action 10.4. Monitor the fishery and adjust the plan, regulations, etc. as necessary.

11. Monitor and evaluate the productivity, abundance, distribution, and genetic and other biological characteristics of indigenous anadromous and resident fish to provide baseline data and to assess the success of management strategies.
    - Action 11.1. Conduct redd and carcass surveys in tributaries to monitor adult populations and to determine adult salmonid spawning escapements.
    - Action 11.2. Evaluate the need for additional trapping or counting facilities.
    - Action 11.3. Evaluate the need for monitoring juvenile anadromous fish production, migration timing and survival by operating a smolt trap in tributaries in the subbasin.
    - Action 11.4. Conduct biological surveys to monitor and evaluate juvenile anadromous and resident fish distribution, abundance, condition, habitat use, life history, etc..
    - Action 11.5. Continue baseline genetic and biological monitoring and evaluation of indigenous salmonid populations in the subbasin.
    - Action 11.7. Use radio telemetry to examine bull trout migration into, and within the Snake River, migration timing, passage efficiency at potential barriers, over-winter and other habitat use, and life history of bull trout.

12. Improve out-of-basin survival of migratory fish.
    - Action 12.1. Support efforts to improve passage and survival of migrant fish within the subbasin and in the Columbia River.
    - Action 12.2. Support research within the Columbia River basin to fully understand the role of native and introduced predators on indigenous fish.
    - Action 12.3. Conduct monitoring of migratory fish to determine survival rates, timing and distribution within the subbasin and in the Columbia River.

Wildlife

WDFW

Overall Goal

To protect, enhance, restore, maintain and/or increase PHS wildlife populations to viable or management objective levels for ecological, social, recreational, subsistence, and aesthetic purposes within the subbasin.

Goals

Goal 1. Establish a nesting population of peregrine falcons within the Lower Snake River corridor.

Objective Establish four nesting pairs over a five-year period.

Strategy 1. Survey the Lower Snake River corridor to determine if nesting peregrines exist.

Strategy 2. Hack two or more sites over three years to establish nesting peregrines.

Strategy 3. Survey the corridor annually for five years to document peregrines.

Goal 2. Increase the number of nesting pairs within the Lower Snake River corridor.

Objective Establish 10 nesting pairs within the Lower Snake River corridor over five years.

Strategy 1. Survey Lower Snake River corridor to document the number of nesting pairs.

Strategy 2. Establish nesting structures for osprey along the Lower Snake River.

Strategy 3. Monitor nesting structure use over a five-year period after installation.

Goal 3. Re-establish a viable sharp-tail grouse population within the subbasin.

Objective Establish six viable leks within the subbasin over five years

Strategy 1. Site evaluations for re-introductions, evaluation time six months

Strategy 2. Re-introduce sharptail grouse.

Strategy 3. Improve habitat quality of CRP lands to make suitable for sharptails, establish abundant legumes within CRP

Strategy 4. Use artificial leks to establish breeding sites

Goal 4. Increase the ground squirrel population.

Objective Establish six viable colonies; 15+ squirrels/colony over five years

Strategy 1. Inventory existing populations, inventory time six months

Strategy 2. Inventory suitable ground squirrel habitat, inventory time six months

Strategy 3. Easements for habitat

Strategy 4. Trap and transplant Washington ground squirrels into historical or existing habitat.

WDFW (1996)

Goal 5. Maintain a population of ferruginous hawks throughout much of the species' range in Washington.

Objective 1. Reach a population of at least 60 breeding pairs statewide averaged over 5 years.

Objective 2. Distribution of breeding pairs equal to or greater than 40 in the Central and ten in the North Recovery Zone.

Goal 6. To manage the elk herd for maximum recreational opportunity and sustained yield and reduce conflicts between agriculture and elk

Strategy 1. Manage all elk units for post-hunting season bull ratios consistent with the statewide plan (currently 15 bulls per 100 cows) in combination with overall bull mortality rates number 50 percent.

Strategy 2. Reduce damage complaints resulting from elk.

Strategy 3. Ensure a healthy elk population that is relatively disease free.

Strategy 4. Increase public awareness of the elk resource and promote non-consumptive values of elk.

Strategy 5. Enhance elk habitat on other state, federal and private land

NPT

Overall goal

To protect, enhance, restore and maintain all wildlife species and their associated habitats. Maintain maximum species and habitat diversity in a healthy and environmentally balanced way. Support the establishment of native habitats and wildlife species back into their historic range.

Goal 1. Secure long term operation and maintenance funding support for the Precious Land to ensure the Nez Perce Tribe will be able to sustain the flow of wildlife mitigation benefits from the property as is called for in the current contract between BPA and the Nez Perce Tribe. Hopefully through the use of a trust fund, managed much like an endowment fund whose balance will grow over time to provide additional revenue ion the future.

Goals 2. Coordinate and cooperate on wildlife projects on Federal lands within the NPT Ceded area within the Lower Snake sub-basin.

Goal 3. Coordinate and cooperate where possible, with wildlife management agencies to protect the wildlife resources available to the NPT and protect access to such resources.

Goal 4. Re-establish native habitats and their native fauna wherever possible paying close attention to culturally relevant subsistence plants in the mix.

Goal 5. Established a native seed bank of trees, shrubs, grasses, forbs to be used to establish native range with emphasis on cultural plant species.

USFWS

Goal 1. Manage the Lower Snake River to minimize the impact of the four lower Snake River dams and reservoirs on juvenile anadromous salmonids survival to the sea.

Objective 1. Increase survival of anadromous salmonid smolts migrating seaward in the Lower Snake River by 2005.

Strategy 1. Identify the flows and water temperatures that are required to maximize survival of anadromous salmonid smolts migrating seaward in the Lower Snake River.

Objective 2. Increase the effectiveness of smolt bypass and transportation efforts presently employed at the lower Snake River dams by 2005.

Strategy 1. Determine the importance of the Lower Snake River as overwintering habitat for juvenile anadromous salmonids.

Strategy 2. Determine if juvenile anadromous salmonid smolts pass the lower Snake River dams during the winter when fish bypass systems are shut down.

Strategy 3. Determine smolt-to-adult return rates for wild fall chinook salmon smolts that are trucked to the Columbia River estuary.

Goal 2. Ensure long term persistence of self-sustaining, complex interacting groups of bull trout in the Lower Snake River sub basin.

Objective 1. Determine temporal and spatial distribution of adult migratory bull trout in the Lower Snake River Reservoirs by 2005.

Strategy 1. Monitor movements of radio tagged bull trout in the Lower Snake River during their winter rearing period.

Strategy 2. Plot movements of individual bull trout to determine timing and frequency of fall back through the dams.

Objective 2. Determine bull trout use and passage efficiency in fishways at Lower Snake River dams by 2005.

Strategy 1. Operate fixed radio-telemetry stations at Lower Snake River dam fishways to monitor the use of the fishways by bull trout.

Strategy 2. Calculate passage rates of bull trout that utilize fishways, and compare them to those rates observed from anadromous salmonids at Snake River dams.

Objective 3. Determine the extent of bull trout losses (take) resulting from the Snake River dams.

Strategy Evaluate movement plots of individual radio-tagged fish to determine if those individuals that leave Lower Monumental Pool return to the Tucannon River the following spring.

Fish and Wildlife Needs

Fish

Reservoirs

- Determine the upstream and downstream passage requirements of bull trout at the Lower Snake River dams. These investigations should address entrainment, both upstream and downstream adult passage, and juvenile passage. Consideration of spill, flow attraction, temperature and other issues affecting passage should be included.

- Determine the presence of, and use by, bull trout in the mainstem Snake River, and implement monitoring and studies to provide critical information on bull trout distribution, timing, and usage of the lower Snake River dams and reservoir system. If the information from these studies warrants consideration of additional modifications to facilities or operations, then implementation of these modifications should occur, as appropriate, to minimize adverse effects to bull trout.

- The monitoring of TDG levels should continue, and investments in facility improvements to keep TDG levels at or below 110% (or other applicable state water quality standards) should be initiated.

- Determine the relation between flow and water temperature in the lower Snake River reservoirs and passage survival of juvenile anadromous salmonid smolts. These investigations should address the effects of flow augmentation and spill.

- Determine the presence of anadromous salmonid juveniles during winter in the lower Snake River reservoirs, and implement monitoring and studies to provide critical information on passage timing of these juveniles at the lower Snake River dams. If the information from these studies warrants consideration of additional modifications to facilities or operations, then implementation of these modifications should occur, as appropriate, to minimize adverse effects to juvenile anadromous salmonids.

- Determine the smolt-to-adult return rates for wild fall chinook salmon that are collected at the lower Snake River dams and then trucked to the Columbia River estuary. Implement monitoring and studies to provide critical information on the effectiveness of transportation passage timing of these juveniles at the lower Snake River dams. If the information from these studies warrants consideration of additional modifications to transportation operations, then implementation of these modifications should occur, as appropriate, to minimize adverse effects to wild fall chinook salmon smolts.

- Increase understanding of habitat use of adult and juvenile Pacific lamprey in the tailwater of mainstem Snake River dams.

- Increase understanding of riverine ecosystem processes in large rivers, as applied to the Lower Snake River.

- Develop a greater understanding of the riverine habitat potential in the tailraces of mainstem dams under various hydrosystem operational scenarios.

- Apply the concepts and empirical relationships developed under the Hanford Reach fall chinook conceptual spawning habitat model to reaches in the Lower Snake River, in order to improve estimates of production potential and identify reaches with greatest restoration potential.

- Develop a greater understanding of steelhead production (spawning and rearing) and habitat requirements in the Lower Snake River.

- Assess American shad – salmonid interactions. Specifically, there is a need to evaluate the effects to migrating anadromous adults from shad "clogging" adult ladders at mainstem dams. There is also a need to determine if American shad create deleterious conditions to juvenile salmonids through predation and competition in the rearing environment.

- Increase understanding of white sturgeon adult and juvenile habitat use in the section from Lower Granite Dam upstream to the head of the reservoir.

- Develop energy budget for white sturgeon in the section from Lower Granite Dam upstream to the head of the reservoir.

Tributaries

Alpowa Creek, Deadman Creek, and other perennial tributaries of the Lower Snake River

- Conduct baseline assessments and periodic monitoring of fish abundance, distribution, and habitat conditions in tributaries.
- Collect hydrologic data to thoroughly characterize the area.

- Evaluate the regional groundwater dynamics and recharge areas.
- Identify the history and extent of human alteration to the hydrologic regime.
- Identify the location of channel and riparian vegetation alteration and the amount of water removed from the stream.
- Quantify the impacts of land and water use on the hydrology.
- Restore riparian habitat along perennial and ephemeral streams.
- Reduce sedimentation entering perennial streams.
- Soil conservation measures should be integrated into upland cultivation practices to reduce sedimentation of the stream channel.
- Re-establishment of a healthy riparian vegetative community would also help stabilize streambanks presently eroding or prone to future erosion.
- Restore riparian habitat along critical area of Deadman Creek
- Reduce sedimentation entering Deadman Creek

Wildlife

- Monitor ferruginous hawk nesting populations and productivity on a more frequent basis.
- Inventory potential sharptail grouse habitat.
- Re-introduce and establish a viable population of sharptail grouse in the subbasin.
- Inventory Washington ground squirrel populations and habitat.
- Re-introduce Washington ground squirrels into the subbasin if surveys determine populations are insufficient to re-establish viable colonies.
- Increase pre & post-season deer surveys.
- Control the spread of noxious weeds within the subbasin.
- Improve and diversify the vegetative composition of CRP so they are more beneficial to existing wildlife populations.
- Survey prairie falcon eyries.
- Survey for peregrine falcons.
- Survey for osprey.
- GIS data base of soils, vegetation, roads, streams, rivers, springs and other water resources, weeds, wildlife resources, DEM public land survey, all at the 1:24,000 scale.
- Current aerial photography of SE Washington overall land ownerships used to establish a current cover map.
- Establish a non-game inventory and monitoring program

Research, Monitoring and Evaluation Activities

NPT

The BPA has funded research (project 86-50) to determine stock status and factors limiting production of white sturgeon in the Lower Snake River. In 1995 theWDFW, ODFW, and CRITFC assessed white sturgeon stock status in McNary Reservoir including the lower Snake River reach from the confluence with the Columbia River upstream to Ice Harbor Dam. This research was conducted using baited setlines anchored to the bottom; gear that targets subadult and adult white sturgeon without impacting listed salmonids. Multiple passes through the study area, systematic mark and recapture sampling, and biological sampling produced estimates of population abundance and age structure, reproductive potential, growth rate, and rates of mortality. A similar assessment was made in 1996 in Ice Harbor Reservoir upstream to Lower Monumental Dam (DeVore *et al*. 1997) and in 1997 in Lower Monumental and Little Goose reservoirs by the WDFW and the ODFW (DeVore *et al*. 1998).

Early life history studies of white sturgeon, as well as surveys of critical spawning habitats in the Lower Snake, were conducted by the Biological Resource Division of the USGS in 1996-98 and funded by the BPA under project 86-50. Artificial substrates and D-ring plankton nets were deployed in lower Snake Reaches to capture sturgeon eggs and larva. These surveys revealed where and when white sturgeon spawned in the Lower Snake River. Water depths, temperatures, velocities, and bottom substrates were noted to provide physical descriptions of sturgeon spawning habitats. The USGS and the USFWS cooperated and coordinated efforts to survey and model these critical habitats.

Recruitment of white sturgeon in the Lower Snake River is determined by annual surveys of young-of-year (YOY) white sturgeon. Small mesh gill nets (2-inch stretch measure) are systematically fished in Ice Harbor and Little Goose reservoirs by the ODFW and the WDFW to index annual recruitment of YOY white sturgeon. These data will be correlated to environmental variables that have been shown to influence reproductive success and recruitment of white sturgeon (Counihan *et al*. In Press). These ongoing studies were initiated in 1997 in Ice Harbor Reservoir and 1998 in Little Goose Reservoir and funded under BPA project 86-50.

WDFW

The WDFW manages wildlife populations within the subbasin. Annual surveys are conducted for deer, and various diversity species. The Upland Restoration Program works with landowners to improve wildlife habitat on private land.

- Ferruginous hawk surveys.
- Washington ground squirrel surveys.
- Burrowing owl surveys.
- Deer surveys.
- Deer harvest surveys.
- Upland Restoration Projects: private land.

USFWS

The USFWS conducts research in cooperation with state agencies and tribes that is focused on early life history and passage survival of anadromous salmonid smolts in the Lower Snake River reservoirs. Survival of smolts to the tailraces of the Lower Snake River dams is monitored annually using tagging and mark-recapture technology. There are four research, monitoring, and evaluation activities that are crucial to the recovery of Snake River fall and spring/summer chinook salmon and steelhead. These are the following:

- Where do smolts die in the Lower Snake River?

- When do smolts die in the Lower Snake River?

- How many smolts overwinter in the reservoirs and pass the dams before the bypass systems are operational?

- Does transportation work?

Studies should be continued or implemented to answer questions.

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FY 2002 Projects Proposals Review

The following subbasin proposals were reviewed by the Lower Snake River Mainstem River Subbasin Team and the Province Budget Work Group and are recommended for Bonneville Power Administration project funding for the next three years.

Table 1 provides a summary of how each project relates to resource needs, management goals, objectives, and strategies, and other activities in the subbasin.

Projects and Budgets

Continuation of Ongoing Projects

Project: 199401807 – Garfield County Sediment Reduction and Riparian Improvement Program

Sponsor: PCD
Short Description:
Coordinate, implement, and monitor conservation practices for the reduction of sediment from the uplands of Garfield County and enhance habitat in the riparian zones of the streams to improve water quality for Steelhead and Chinook Salmon.

Abbreviated Abstract
This project proposal is continuation and an expansion of the area covered under BPA project ID 199401807. The reason for this expansion is because of the recent subbasin summaries completed in the Columbia Plateau. The southern portion of Garfield County has been covered under the Pataha Creek Model Watershed project since 1995. It is included in the Tucannon Subbasin Summary. The northern portion of the county is in the Lower Snake Subbasin Summary and is now included in this proposal.

This project proposal is to aid the farmers and ranchers of Garfield County in their continuing effort to reduce the amount of soil erosion on cropland, rangeland, and riparian areas. The soil erosion coupled with other contaminates has led to a degradation of the water quality and quantity of most of the streams in the county. The Pomeroy Conservation District is currently working with the Natural Resources Conservation Service (NRCS) and the Farm Service Agency (FSA) in getting as many farmers and ranchers enrolled in the Continuous Conservation Reserve Program (CRP) and Conservation Reserve Enhancement Program (CREP) as possible. These programs are designed to restore and enhance habitat along certain eligible streams and drainages to benefit fish and wildlife.

Although these programs are available and successful, the issue of sediment in the streams is not entirely covered. This proposal is to use additional funding to address areas not covered by these two federal programs. Examples: additional funding for off-site watering facilities outside the riparian zones; the introduction and eventual conversion of more cropland acres into a no-till or direct seed program and other effective conservation programs.

Our current cost share program through BPA has been working very well in the Pataha Watershed and other funding has been used in a limited amount throughout the remainder of the county. However, there is still an immense arena of cooperators in Garfield that have not utilized these programs. The upland portion of this program would address those cooperators that have not used existing programs or reached their district limitation. A new emphasis is also being directed towards cattle operations along streams and must also be addressed to improve salmon habitat and water quality.

The pictures below illustrate what we want to accomplish.

 Erosion on convention seeded ground	 Closeup of water running off field
 No-till seeded field within 100 yards of above picture taken at the same time.	 Closeup of no-till field with water infiltrating rather than running off.

Relationship to Existing Goals, Objectives and Strategies
This project proposal addresses the PCD's objectives 1-4 and the associated strategies (pages 143-144) as well as the all of WDFW's goals and objectives for the Lower Snake River Subbasin. Specific WDFW objectives and strategies (i.e., actions) that are addressed include Objective 2 and Actions 2.1-2.8, Objective 3 and Actions 3.1-3.10, Objective 4 and Actions 4.1-4.5, Objective 5 and Actions 5.1-5.5.

Review Comments
This project benefits an ESU by reducing the amount of soil erosion on cropland, rangeland, and riparian areas through conservation efforts. Project may address RPA 153. This project needs to be implemented consistent with limiting factors and problem locations identified in subbasin summaries and eventually subbasin planning to insure fisheries benefits to target species. There needs to be oversight by the COTR to insure that actions taken will benefit fish and wildlife.

Budget

FY02	FY03	FY04
$212,000 Category: High Priority	$199,500 Category: High Priority	$231,000 Category: High Priority

Project: 199102900– Understanding the Effects of Summer Flow Augmentation on the Migratory Behavior and Survival of Fall Chinook Salmon Migrating through Lower Granite Reservoir

Sponsor: USFWS and USGS
Short Description:
Increase the potential for fall chinook salmon recovery by providing data and analyses for implementing, evaluating, and understanding the mechanisms of summer flow augmentation.

Abbreviated Abstract
Dams reduce the survival of chinook salmon smolts during early seaward migration. Summer flow augmentation is implemented annually to mitigate for Snake River fall chinook smolt mortality caused by the four dams in the lower Snake River by increasing downstream migration rate and survival. There are two philosophies regarding summer flow augmentation within the resource management community of the Columbia River basin. One philosophy embraces summer flow augmentation based on studies that show flow augmentation increases the migration rate and survival of fall chinook salmon smolts. The other questions the existing migration rate and survival studies, and advocates the use of limited reservoir water for other fishery and economic purposes. For the present and near future, summer flow augmentation will be implemented annually as one measure to recover Snake River fall chinook salmon, which are listed for protection under the Endangered Species Act. This project will forecast juvenile fall chinook salmon run timing past Lower Granite Dam to aid fishery managers develop annual water management plans. In addition we will estimate fish survival and relate it to variables such as flow and temperature as part of a continuing evaluation of the effectiveness of flow augmentation. This project will also examine water velocity effects on fall chinook salmon migration behavior, and also how cool Clearwater River water temperatures influence the thermal environment of Lower Granite Reservoir and whether migrating fish are delayed by this influx.

Relationship to Other Projects

Project ID	Title	Nature of Relationship
199302900	Estimate Survival of Juvenile Salmon through Lower Snake River	Collaborative effort to estimate survival of hatchery and wild fall chinook in the Snake River. Information Sharing
0	Simulate Flow and Temperature in Lower Snake River	New proposal by Battelle PNNL. Share empirical physical and biological data for Batelle's modeling efforts.

Relationship to Existing Goals, Objectives and Strategies
This project proposal addresses the USFWS Objectives 1 and 2 and associated Strategies (page 153).

Review Comments
This proposal will need to be reviewed in the Systemwide Project Review Process to put it in context with all other passage projects. Funding should be provided to insure that this project is supported through the Systemwide review process.

Budget

FY02	FY03	FY04
$630,375 Category: High Priority	$610,375 Category: High Priority	$610,375 Category: High Priority

New Projects

Project: 25049 – Numerically Simulating the Hydrodynamic and Water Quality Environment for Migrating Salmon in the Lower Snake River

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Sponsor: PNNL
Short Description:
The objective of this work is to apply state-of-the-art computer models that can describe the complex hydrodynamic and water quality environment in the lower Snake River, and to relate that information to migrating salmon.

Abbreviated Abstract
Summer flow augmentation is implemented annually from Dworshak Reservoir and other Snake River reservoirs to increase water velocities and decrease water temperatures in Lower Granite Reservoir (LGR) during periods of fall chinook salmon smolt passage and adult migration. Previous research has shown that summer flow augmentation decreases water temperature, however little is presently known regarding hydrodynamic impacts or three-dimensional temperature variations. The primary goal of this study is to provide information on the physical river environment, related specifically to the anadromous salmonids species, to various river mangers (e.g. fisheries, hydropower, etc.,) at locations of concern throughout the lower Snake River system.

Hydrodynamic and water quality information will be developed using multi-dimensional computational fluid dynamics (CFD) models to simulate the river system from above Lower Granite Reservoir (i.e. above the Clearwater R. confluence) to its confluence with the Columbia River. Numerical data from the model would then be used in conjunction with field data from salmon tracking studies by combining these datasets in a geographic information system (GIS). In addition to simulating periods when the salmon were tracked, the CFD models can also be used to simulate periods with alternative release strategies (e.g. increased/decreased flows and/or increased/decreased temperatures) from upstream reservoirs. In combination with fish tracking data, this work will provide a better understanding of how potential flow augmentation strategies could influence the exposure histories (to both dissolved gas and water temperatures) of adult and juvenile salmon in the lower Snake River.

A secondary goal would be to augment the FINS individual fish model from two- to three-dimensions (Scheibe and Richmond, 2001). This would be most appropriate in LGR, were a stratified thermal regime may exist for an extended period, and a three-dimensional CFD model is necessary. Density driven currents, generated primarily from cold water emanating from the Clearwater River, may influence juvenile salmon migrants and be a beneficial measure for enhancing survival. By using the combination of a three-dimensional CFD and an individual fish-tracking model, a powerful predictive tool will be developed that will provide additional insight into the river's environment that is not possible from field data alone.

Relationship to Other Projects

Project ID	Title	Nature of Relationship
199102900	Life history and Survival of Fall Chinook Salmon in the Columbia River Basin	Numerical models applied in this proposal will augment this ongoing project by providing information on the physical river environment, under existing and proposed flow strategies, that is not possible by monitoring alone.
199302900	Survival Estimates for the passage of Juvenile Salmonids through Snake and Columbia River Dams and Reservoirs	Numerical models applied to this project will examine physical environment experienced by PIT tagged fish, plus predict river conditions under augmented or reduced flow conditions.

Relationship to Existing Goals, Objectives and Strategies

This proposal addresses Objective 1 and its associated strategy (page 142). The use of numerical CFD models, as recognized in the NMFS Biological Opinion, Appendix B, which states that a two or three-dimensional model should be developed "to yield a better understanding of water temperature impacts and possible solutions" (pg. B-17).

The NMFS Biological Opinion lists several action items that are pertinent to the lower Snake Sub-basin. Proceeding in numerical order, the following relationships between these action items and this proposal have been noted:

Action 34: draft Dworshak Reservoir to elevation 1500 ft in September.

This action is suggested to provide cooler water for reduction in water temperatures along the lower Snake, and to possibly eliminate a thermal block that delays adult migration. The numerical models discussed in this proposal would be capable of simulating various releases from Dworshak, including the one discussed in this Action item, and routing these flows throughout the system. Incremental differences in temperature and water velocity would be compared at numerous locations to further understanding of the management scenario's impact on the river environment.

Action 50: adult PIT-tag detection.

Data gathered through this action item would be beneficial for calibration of the FINS model. In addition, adult fish tracks could be inserted into the simulated domain, and the history of temperature and dissolved gas concentrations experienced by the fish could be extrapolated.

Action 105: develop a pilot study to assess the feasibility of enhancing ecological communities, including hydrosystem operations.

Basic hydrodynamic information such as residence time, water velocity and depth under a variety of release flows can be simulated in the numerical models. By using the numerical models, various management scenarios could be examined before they were implemented in the field for optimum system efficiency. These scenarios could be applied to the pilot study, or to the system wide results developed after the studies completion.

Action 107: conduct a comprehensive evaluation to assess survival of adult salmonids.

Using the numerical models to further increase understanding of the river system may augment information obtained under several of the research items listed in this Action.

Action 131: monitoring the effects of TDG.

Data gathered through this action item would be beneficial for calibration and verification of the MASS2 model. In addition, if the numerical model were to isolate additional (and perhaps improved) spill patterns, these could then be verified with field data under this Action.

Action 141: evaluate juvenile fish condition due to disease in relation to high temperature impacts during critical migration period.

Review Comments

Addresses NMFS RPA 141 and 143 and is linked directly to flow augmentation from Snake River reservoirs. Reviewers question whether this proposed work is is duplicative with EPA 's water quality monitoring of the Snake River.

Budget

FY02	FY03	FY04
$207,360 Category: High Priority	$183,322 Category: High Priority	$107,917 Category: High Priority

Project: 25053 – Evaluate Bull Trout Movements in the Tucannon and Lower Snake Rivers

Sponsor: USFWS - IFRO
Short Description:
Determine spatial and temporal distribution of migratory bull trout in the Tucannon River and Lower Snake River. Estimate "take" and identify passage limitations in the Snake River resulting from the hydropower system.

Abbreviated Abstract
The overall goals of the project are to determine the temporal and spatial distribution of bull trout within the Tucannon and Snake rivers, and whether the Hydropower System on the Lower Snake River is adversely affecting the migratory component of the Tucannon River bull trout subpopulation. The project will help meet measures 10.1A.1 and 10.5A in the 1994 Fish and Wildlife Program, and provide useful information for bull trout recovery planning and hydrosystem effects determinations. We will use radio-telemetry to monitor the movements of adult bull trout within the Tucannon River and as they leave the Tucannon subbasin and move into the main stem Snake River in the fall and winter, 2002 - 2005. Adult bull trout will be captured at the Tucannon Hatchery weir in the spring, and surgically implanted with radio-transmitters in years 2002 - 2005. By using long-term tags and surgical implants in spring, we allow ample time for surgical recovery to minimize effects on fish spawning or movements. We will use fixed station data loggers to help monitor fish movements within the Tucannon River and to evaluate passage efficiency in fishways at Snake River dams. We will also determine the extent of "take" if a portion of the subpopulation becomes stranded in the mainstem as fish move past the dams and out of Lower Monumental Pool. Tracking from boat, shore, and/or aircraft will also be used to monitor bull trout distribution in the Tucannon or Snake rivers.

Relationship to Other Projects

Project ID	Title	Nature of Relationship
199401807	Continue with Implementation of the Pataha Model Watershed Plan	The prposed project will provide information about bull trout distribution and movements in the Tucannon River that may effect the model watershed project for planning and implementing habitat improvement projects in Pataha Creek, a Tucannon tributary.
199401806	Implement the Tucannon River Model Watershed Plan to Restore Salmonid Habitats	The proposed project will provide information about bull trout distribution and movements that should be of benefit to the model watershed project for planning and implementing habitat improvement projects.

Relationship to Existing Goals, Objectives and Strategies
This proposal addresses the USFWS's Goal 2, Objectives 1-3 and the associated strategies (page 153-154).

Review Comments
Tied to the USFWS bull trout bi-op.

Budget

FY02	FY03	FY04
$81,626 Category: High Priority	$193,641 Category: High Priority	$202,224 Category: High Priority

Project: 25064 – Investigating passage of ESA-listed Juvenile Fall Chinook Salmon at Lower Granite Dam during Winter when the Fish Bypass System is Inoperable

Sponsor: USFWS and USGS
Short Description:
Describe passage timing, genetic lineage, scale patterns, and locations of fall chinook salmon that hold over in Lower Granite Reservoir during the winter.

Abbreviated Abstract
Juvenile fall chinook salmon, *Oncorhynchus tshawytscha*, listed for protection under the Endangered Species Act typically have an ocean-type life history. Fry emerge in the spring, grow rapidly, and migrate from the Snake River during summer. However, some of the later emerging and slower growing juvenile fall chinook salmon fail to leave the Snake River as subyearlings, and they overwinter in the reservoirs, and then resume seaward migration the following spring. This project will explore holdover behavior of fall chinook salmon in Lower Granite Reservoir and refine existing methods of scale pattern analysis for determining age and DNA analysis for determining genetic lineage of holdover fish. In addition, we will use radio telemetry to determine where fish hold over in Lower Granite Reservoir and document passage timing Lower Granite Dam.

Relationship to Other Projects

Project ID	Title	Nature of Relationship
199102900	Life History and Survival of Fall Chinook Salmon	Use this project's radio telemetry equipment and infrastructure; share recapture data on their PIT-tagged fish.
199302900	Survival of Juvenile Salmon in the Snake River	Share recapture data on their PIT-tagged fish.

Review Comments
This project addresses RPA 190. This proposal will need to be reviewed in the Systemwide Project Review Process to put it in context with all other passage projects. Funding should be provided to insure that this project is supported through the Systemwide review process.

Budget

FY02	FY03	FY04
$176,000 Category: High Priority	$131,000 Category: High Priority	$131,000 Category: High Priority

Project: 25033 – Evaluate Restoration Potential of Mainstem Habitat for Anadromous Salmonids in the Columbia and Snake Rivers

Sponsor: Pacific Northwest National Laboratory
Short Description:
Identify mainstem habitat sampling reaches, collect baseline data on physical habitat conditions, identify opportunities for mimicking the range and diversity of historic habitat conditions, develop improvement recommendations for mainstem reaches.

Abbreviated Abstract
There is now considerable debate within the Columbia Basin regarding management activities directed towards enhancement of mainstem habitat and anadromous salmonid populations. Much of the debate is centered on physical and operational modifications to hydroelectric dams, and the related uncertainties regarding potential restoration sites and specific benefits to salmon (NMFS 2000). The research to be conducted under this proposal will evaluate the restoration potential of mainstem habitats for fall chinook salmon (*Oncorhynchus tshawytscha*). The studies will address two research questions: "Are there sections not currently used by spawning fall chinook salmon within the impounded mainstem Columbia and Snake rivers that possess the physical characteristics suitable for fall chinook spawning habitat?" and "Can hydrosystem operations affecting these sections be adjusted such that the sections closely resemble the physical characteristics of current fall chinook spawning areas in similar physical settings?" This project will result in a report on the location and spatial extent of potential restoration areas, and recommendations to the region for adjusting hydrosystem operations to improve fall chinook spawning habitat, including alternative flow scenarios by water-year type.

Relationship to Other Projects

Project ID	Title	Nature of Relationship
199406900	A spawning habitat model to aid recovery plans for Snake River Fall Chinook	Share physical habitat data and expertise; share data on flow relationships and model development
199900300	Evaluate spawning of salmon below the four lowermost Columbia River dams	Share data on flow relationships and model development
199801003	Monitor and evaluate the spawning distribution of Snake River fall chinook	Share data for Snake and Columbia River fall chinook habitat use
199102900	Life history requirements of fall chinook in the Columbia River Basin	Share data on flow relationships and model development
199701400	Evaluation of juvenile fall chinook stranding on the Hanford Reach	Share data on flow relationships and model development

Relationship to Existing Goals, Objectives and Strategies
This proposal addresses the Pacific Northwest Laboratories Objective 1.

Review Comments
This project is not management priority at this time.

Budget

FY02	FY03	FY04
$314,392 Category: Recommended Action	$398,911 Category: Recommended Action	$407,099 Category: Recommended Action

Research, Monitoring and Evaluation Activities
Specific on-going activities include:

- Coordinating, implementing, and monitoring conservation practices for the reduction of sediment from the uplands of Garfield County and enhancing habitat in the riparian zones of streams to improve water quality for steelhead and chinook salmon.

- Increasing the potential for fall chinook salmon recovery by providing data and analyses for implementing, evaluating, and understanding the mechanisms of summer flow augmentation.

Needed Future Actions
For species that are adversely affected by hydropower operations, there is a need to conclusively document population trends for target and high-priority species along with any other species that show declining populations, develop plans for their recovery, and implement projects to mitigate for operational impacts.

Fish

Reservoirs

- Determine the upstream and downstream passage requirements of bull trout at the Lower Snake River dams. These investigations should address entrainment, both upstream and downstream adult passage, and juvenile passage. Consideration of spill, flow attraction, temperature and other issues affecting passage should be included.
- Determine the presence of, and use by, bull trout in the mainstem Snake River, and implement monitoring and studies to provide critical information on bull trout distribution, timing, and usage of the lower Snake River dams and reservoir system. If the information from these studies warrants consideration of additional modifications to facilities or operations, then implementation of these modifications should occur, as appropriate, to minimize adverse effects to bull trout.
- The monitoring of TDG levels should continue, and investments in facility improvements to keep TDG levels at or below 110% (or other applicable state water quality standards) should be initiated.

- Determine the relation between flow and water temperature in the lower Snake River reservoirs and passage survival of juvenile anadromous salmonid smolts. These investigations should address the effects of flow augmentation and spill.
- Determine the presence of anadromous salmonid juveniles during winter in the lower Snake River reservoirs, and implement monitoring and studies to provide critical information on passage timing of these juveniles at the lower Snake River dams. If the information from these studies warrants consideration of additional modifications to facilities or operations, then implementation of these modifications should occur, as appropriate, to minimize adverse effects to juvenile anadromous salmonids.
- Determine the smolt-to-adult return rates for wild fall chinook salmon that are collected at the lower Snake River dams and then trucked to the Columbia River estuary. Implement monitoring and studies to provide critical information on the effectiveness of transportation passage timing of these juveniles at the lower Snake River dams. If the information from these studies warrants consideration of additional modifications to transportation operations, then implementation of these modifications should occur, as appropriate, to minimize adverse effects to wild fall chinook salmon smolts.
- Increase understanding of habitat use of adult and juvenile Pacific lamprey in the tailwater of mainstem Snake River dams.
- Increase understanding of riverine ecosystem processes in large rivers, as applied to the Lower Snake River.
- Develop a greater understanding of the riverine habitat potential in the tailraces of mainstem dams under various hydrosystem operational scenarios.
- Apply the concepts and empirical relationships developed under the Hanford Reach fall chinook conceptual spawning habitat model to reaches in the Lower Snake River, in order to improve estimates of production potential and identify reaches with greatest restoration potential.
- Develop a greater understanding of steelhead production (spawning and rearing) and habitat requirements in the Lower Snake River.
- Assess American shad – salmonid interactions. Specifically, there is a need to evaluate the effects to migrating anadromous adults from shad “clogging” adult ladders at mainstem dams. There is also a need to determine if American shad create deleterious conditions to juvenile salmonids through predation and competition in the rearing environment.
- Increase understanding of white sturgeon adult and juvenile habitat use in the section from Lower Granite Dam upstream to the head of the reservoir.
- Develop energy budget for white sturgeon in the section from Lower Granite Dam upstream to the head of the reservoir.

Tributaries

Alpowa Creek, Deadman Creek, and other perennial tributaries of the Lower Snake River

- Conduct baseline assessments and periodic monitoring of fish abundance, distribution, and habitat conditions in tributaries.

- Collect hydrologic data to thoroughly characterize the area.
- Evaluate the regional groundwater dynamics and recharge areas.
- Identify the history and extent of human alteration to the hydrologic regime.
- Identify the location of channel and riparian vegetation alteration and the amount of water removed from the stream.
- Quantify the impacts of land and water use on the hydrology.
- Restore riparian habitat along perennial and ephemeral streams.
- Reduce sedimentation entering perennial streams.
- Soil conservation measures should be integrated into upland cultivation practices to reduce sedimentation of the stream channel.
- Re-establishment of a healthy riparian vegetative community would also help stabilize streambanks presently eroding or prone to future erosion.
- Restore riparian habitat along critical area of Deadman Creek
- Reduce sedimentation entering Deadman Creek

Wildlife

- Monitor ferruginous hawk nesting populations and productivity on a more frequent basis.
- Inventory potential sharptail grouse habitat.
- Re-introduce and establish a viable population of sharptail grouse in the subbasin.
- Inventory Washington ground squirrel populations and habitat.
- Re-introduce Washington ground squirrels into the subbasin if surveys determine populations are insufficient to re-establish viable colonies.
- Increase pre & post-season deer surveys.
- Control the spread of noxious weeds within the subbasin.
- Improve and diversify the vegetative composition of CRP so they are more beneficial to existing wildlife populations.
- Survey prairie falcon eyries.
- Survey for peregrine falcons.
- Survey for osprey.
- GIS data base of soils, vegetation, roads, streams, rivers, springs and other water resources, weeds, wildlife resources, DEM public land survey, all at the 1:24,000 scale.
- Current aerial photography of SE Washington overall land ownerships used to establish a current cover map.
- Establish a non-game inventory and monitoring program

Table 1. Lower Snake River Subbasin Summary FY 2002 - 2004 BPA Funding Proposal Matrix

Project Proposal ID	**199102900**	**199401807**	**25049**	**25033**	**25053**	**25064**
Provincial Team Funding Recommendation	**High Priority**	**High Priority**	**High Priority**	**Recommended Action**	**High Priority**	**High Priority**
Pacific Northwest Laboratory						
Objective 1: Restore riverine ecosystem processes to key sections of the lower Snake River.				x		
Pomeroy Conservation District						
Objective 1: Reduce sediment delivery.		x				
Objective 2: Maintain cool water temperatures.		x				
Objective 3: Reduce sediment delivery into Deadman Creek and its tributaries.		x				
USFWS						
Anadromous Fish						
Objective 1 : Increase survival of anadromous salmonid smolts migrating seaward in the lower Snake River by 2005.	x					x
Objective 2: Increase the effectiveness of smolt bypass and transportation efforts presently employed at the lower Snake River dams by 2005.						x
Resident Fish						
Objective 1: Determine temporal and spatial distribution of adult migratory bull trout in the lower Snake River reservoirs by 2005.					X	
Objecive 2: Determine bull trout use and passage efficiency in fishways at lower Snake River dams by 2005.					X	
Objective 3: Determine the extent of bull trout losses (take) resulting from the Snake Rivers dams.					X	

Note: x = potential or anticipated effect on subbasin objectives.
25033 – Evaluate Restoration Potential of Mainstem Habitatfor Anadromous Salmonids in the Columbia and Snake Rivers
25053 – Evaluate Bull Trout Movements in the Tucannon and Lower Snake Rivers
25064 – Investigating passage of ESA-listed Juvenile Fall Chinook Salmon at Lower Granite Dam during Winter when the Fish Bypass System is Inoperable
25049 – Numerically Simulating the Hydrodynamic and Water Quality Environment for Migrating Salmon in the Lower Snake River
199102900 – Understanding the Effects of Summer Flow Augmentation on the Migratory Behavior and Survival of Fall Chinook Salmon Migrating through Lower Granite Reservoir
199401807 – Garfield County Sediment Reduction and Riparian Improvement Program

Bull Trout

Objectives

- Fill data gaps

Limiting Factors

- Regulated flows
- Passage/entrainment
- Water quality
- Water quantity

Strategy

- Develop water mgmt plans
- Modify fishways

Projects

Migration timing	Passage efficiency
25053	25053

Fall Chinook

Objectives

- $\geq$ 2,500 adult fall chinook at Lower Granite Dam
- Average return of 18,300 hatchery fall chinook to the Snake River

Limiting Factors

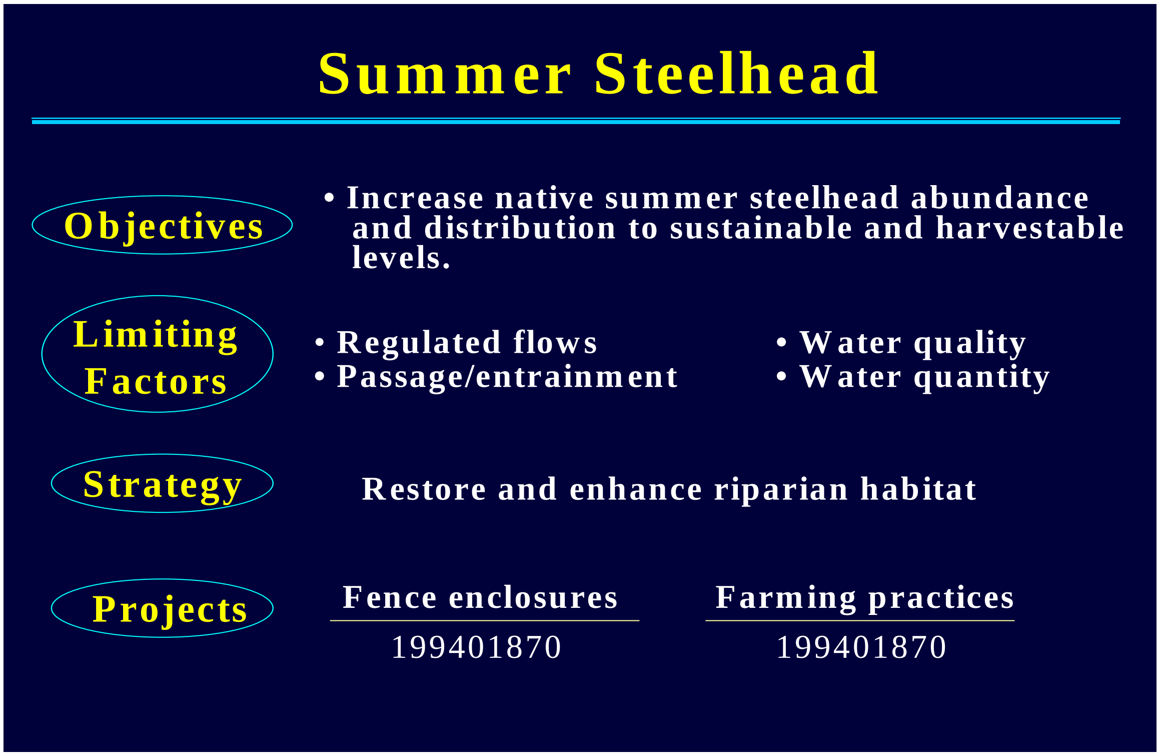
- Regulated flows
- Passage/entrainment
- Water quality
- Water quantity

Strategy

- Develop water mgmt plans
- Modify bypass operations
- Restore and enhance habitat

Projects

Hydrodynamic Water Quality	Migration timing	Fencing and farming
25049 199102900	25064	199401807 25033



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