Nez Perce–Clearwater National Forests
Forest Plan Assessment

2.0 Air, Soil, and Water Resources and Quality

June 2014

Table of Contents

List of Tables

List of Figures

2.0 Air, Soil, and Water Resources and Quality

2.1 Air Resources and Quality

2.1.1 *Existing Information*

Relevant existing information regarding air quality can be separated into regulatory and implementation guidance documents. The following documents regulate air quality in the Forest Plan area:

- State of Idaho, Department of Environmental Quality Regulations
- Environmental Protection Agency Regulations
- U.S. Forest Service Organic Act of 1897
- Sustained Yield Act of 1960
- Multiple Use, Wilderness Act of 1964
- National Environmental Policy Act (NEPA) 1969
- Clean Air Act 1963, with amendments in 1977 and 1990

The following air quality guidance documents exist for the Plan area:

- Western Montana/North Idaho Smoke Management Plan
- Clearwater and Nez Perce Fire Management Plan

2.1.2 *Informing the Assessment*

Air quality on the Nez Perce–Clearwater National Forests is generally good with limited upwind industrial sources and periodic robust wind dispersion. The Forests are subject to long-distance transport emissions from sources to the west in Oregon and Washington. Existing sources of emissions include dust from trails during dry conditions and smoke emissions from wildfires and prescribed burns. Adjacent area sources are primarily occasional construction equipment, vehicles, road dust, residential wood burning, wood fires and smoke from logging emissions, slash disposal, prescribed burns, and wildfires. The Forests receive some vehicle, residential, and construction emissions from the Grangeville, Kamiah, and Orofino areas; jet boat emissions on the Salmon River; and snowmobile emissions during the winter months. Local emission levels are low due to the sparse population and vast areas for dispersion.

2.1.2.1 Atmospheric Pollution Impacts

In the study of air pollution, a “critical load” is defined as “a quantitative estimate of an exposure to one or more pollutants, below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge” (Nilsson and Greenfelt 1988).

Table 2-1 depicts modeled critical loads/exceedances of Nitrogen for surface waters, forested ecosystems, lichens, herbaceous plants, and shrubs on the Forests.

Table 2-1. Modeled critical loads/exceedances of Nitrogen for surface waters (measured in milliequivalents per meter squared per year [$meq/m^2/yr$]), forested ecosystems, lichens (measured as kilograms (kg) of Nitrogen per hectare per year [N/ha/yr]), and herbaceous plants and shrubs (measured as kg N/ha/yr) on the Nez Perce–Clearwater National Forests

Exceedance Metrics	Critical Loads			
	Acidity: Surface Waters	Acidity: Forested Ecosystems	Nutrient Nitrogen: Lichens	Nutrient Nitrogen: Herbaceous Plants and Shrubs
Extent	15 out of 37 surface waters exceeding critical loads	0%	100%	0.001% (1/214 pixels)
Severity—range of exceedance amount	0.61–21.47 meq/m2/yr	No exceedances present within forest boundaries	1.89–3.28 kg N/ha/yr	0.28 kg N/ha/yr
Severity—95% exceedance value	95% of sites do not exceed critical load	No exceedances present within forest boundaries	95% of grid cells exceed critical load by ≥2.99 kg N/ha/yr	95% of grid cells do not exceed critical load
Reliability	High	Low	High	Variable

Forest Service air quality policy directs coordination of National Forest activities with State and federal air quality control efforts. This is done by properly managing and/or mitigating the sources of air pollution created by Forest Service activities, such as prescribed burning, the construction and use of roads, and the operation of various facilities. The Forest Service has established pollution- and air quality-related value impact monitoring efforts in wilderness areas to understand conditions and trends particularly related to resources of concern, such as lichen or sensitive lakes. The Forest Service is assigned a stewardship role under the Organic Act and responsibility under the Clean Air Act's Prevention of Significant Deterioration (PSD) provisions to protect and enhance Air Quality Related Values (AQRV) in designated Class I wilderness areas.

Regulatory agencies require compliance with established standards as they relate to air quality. These standards usually have spatial as well as temporal threshold(s) assigned to them. These standards are the basis for the implementation guides. The implementation guides or plans explain how management activities can or will occur while staying within established regulations and associated thresholds for air quality. They also explain and outline more site-specific concerns, such as cumulative effects and impacts to local entities and how all effects will be taken into account for meeting regulations and laws.

The Clearwater and Nez Perce Fire Management Plan (FMP) is revised annually and provides guidance for implementing federal fire policy, Forest Service Manual direction, and Forest Plan direction. The FMP incorporates existing interagency plans and assessments and considers the best available science to assess and plan on a landscape scale. The Montana/Idaho Airshed Group (Group) is composed of State, federal, tribal, and private member organizations that are dedicated to preserving the air quality in Montana and Idaho. The Montana/Idaho Airshed Group Operating Guide (Montana/Idaho Airshed Group 2010) is meant to provide accurate and reliable guidance to Group members and contains pertinent agreements, guidelines, deadlines, plans, and procedures inherent to successfully operating the Group smoke management program. The intent of the smoke management program is to minimize or prevent smoke impacts while using fire to accomplish land management objectives. The smoke management program is designed to help burners meet Idaho and Montana regulatory requirements.

2.1.3 *Information Needs*

New critical load exceedances data will be available later this year.

2.1.4 *Literature Cited*

Nilsson J., and P. Greenfelt. 1988. Critical loads for sulpher and nitrogen. Stockholm, Sweden: Nordic Council of Ministers and the United Nations Economic Commission for Europe.

Montana/Idaho Airshed Group. 2010. Operating guide. Montana/Idaho Airshed Group, Smoke Management Program.

2.2 Soil Resources and Quality

2.2.1 *Existing Information*

The publications listed below are considered the best available science used to inform soil quality management in the planning area. This research helps define the relationships between soil quality and productivity, soil disturbance, and forest land management.

- Forest soil conservation and rehabilitation in British Columbia (B.C Ministry of Forestry 2002)
- Coarse woody debris: Managing benefits and fire hazard in the recovering forest (Brown et al. 2003)
- Using soil quality indicators to assess forest stand management (Burger and Ketling 1999)
- Managing coarse woody debris in forests of the Rocky Mountains (Graham et al. 1994)
- Decaying organic materials and soil quality in the inland Northwest: A management opportunity (Harvey et al. 1987)
- Assessment of soil disturbance in forests of the interior Columbia River Basin: A critique (Miller et al. 2010)
- Sustained productivity of forests is a continuing challenge to soil science (Nambiar 1996)
- Wildland fire in ecosystems: Effects of fire on soils and water (Neary et al. 2005)
- Soil quality standards and guidelines for forest sustainability in Northwestern North America (Page-Dumroese et al. 2000)
- Soil carbon and nitrogen pools in mid- to late-successional forest stands of the Northwestern United States: Potential impact of fire (Page-Dumroese and Jurgensen 2006)
- National soil disturbance monitoring protocol (Page-Dumroese et al. 2009)
- Scientific background for soil monitoring on National Forests and Rangelands (Page-Dumroese et al. 2010)
- Are we maintaining productivity of forest lands? Establishing guidelines through a network of long-term studies (Powers 1990)
- Volcanic-ash derived forest soils of the inland Northwest: Properties and implications for management and restoration (Page-Dumroese et al. 2007)
- Assessing soil quality: Practicable standards for sustainable forest productivity (Powers et al. 1998)
- Effects of soil disturbance on the fundamental, sustainable productivity of managed forest (Powers 2002)
- The North American long-term soil productivity experiment: Coast-to-coast findings from the first decade (Powers et al. 2004)
- The North American long-term soil productivity experiment: Findings from the first decade of research (Powers et al. 2005)
- Detrimental soil disturbance associated with timber harvest systems on National Forests in the Northern Region (Reeves et al. 2011)
- Managing organic debris for forest health (Schnepf et al. 2009)

- A review of chemical and physical properties as indicators of forest soil quality: Challenges and opportunities (Schoenholtz et al. 2000)
- Soil survey of the Nez Perce National Forest area, Idaho (USDA NRCS 2006)
- Land system inventory: First review draft, Clearwater National Forest (Wilson et al. 1983)

2.2.2 ***Informing the Assessment***

For the soil resources, the best available science was used to inform the assessment.

2.2.2.1 **Current Condition**

Soils of the Nez Perce–Clearwater National Forests

Soil development is dominated by 5 major soil formation factors: time, parent material, topography, climate, and biology. Each of these factors for the soils of the Nez Perce–Clearwater National Forests is discussed in this assessment.

Time and Parent Material

Most soils in the Forests were formed during recent times (Holocene; 10,000 years ago). The bedrock in the area, which provides soil parent materials upon weathering, was emplaced over much longer periods of time. Most soils have surface layers formed in loess that has been influenced by volcanic ash. Several ash deposits exist on the Forests from Pacific Rim volcanoes in the past several thousand years to as recently as Mount Saint Helens (Figure 2-1). The most significant and influential layer of this loess was deposited on the Forests approximately 6,700 years ago by the eruption of Mount Mazama, or Crater Lake, in Oregon. Additional loess that has been influenced by volcanic ash was deposited by eruptions of Mount St. Helens and Glacier Peak. These ash deposits range from over 36-inches thick in depressions to very thin deposits that may be mixed with underlying materials on steep southerly aspects at lower elevations to no deposits remaining on the most southerly end of the Forests. Soil surface layers formed in ash and loess are an excellent medium for plant growth. Soils with the thickest loess surface layers tend to be the most productive. Most soil surface layers are formed in volcanic ash or loess mixed with subsoil material; lower soil layers are formed in materials derived from other sources. An ash-influenced surface layer is resistant to erosion when undisturbed; but if disturbed, it has a high risk of surface erosion. These surface soils are also highly susceptible to compaction.

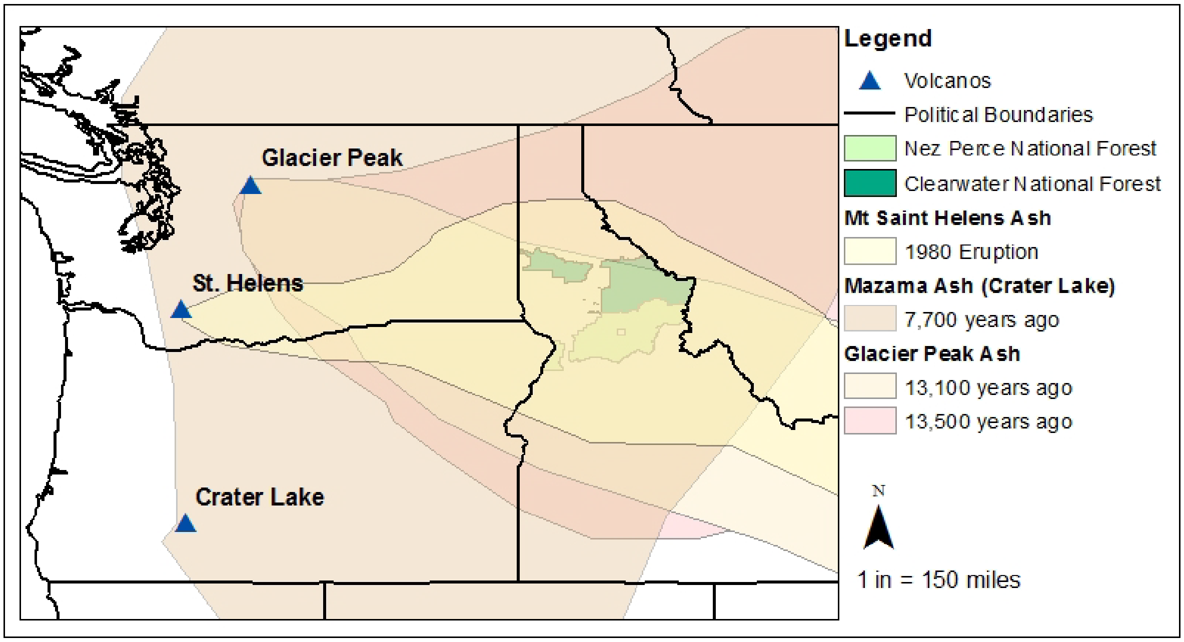

Figure 2-1. Known volcanic ash deposits and approximate distributions

The Forests are located mostly in the Clearwater Mountains but also include part of the Seven Devils Mountains (Figure 2-2). The Clearwater Mountains are intrusive mountains formed on the Idaho Batholith. The Idaho Batholith granitics were intruded during late Cretaceous time (66 to 110 million years ago). Most of these rocks are quartz monzonite, granodiorite, quartz diorite, and granite. These rocks weather to sandy loam or loamy sand or to sand. The content and hardness of rock fragments vary with the degree of chemical weathering of the rock. Chemical weathering is most intense at low elevations and in zones of high precipitation. Lower soil layers are erodible. Some smaller granitic areas were apparently implanted within the Idaho Batholith during early Tertiary time (60 million years ago). A highly dissected hilly landscape initially formed on the Idaho Batholith and was later uplifted. Major streams carved deep canyons into the hilly landscape as the result of uplift. Remnants of the old hilly landscape remain in the southwestern part of the Clearwater National Forest and on major mountain ridgetops.

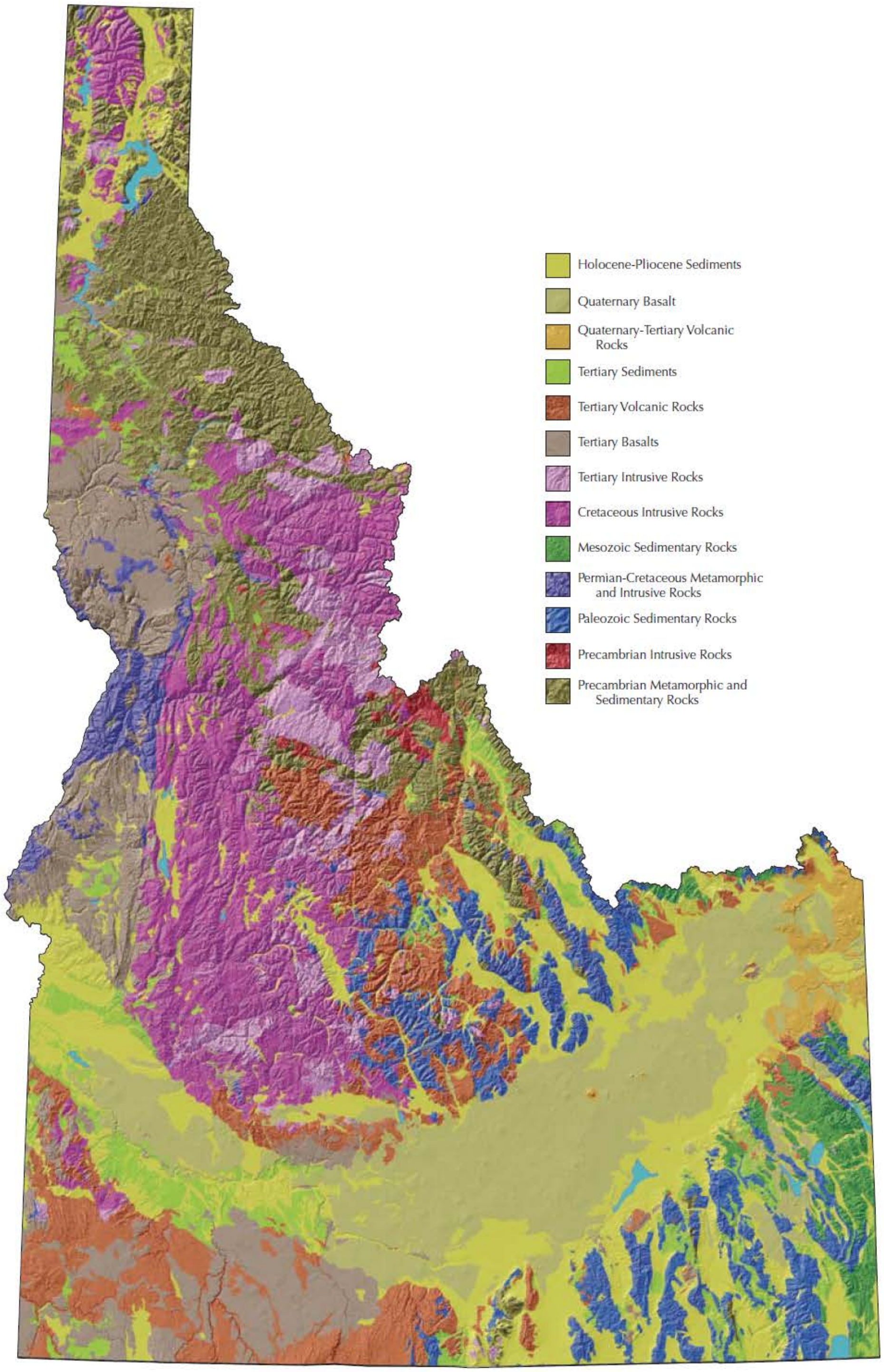

Figure 2-2. Geology types of Idaho (Source: Idaho State University Department of Geosciences[1])

[1] http://geology.isu.edu/Digital_Geology_Idaho/Intro/Geology_Idaho.pdf

A variety of metamorphic rocks are associated with the Idaho Batholith consisting mostly of the Belt Supergroup rocks of Precambrian Age (more than 600 million years old). These rocks are dominantly schist, gneiss, siltite, argillite, and quartzite that are located near the margins of the granitics and probably represent the metamorphism associated with the intrusions. The Belt Supergroup rocks were laid down in a seabed and subsequently metamorphosed. Metasedimentary rocks form sandy loam, loam, and silt loam textured soils. Rock fragment content and hardness depend upon the degree of the rock's chemical weathering. Parent materials derived from metasedimentary rocks are divided into two groups according to the amount and hardness of rock fragments. These properties affect the erodibility of soils formed in these parent materials. Weakly weathered metasedimentary rocks have subsoils and substrata resistant to erosion and can be identified by containing many angular rock fragments. Micaceous schist soils tend to have weak subsoil clay accumulations and are resistant to erosion; however, these soils are prone to mass wasting. Well-weathered quartzite geologies have very highly erodible subsoils and substrata.

The Seven Devils Volcanics were extruded in the southwestern part of the Nez Perce National Forest and are of Permian and Triassic Age (208 to 286 million years old). These volcanics are intensely folded and faulted metamorphosed rhyolitic rock flows associated with shale and limestone. Rhyolitic rocks are mostly hard, well-fractured andesite. Soil derived from rhyolitic rocks is loamy and contains many hard, angular rock fragments. Subsoil clay accumulations are associated with rhyolitic rocks.

In the western part of the Nez Perce National Forest, basalt flows formed plateaus. Miocene basalt flows (13 to 25 million years old) overlie portions of the western part of the Clearwater National Forest and the southwestern corner of the Nez Perce National Forest. Basalt is hard, commonly well-fractured bedrock. Soil derived from basalt is loamy and contains many hard, angular or subangular rock fragments. Soil with subsoil clay accumulations is associated with basalt.

Topography

Riparian areas on the Forests are dominated by stream bottoms, stream terraces, alluvial fans, and nivational hollows. Stream bottoms are nearly level, slightly concave areas near streams containing stream flood plains, low terraces, and alluvial fans. These landforms are long and narrow. Lower soil layers are porous and gravelly. Soils have fluctuating water tables. Stream terraces and alluvial fans are nearly level to gently sloping deposits of alluvial material along rivers. Stream terraces are flat to slightly concave step-like benches with short, steep descending slopes facing the stream. Lower soil layers are gravelly and permeable. Alluvial fans are cone-shaped deposits at the mouths of steeply graded streams. Materials may be stratified and contain many rock fragments. Stream terraces and alluvial fans can deliver sediment to streams efficiently because of proximity to higher-order streams. Limitations due to flooding, high water tables, and proximity to major streams are associated with these deposits. Nivational hollows are depressions on northerly aspects of high elevation mountain slopes that form the upper reaches of drainageways. These hollows have a teardrop shape in outline, with the narrow end downslope. Slopes are concave with gradients of 10%–45%. Their origins are thought to be related to snow accumulation on the lee side of ridges in periglacial climates.

Rolling foothills and uplands consist of low-relief rolling foothills. Slope gradients are straight to convex and generally <50%. Soils usually have a volcanic ash surface overlying deep, weakly developed, nonskeletal subsoils. This landtype association is highly productive and intensely managed for timber production. Slope gradients and aspects are complex; and combinations of tractor and cable yarding are needed to harvest timber. Many forest roads built on this landform have a high potential to contribute sediment to the channels.

Plateaus are broad, undulating rolling hills and mountain summits. Slopes are straight to slightly convex with gradients of <30%. Ancient alluvium and Palouse loess of varying thickness overlie the basalt. Soils are silty textured with a thick ash cap and are well developed. These lands are highly productive and have few silvicultural limitations. Plateaus deliver sediment to streams inefficiently because of gentle slopes and widely spaced channels. Road limitations include rutting and subsequent erosion during wet periods.

Mountain slopes and ridges are complexes of narrow to broadly rounded ridges and steep mountainsides. Bedrock is moderately weathered at lower elevations and weakly weathered at higher elevations. Slopes are steep, dissected, and straight to slightly convex at lower elevations. Slopes become broad and rounded with few stream dissections at higher elevations with gradients of 5%–60%. Soils are moderately deep, to deep, and are usually covered with an ash cap. Coarse fragment content increases with elevation and reaches 75% on higher ridges. Productivity is moderate to high at the lower elevations, depending on aspect, and low to moderate at higher elevations. Silvicultural limitations and opportunities are wide ranging due to the variation in soils, climate, and vegetation. Lower slopes are moderately stable with localized zones of mass instability. Stability increases with elevation; the broad, rounded upper ridges are among the most stable lands on the Forests. Mountain slopes deliver sediment to streams efficiently because of moderately steep, to steep straight slopes and channels that are relatively close together. Mountain ridges deliver sediment to streams inefficiently because of gently sloping, broadly convex slopes and widely spaced streams. Many forest roads built on this landform have the potential to contribute sediment to streams.

The mountains with the highest elevations were glaciated by alpine glaciers. Alpine glaciation produced a distinctive landscape dominated by glacial cirques, U-shaped glacial valleys, and broad glaciated mountain ridgetops. Elevations are over 5,500 feet and usually over 6,000 feet except in the bottom of deep troughs. Alpine lakes are common. Bedrock is scoured and very weakly weathered, with rock outcrop occupying a large percentage of the unit. Soils have developed in glacial tills of varying depths, but they are predominantly shallow and excessively well drained. Most glacial till is of local origin, and characteristics of the local bedrock determine its properties. Tills derived from granitic rocks have sandy textures. Tills derived from basalt, andesite, and Tertiary sediments have loamy textures. Glacial till occurs on moraines, in glacial trough bottoms, and on the lower slopes of glacial trough walls and cirque headwalls. Glacial till deposits ravel on steep road cutbanks. Most of this landtype is considered noncommercial because of poor site quality, difficult access, and high values for dispersed recreation.

Ice cap scoured and depositional lands occur on the southern and eastern portion of the Powell District. It consists of undulating uplands with low relief. The uplands are dissected by broad U-shaped valleys. Elevations for the uplands range between 5,000 and 6,000 feet with valley bottoms dropping to 4,000 feet. The entire area was overlain by a thick ice cap that caused scoured ridges and till deposition in draws and depressions. Bedrock is hard, fractured, and weakly weathered. Soils on scoured ridges have thick ash caps over moderate depth, stony, well-drained subsoils. Soils in draws and depressions are deep and commonly have compacted layers within 4 feet of the surface. Areas with compacted soils are poorly drained and wet much of the year. Management characteristics of this unit are dominated by large amounts of spring runoff and high water tables in areas with compacted tills. Water tables can be raised to or near the surface through vegetation removal. Surface soil erosion can be severe on disturbed soils with high water tables. Well-drained areas are quite stable and have few watershed problems. However, these areas are intermingled with poorly drained areas over much of the unit, complicating management potential.

Breaklands consist of steep slopes and drainageways adjacent to rivers and their tributaries. They have straight to concave slopes with gradients of 60% or more. The slopes are overly steep as a result of streams downcutting faster than the adjoining slopes could retreat. Elevation varies from 1,600 to 6,000 feet, and relief of several thousand feet is common. Bedrock is moderately to weakly weathered. Rock outcrop is common. Soils are colluvial and weakly developed and vary widely in properties. Soils on northerly aspects tend to be deep and skeletal with a mixed ash cap. On southerly slopes, soil depths vary from deep to <20 inches deep. Ash caps are thin or missing on shallow soils and are mixed on others. These lands are the most unstable on the Forests. Stability and the high cost of access limit management potential. Productivity varies from high on the northerly aspects to low or noncommercial for shallow droughty soils on southerly aspects. Regeneration is a problem on southerly slopes because of droughtiness and high soil temperatures. Breaklands deliver sediment to streams very efficiently because of steep slopes and closely spaced drainageways. The point where drainageways converge at the lower apex of the landform tends to accumulate sediment. This convergence may be a source of debris avalanches and flash floods. Many forest roads built on this landform have the potential to contribute sediment to the streams.

Climate and Biology

The climate of the area is dominated by prevailing westerlies which carry maritime air masses from the northern Pacific Ocean across the Northern Rockies during the winter and spring. Winter temperatures are 8–14 °C (15–25 °F) warmer than continental or East Coast locations of comparable latitude, except during Chinook periods, when locations east of the Continental Divide reach 10–16 °C (50–60 °F). Temperatures on the east side of the Northern Rocky Mountains are much more extreme at both ends of the scale. The mild, moderate winters are in part responsible for the productive forests of northern Idaho. Precipitation ranges from around 18 inches annually in the southwestern part of the Forest to about 100 inches annually near the Bitterroot Divide. Summers (specifically July and August) are very dry, usually <1 inch precipitation per month as a consequence of West Coast subtropical high pressure system shifting northward in late June causing the prevailing westerlies to carry dry subsiding air across northern Idaho. Most summer precipitation is associated with convectional storms; however, there are occasional “dry” thunderstorms, which constitute a severe fire hazard when coupled with dry fuels. Climatic conditions in mountainous areas are intensely variable over short geographic distances because of topographic effects on wind patterns and variability of elevation, slope, and aspect. The frost-free season can vary from about 160 days in canyon bottoms at elevations near 1,600 feet to <70 days on ridgetops at elevations near 10,000 feet. Night time temperatures below freezing can occur anytime at elevations above 6,000 feet. Frost pockets are common at lower elevations. They are caused by night time downslope winds. These cool air currents are heavier than surrounding warmer air and tend to collect in low-lying areas.

The soil temperature for the Forests is dominated by frigid and cryic soil temperature regimes. Frigid soils are warmer in summer than a soil with a cryic regime, but its mean annual temperature is lower than 8°C, and the difference between mean summer and mean winter soil temperatures (June-July-August and December-January-February) is more than 5 °C either at a depth of 20 inches from the soil surface or at a densic, lithic, or paralithic contact, whichever is shallower. Cryic soils have a mean annual and mean summer temperature higher than 0°C but lower than 8°C but do not have permafrost.

The soil moisture for the Forests is dominated by udic soil moisture regimes with areas of xeric regimes. The udic moisture regime is one in which the soil moisture control section is not dry in any part for as long as 90 cumulative days in normal years. In addition, the udic moisture regime requires, except for short periods, a 3-phase system, solid-liquid-gas, in part or all of the soil moisture control section when the soil temperature is above 5° C. The udic moisture regime is common to the soils of humid climates that have well distributed rainfall; have enough rain in summer so that the amount of stored moisture plus rainfall is approximately equal to, or exceeds, the amount of evapotranspiration; or have adequate winter rains to recharge the soils and cool, foggy summers, as in coastal areas. Water moves downward through the soils at some time in normal years. The xeric moisture regime is the typical moisture regime in areas of Mediterranean climates, where winters are moist and cool and summers are warm and dry. The moisture, which falls during the winter, when potential evapotranspiration is at a minimum, is particularly effective for leaching.

The kind and amount of vegetation that grows on a soil over a long period of time has a strong influence on the amount of organic matter in the soil. The survey area is predominantly coniferous forest. Soils formed under dense forests have a layer of litter and duff overlying light colored mineral soil or thin layers of mineral soil darkened by accumulation of organic matter. Soils under moist forest openings or open-canopied forests on steep southerly aspects have thicker dark colored surface layers. Plant communities dominated by alder, ferns, western coneflower, or grasses add humus to the soil. Southerly aspects at low and mid elevations in the Salmon River drainages are dominated by grasslands. Soils under grasslands tend to develop deep surface horizons with a high amount of organic matter accumulation to the depth of roots.

Soil Taxonomy

The system of soil classification used by the National Cooperative Soil Survey (NCSS) has six levels. Beginning with the broadest, these categories are order, suborder, great group, subgroup, family, and series. Each level of taxonomy gives more detailed information about the soils. The dominant soil orders found in the Forests are Inceptisols, Mollisols, and Alfisols. Inceptisols are soils with poorly developed characteristics. Mollisols are grassland soils with thick dark surface horizons. Alfisols are soils that have clay-enriched subsoils and high base saturation. While volcanic ash plays an important role in the soils of the forest, the soils do not have ash depths that would classify to Andisols. Many soils are within Andic and Vitrandic suborder, great group, or subgroups. The soils of the Forests were mapped to the family level.

Current Forest Service Direction for Soil Management

Soil quality management on the Nez Perce–Clearwater National Forests is guided by nNational and regional direction found in the Forest Service Manual (FSM) Chapter 2550 Soil Management and Chapter 2550 Region 1 Soil Management Supplement (1999) Soil Quality Standards (SQS).

Soil disturbance has been the focus of soil management on NFS lands for many years. The two existing Forest Plans for the Forests place disturbance caps on management activities. While the limits are different, the goal for each is the same: to maintain the productivity of the land. The effort was continued with the FSM Chapter 2550 Region 1 Soil Management Supplement, which placed a detrimental soil disturbance cap of 15% on management activities. Detrimental soil disturbance (DSD) is defined as disturbances, including the effects of compaction, displacement, rutting, severe burning, surface erosion, loss of surface organic matter, and soil mass movement that indicate when changes in soil properties and soil conditions would result in significant change or impairment of soil quality.

In 2010, FSM Chapter 2550 Soil Management was revised at the national level. The emphasis of soil management was changed to an approach focusing on long-term soil quality and ecological function instead of disturbance tracking. The FSM defines 6 soil functions: soil biology, soil hydrology, nutrient cycling, carbon storage, soil stability and support, and filtering and buffering. The objectives of the national direction are 1) to maintain or restore soil quality on National Forest System lands and 2) to manage resource uses and soil resources on National Forest System lands to sustain ecological processes and function so that desired ecosystem services are provided in perpetuity.

2.2.2.2 **Trends and Drivers**

- Identify important attributes or characteristics of soils and sites that make them susceptible to loss of integrity because of specific uses, disturbances, or environmental change.
- Identify existing impairments, such as critical loads, acidification, or invasive species impacts.

Sensitive Soils

Certain attributes associated with the soils on the Forests make them sensitive or susceptible to decreased soil quality and productivity. Sensitive soil properties on the Forest are the ash cap, organic surface horizons, grussic soils, and soils susceptible to mass wasting events.

The surficial volcanic ash deposits, or ash cap, of the soils on the Forest are instrumental to the high productivity of the Forests. The ash cap on the Forests is characterized by a low bulk density, high water holding capacity, and a high cation exchange capacity that can lead to a concentration of nutrients. The ash caps found on the Forests are in varying forms from thick mantles of pure ash to mixed layers of ash and weathered mineral soil derived from resident parent materials. The ash deposited on the Forests tends to be fine particles forming loam and silt loam textured soils. The high water holding capacity of the ash cap is arguably the most important feature of the ash cap locally (Figure 2-3). The ash was deposited over rocky and sandy coarse textured soils with relatively low water holding capacities in north and central Idaho and therefore the majority of the plant-available water in this landscape is held in the ash cap.

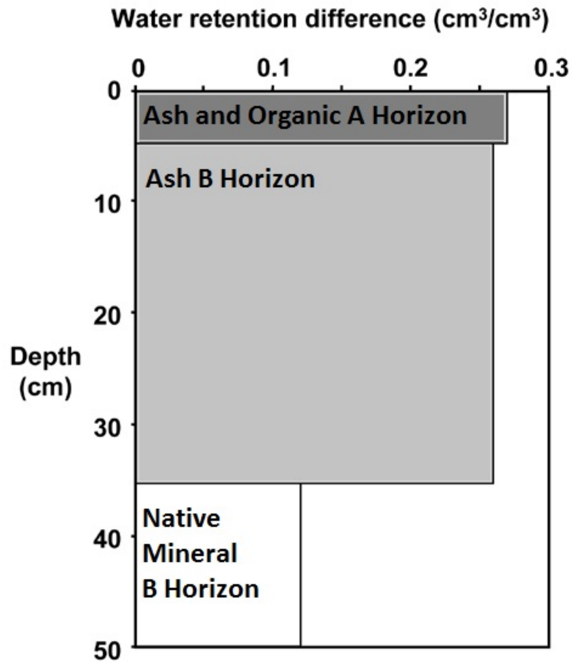

Figure 2-3. Water-holding capacity of ash versus mineral soil (adapted from Page-Dumroese et al. 2007)

Ash caps are extremely susceptible to decreased soil quality due to compaction, erosion, and soil mixing. Ashy soils have low soil bearing capacity and therefore compact very easily within a large range of soil moisture levels. Compaction causes a restriction to plant rooting, lowered water-holding capacity, and lowered infiltration rates. Ashy soils also do not recover from compaction as quickly as other soil types. Several hypotheses exist regarding the slower recovery times, including the low amounts of clay and therefore limited natural shrink and swell cycles or the possible physical locking of jagged edge ash particles during compaction.

Ash cap layers tend to be resistant to erosive forces when fully vegetated due to high infiltration rates and strong soil structure. When vegetation and litter layers are removed, the ashy surface is highly susceptible to severe erosion. The loss of the Mazama ash cap layer would reduce the water-holding capacity and increase the overall soil bulk density. These effects would decrease available soil moisture and tree root penetrability. The effects of mixing the ash cap with subsoil are similar and would result in comparable productivity decreases. Since volcanic ash is not replaced, the effects of erosional losses of the ash cap would be long term. Areas with ground disturbance may become more favorable for weed invasion, which could reduce overall soil productivity.

The soil organic layer is extremely important to all soils on the Forests, especially those formed from low-nutrient geologies like granite. Soil organic matter is fundamentally important to sustaining soil productivity. Soil organic matter is influenced by fire, silviculture activities, and decomposition and accumulation rates. The organic component of soil is a large reserve of nutrients and carbon and is the primary site for microbial activity. Forest soil organic matter influences many critical ecosystem processes, including the formation of soil structure. Soil structure influences soil gas exchange, water infiltration rates, and water-holding capacity. Soil organic matter is also the primary location for nutrient recycling and humus formation, which enhances soil cation exchange capacity and overall fertility. Soil organic matter depends on inputs of biomass (e.g., vegetative litter, fine and coarse woody debris) to build and maintain the surface soil horizons, support soil biota, enhance moisture-holding capacity, and prevent surface erosion. Woody debris in the form of slash provides a practical and effective mitigation for reducing harvest impacts on soil physical function and processes. The retention of coarse (>3 inches in diameter) woody debris is essential to maintaining soil organic matter, soil productivity, and sustainable forest ecosystems.

The third group of sensitive soils on the Forests is soils formed from grussic granitics. Weathered granitics (grus) are granitic rocks that have rock structure, are soft, and can be dug with a spade. Soil derived from these rocks contains large amounts of fine gravel-sized particles of weakly consolidated rock. Many of these particles can be crushed with the fingers. The lower soil layers are formed in weathered granitic rock in places and are relatively impermeable to roots and water. The layers rapidly break into a mixture of pea-sized gravel and sand when exposed by excavation. These parent materials generally occur on rolling uplands and are associated with erodible subsoils and very erodible lower soil layers. Lower soil layers formed in weathered granitic rocks are very difficult to revegetate when exposed. These soils are typically noncohesive coarse textured soils that are susceptible to erosion and mass wasting. These grus soils are droughty with low water- and nutrient-holding capacities; therefore, keeping the thin surface organic layer intact is extremely important.

The final sensitivity group comprises landslide prone soils. Forest soils that have high mass wasting hazards are considered landslide prone. Landslide is the general term used to describe several mass wasting events including slides, slumps, soil creep, flows, topples, and falls of soil and rock. A slide is a rapid movement of a large mass of earth and rocks down a hill or a mountainside. Little or no flowage of the materials occurs on a given slope until heavy rain and resultant lubrication by the same rainwater facilitate the movement of the materials, causing a slide to occur. Slumps consist of a slipping of coherent rock material along the curved surface of a decline. Slumps involve a mass of soil or other material sliding along a curved surface (shaped like a spoon). It forms a small, crescent-shaped cliff, or abrupt scarp at the top end of the slope. More than one scarp can exist down the slope. Soil creep is a long-term process. The combination of small movements of soil or rock in different directions over time are directed by gravity gradually downslope. The steeper the slope, the faster the creep. The creep makes trees and shrubs curve to maintain their perpendicularity, and they can trigger landslides if they lose their root footing. The surface soil can migrate under the influence of cycles of freezing and thawing, or hot and cold temperatures, inching its way toward the bottom of the slope forming terracettes. Flows are movement of soil and regolith that more resembles fluid behavior. These include avalanches, mudflows, debris flows, earth flow, lahars, and sturzstroms. Water, air, and ice are often involved in enabling fluid-like motion of the material. Topples are instances when blocks of rock pivot and fall away from a slope. A fall, including rockfall, is where regolith cascades down a slope, but is not of sufficient volume or viscosity to behave as a flow. Falls occur with rocks that are characterized by presence of vertical cracks. They usually occur at very steep slopes such as a cliff face. The rock material may be loosened by earthquakes, rain, plant-root wedging, and expanding ice, among other things. The accumulation of fallen rock material residing at the base of the structure is known as talus.

Landslides are mostly likely to occur in areas where they have already occurred in the past. In many cases, the landscape features surrounding a location where recent landslide catastrophes have occurred, provide evidence of past and ongoing landslide activity. Landsliding is part of the processes behind the evolution of the landscape. Landslides are triggered by earthquakes, major storms, volcanic activity, or other natural or human-induced activities that may cause the earth to move. The additional weight of storm rains or snow melt can cause slopes to fail or reactivate older landslides.

Several definitions distinquish unstable soils on the Forests. There are hazard ratings for each Forest for mass wasting; and each Forest has defined landslide prone lands. The hazard ratings in the Nez Perce National Forest Soil Survey were based on the Level I Slope Stability Analysis (LISA) modeling program. Hazard ratings are based on application of the LISA model to dominant mid-slope soil, slope, moisture, and vegetation characteristics of each landtype. Landtypes with a factor of safety <1.00 have a High Hazard Rating; landtypes with a factor of safety from 1.00 to 1.20 have a Moderate Hazard Rating; and landtypes with a factor of safety >1.20 have a Low Hazard Rating. Most of the landtypes classified as landslide prone often have a range of hazard ratings from Moderate to High. The land areas modeled were assumed to be clear-cut prescription. Landtypes where concentrations of soil moisture increase the hazard from Moderate to High in these local zones, have a rating of High when Wet.

The Clearwater National Forest Land System Inventory assigned hazards for mass wasting potential in both rotational mass wasting and debris avalanches. The rotational mass wasting potential was developed based on slope gradient, presence of concentrated subsurface water, substratum texture, regolith depth, and presence of mica (Table 2-2). All landtypes with a history of mass wasting were also considered to have a High hazard rating. Debris avalanche ratings were developed based on the following properties: slope gradient, slope shape, topsoil texture, and occurrence of old slide scars and debris at the slope base (Table 2-3).

Table 2-2. Rotational mass wasting hazards for the Clearwater National Forest

	Low Hazard		Moderate Hazard				High Hazard				Very High Hazard	
Slope Gradient (%)	<40	40–60	<40		40–60	60+	40-60		60+		60+	
Dissections	Dry	No	Wet	Yes	Yes	All	Wet	Yes	No	Yes	Yes	Wet
Texture	All	Sandy loam and loamy sand	All	All	Sandy loam and loamy sand	All	All	Sandy loam and heavier	All	Sandy loam and loamy sand	Sandy loam and heavier	All
Regolith Depth (cm)	All	<150	>150	>150	>150	<150	>150	>150	>150	>150	>150	>150
Mica	All	No	All	Yes	No	No	All	Yes	All	No	Yes	All

Table 2-3. Debris torrent hazard for the Clearwater National Forest

	Low Hazard		Moderate Hazard		High Hazard	
Slope (%)	<40	40–60	40–60	60+	60+	
Slope Shape	Variable	Convex	Convex and Straight	Concave and Straight	Concave	Straight
Topsoil Texture	Variable	Clay loam and silt loam	Sandy loam and loamy sand	Silt loam and loam	Sandy loam and loamy sand	
Occurrence of Old Slides	Rare		Common		Many	

For the Nez Perce National Forest, landslide prone areas are defined as generally located on slopes over 60% and landslide deposit landtypes. Characteristics used to identify landslide-prone terrain on the Nez Perce National Forest are: steep (>60%) concave slopes; hydrophytic vegetation (e.g., sedges, moist site ferns, *Boykinia*); slumps, draws, and basins; past landslide locations; obvious soil movement areas (typically indicated by curved and/or buttressed tree boles, soil creep, tension cracks); and micaceous schist bedrock. Past landslide deposits are lobate deposits of material. Slip scarps and toes of small slumps give the surface of these deposits an irregular, hummocky appearance. Landslide deposits deliver sediment to streams efficiently because landslides may be reactivated and deposit sediment directly into closely spaced drainageway channels.

During storm and flood events in 1995 and 1996, over 860 landslides occurred across the Clearwater National Forest. A survey was conducted to review these landslides, and 5 factors were identified to assess the inherent risk of landslides on the Clearwater National Forest. The 5 factors are geologic parent material, elevation, aspect, slope angle, and landform (Table 2-4). The result of this study has been used to define landslide prone areas on the Clearwater National Forest. The majority of these landslides were triggered by a heavy rainfall season with rain-on-snow events. Over half of the landslides documented were associated with roads.

Table 2-4. Landslide hazard factors and hazard risk rating for the Clearwater National Forest

Factor	Type	Rating[a]
Geologic Parent Material	Border Zone metamorphics (1.06 slides/1,000 acres)	High
	Belt Series metasediments (0.56 slides/1,000 acres)	Moderate
	Idaho Batholith granitics (0.28 slides/1,000 acres)	Low
	Volcanics (0.16 slides/1,000 acres)	Low
	Sediments (0.16 slides/1,000 acres)	Low
Elevation	3001–3500 feet (1.66 slides/1,000 acres)	High
	Less than 2000 feet (1.65 slides/1,000 acres)	High
	2501–3000 feet (1.48 slides/1,000 acres)	High
	3501–4000 feet (1.10 slides/1,000 acres)	High
	2001–2500 feet (0.90 slides/1,000acres)	Moderate
	4001–4500 feet (0.85 slides/1,000 acres)	Moderate
	4501–5000 feet (0.50 slides/1,000 acres)	Low
	Above 5000 feet (few)	Low
Aspect	South (21.8% of the slides)	High
	Southwest (20.8%)	High
	West (16.8%)	Moderate
	Southeast (14.9%)	Moderate
	Northwest, north, northeast, east (few)	Low
Slope Angle	Greater than 56% (2.00 slides/1,000 acres)	High
	46%–50% slopes (0.73 slides/1,000 acres)	Moderate
	51%–55% slopes (0.59 slides/1,000 acres)	Moderate
	41%–45% slopes (0.43 slides/1,000 acres)	Low
	Less than 35% (few)	Low
Landform	Mass wasted slopes (1.72 slides/1,000 acres)	High
	Breaklands (1.12 slides/1,000 acres)	High
	Stream terraces/valley bottoms (0.70 slides/1,000 acres)	Moderate
	Colluvial midslopes (0.54 slides/1,000 acres)	Moderate
	Low-relief hills, frost-churned ridges (few)	Low

[a]High ≥1.0 slides/1,000 acres; Moderate = 0.5–1.0 slides/1,000 acres; Low ≤0.5 slides/1,000 acres

Ability of Soil to Maintain Ecological Functions

FSM Chapter 2550 Soil Management defines soil function as any ecological service, role, or task that soil performs. The FSM identifies 6 soil functions: soil biology, soil hydrology, nutrient cycling, carbon storage, soil stability and support, and filtering and buffering. Soil is the foundation of the ecosystem; in order to provide multiple uses and ecosystem services in perpetuity, these 6 soil functions need to be active.

Soil biology is the presence of roots, fungi, and microorganisms in the upper sections of the soil. Diversity of soil biology is beneficial for several reasons:

- The complex process of decomposition and nutrient cycling requires a varied set of microorganisms.
- An intricate group of soil organisms can compete with disease-causing organisms and prevent a problem-causing species from becoming dominant.

- Several organisms are involved in creating and maintaining the soil structure important to water dynamics in soil.
- Many antibiotics and other drugs and compounds used by humans come from soil organisms.
- Most soil organisms cannot grow outside of soil, so it is necessary to preserve healthy and diverse soil ecosystems to preserve beneficial microorganisms.

The soil biology attributes of note on the Forests are roots and aeration, plant community potential, and thermodynamics. Roots and aeration can be assessed by evaluating vertical and lateral root growth, root distribution, and porosity. Compaction and topsoil impacts affect the roots and aeration soil quality indicators. Plant community potential and thermodynamics can be evaluated using plant community composition and canopy and soil cover. Invasive species, loss of topsoil layers, and major changes in cover affect these soil quality indicators.

Soil hydrology is the ability of the soil to absorb, store, and transmit water, both vertically and horizontally. Soil hydrology is extremely important on the Forests because the ecosystem productivity is typically limited by water. Soil can regulate the drainage, flow, and storage of water and solutes, including nitrogen, phosphorus, pesticides, and other nutrients and compounds dissolved in the water. With proper functioning, soil partitions water for groundwater recharge and use by plants and animals. Infiltration, water absorption and storage, and water transmission can be assessed by using surface soil structure, surface pore structure, surface crusting, available water, and subsurface flow connectivity. Changes in soil bulk density, soil chemistry, soil structure, soil pores, and ground cover can alter soil hydrology. The main impacts to soil hydrology on the Forests are compaction, erosion, loss of vegetation cover, loss of ash cap, and hydrophobicity from severe burns. The historic soil impacts from past activities have affected soil hydrology especially in areas where road and trail densities are high.

Nutrient cycling is the movement and exchange of organic and inorganic matter back into the production of living matter. Soil stores, moderates the release of, and cycles nutrients and other elements. During these biogeochemical processes, analogous to the water cycle, nutrients can be transformed into plant available forms, held in the soil, or even lost to atmosphere or water. Soil is the major "switching yard" for the global cycles of carbon, water, and nutrients. Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled through soil. Decomposition by soil organisms is at the center of the transformation and cycling of nutrients through the environment. Decomposition liberates carbon and nutrients from the complex material making up life forms and puts them back into biological circulation so they are available to plants and other organisms. Decomposition also degrades compounds in soil that would be pollutants if they entered ground or surface water. Nutrient cycling can be assessed by considering organic matter composition on a site (forest and rangeland floor, fine and coarse woody material) and the nutrient availability (topsoil horizons and nutrient deficiencies). The major impacts to nutrient cycling are compaction and loss of organic matter and topsoil.

Nearly all the nitrogen (N) in forest systems is bound to organic matter. Very little of the total pool of N is available to plants; only about 2.5% of total organic N is released annually (Grigal and Vance 2000). The rate of N release from organic matter (a process called “mineralization”) is controlled by microbial decomposition, which in turn is controlled by environmental factors as well as the amount and chemical composition of organic matter

(Drury et al. 1991, Grigal and Vance 2000). Rates of mineralization are highly spatially variable within stands (Campbell and Gower 2000). The availability of N from organic matter has been said to “most often limit the productivity of temperate forests” (Hassett and Zak 2005). Logging residues are a source of N during early periods of stand growth after harvest (Mälkönen 1976, Hyvonen et al. 2000). Dead woody material left after logging provides carbon-rich material for microbes to feed upon; and typically microbial populations increase after forest harvests due to the input of logging residues. Microbes immobilize N in their tissues and limit losses that could otherwise occur through leaching or volatilization. As dead woody material gradually decomposes during the 15–20 years following harvest, microbial populations decline and slowly release the N to regrowing vegetation. A study in North Carolina found that nearly all the N and much of the phosphorous (P) that moved down through the litter layer into mineral soil was in organic forms as a result of microbial transformations of organic matter in the forest floor (Qualls et al. 1991). This indicates that some N and P can be moved from the litter layer into mineral soil where it may be stable for a longer period. P is another essential nutrient that is mainly supplied, in forms available to plants, by the microbial breakdown of organic materials. A deficiency of available P can limit plant metabolism of N, and some forests may be limited by P availability (Trettin et al. 1999). Inorganic P is often present in soil minerals, but under low-pH conditions often found in forest soils; soluble aluminum (Al) and iron (Fe) react with inorganic P to form insoluble compounds that are unavailable to most plants (Pritchett 1979). Sulfur (S), like N, occurs in soil primarily as organic compounds and is made available for plant growth through oxidation by microbes to sulfate forms (Fisher and Binkley 2000).

Carbon storage is the ability of the soil to store carbon. The carbon cycle illustrates the role of soil in cycling nutrients through the environment. More carbon is stored in soil than in the atmosphere and above-ground biomass combined. Soil carbon is in the form of organic compounds originally created through photosynthesis in which plants convert atmospheric carbon dioxide (CO2) into plant matter made of organic carbon compounds, such as carbohydrates, proteins, oils, and fibers. The organic compounds enter the soil system when plants and animals die and leave their residue in or on the soil. Immediately, soil organisms begin consuming the organic matter; extracting energy and nutrients; and releasing water, heat, and CO2 back to the atmosphere. Thus, if no new plant residue is added to the soil, soil organic matter will gradually disappear. If plant residue is added to the soil at a faster rate than soil organisms convert it to CO2, carbon will gradually be removed from the atmosphere and stored (sequestered) in the soil. It is unknown at this time as to how forest practices affect soil carbon storage. Research is looking into these questions. Compaction and loss of organic matter and topsoil can be assumed to affect carbon storage. For more information on soil carbon please see Section 4.0 Baseline Assessment of Carbon Stocks.

Soil stability and support is necessary to anchor plants and buildings. Soil is flexible (it can be dug) and stable (it can withstand wind and water erosion). Soil also provides valuable long-term storage options including protecting archeological treasures and land-filling human garbage. Inherent soil properties, like soil texture and particle size distribution, play a major role in physical stability. The need for structural support can conflict with other soil uses. For example, soil compaction may be desirable under roads and houses, but it can be devastating for the plants growing nearby. Soil has a porous structure to allow passage of air and water, withstand erosive forces, and provide a medium for plant roots. Soils also provide anchoring support for human structures and protect archeological treasures. The conflict of stability and support with plant growth capabilities is constant when dealing with roads, skid trails, recreation trails, and forest productivity. Support and stability can be assessed by evaluating risk of erosion and mass wasting and observing soil deposition. The main forest impacts to structure and stability are mass wasting, erosion, and loss of organic matter.

In filtering and buffering, soil acts as a filter to protect the quality of water, air, and other resources. Toxic compounds or excess nutrients can be degraded or otherwise made unavailable to plants and animals. The minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits. Soil absorbs contaminants from both water and air. Microorganisms in the soil degrade some of these compounds; others are held safely in place in the soil, preventing contamination of air and water. Wetlands soils especially function as nature's filters. Filtering and buffering on the Forests is impacted by chemical pollutants and industrial contamination at a very small scale.

With past forest practices there have been several impacts to soil functions. The soil functions are intertwined, making it difficult to discuss them separately. Several impacts can impair the majority of soil functions. These impacts are compaction, erosion, and loss of organic matter. While these impacts have not been eliminated in current practices, the Forest Service has decreased these types of effects substantially in management practices. This reduction of impacts, coupled with soil restoration activities, should show an increased capacity of the soils to provide multiple uses and ecosystem services in perpetuity.

Existing Impairments and Disturbances

Land use practices, such as grazing, logging, and mining, have been occurring on the Nez Perce–Clearwater National Forests since their creation. Impacts of these uses are evident in the soils today. In current day forest management, soil restoration is included in the majority of projects in order to meet the desired productivity for the land.

Grazing has been occurring on the lands that comprise the Forests since the 1860s. The largest herds of livestock on the Nez Perce National Forest were found in the late 1910s with about 14,000 cattle in 1919 and 70,500 sheep in 1918. The peak of sheep grazing on the Clearwater National Forest was in 1933 with 35,000 animals. Cattle grazing on the Clearwater National Forest has never seen the large numbers as on the Nez Perce National Forest. The effects of these large numbers of livestock can still be seen on the ground today. Long-term grazing of livestock has formed terraces on the steep slopes of grasslands in the White Bird area. The grazing has also caused long-term changes in the plant community dynamics in upland areas of the Forests. Livestock numbers have been adjusted to meet the capabilities of the land.

Timber harvest has been ongoing on the Forests at some level since their establishment. Harvesting methods and amounts have changed over time. The highest volumes were being removed off of the Forests sometime between the 1940s and 1970s. Some early mechanized logging practices on the Forests include Idaho Jammer Logging. This style of logging involved building parallel roads across the hillslope at spaces of 100 to 500 feet, which resulted in harvest units with up to 40% of the area in roads. Many of these roads remain on the landscape today. Over time, practices have evolved to be more conscious of the impacts to soils by shifting to less-impactive equipment (e.g., cable and skyline methods).

Soils across the forest have been disturbed by mining activities since the discovery of gold in the region. The soils of historic mining regions of the Forests such as Florence and Pierce have reduced productivity due to loss of topsoil and organic material, mixing of subsoil, and displacement. Mining practices have changed over time and operations are required to reclaim their areas of impact.

Fires are an important ecological driver for the Forests. Over history there have been several landscape scale fires throughout the Forests. Such fires, if hot enough, can cause damage to soils. When the organic layers are removed through fire, the soil is susceptible to erosion. In specific areas of the Forests, the majority of soils have eroded because of the fires of the early 1900s. Some of these soils are found in brushfields recovering from those historic fires.

2.2.2.3 Resource-Specific Information

Current Soil Inventories and Improvement Needs

Terrestrial Ecological Unit Inventories including soil mapping have been completed on both Forests in the 1970s and 1980s. Nez Perce National Forest Soil Mapping was completed in 1981–1986 by U.S. Forest Service soil scientists and ecologists. A local forest publication of the data was printed in 1987. In 2006, National Cooperative Soil Survey (NCSS) published a copy of the survey. The survey encompasses approximately 1.3 million acres of the Forest; Wilderness areas were not mapped. The Nez Perce National Forest soil survey has been correlated and entered into the National Soil Information System (NASIS) database and the Soil Survey Geographic Database (SSURGO). Information garnered during the joining efforts showed inconsistencies within the Nez Perce National Forest survey as well as inconsistencies with the Idaho County Survey.

The Clearwater National Forest Land System Inventory was completed in 1971–1979 by U.S. Forest Service soil scientists and additional staff. A local forest publication of the data was printed in 1983. The survey encompasses approximately 1.5 million acres of the Forest; Wilderness areas were not mapped. The Clearwater National Forest soil survey is currently being correlated and entered into NASIS and SSURGO by Natural Resources Conservation Service (NRCS).

Once all of the data has been entered into national databases the next step is updating the surveys and gathering more detailed information on soil series located on the Forests.

No Forest-wide inventories of soil improvement needs exist. Soil improvement needs have been identified on a project-by-project basis.

2.2.3 *Information Needs*

A comparable soil survey of the two Forests would be advantageous for land planning and consistency. Both Forests were mapped as landtype inventories with the NCSS soil mapping as a part of the process. The mapping relied heavily on plotting boundaries using aerial photography. Major features used for boundaries were landform, vegetation, geology, and elevation. The terms “map unit” and “landtype” were used synonymously. For example, Map Unit (Landtype) 22AH5 (NPNF) was delineated by identifying low-relief rolling uplands on 10%–30% slopes from granitic bedrock with cold, mixed coniferous forest in an elevation range of 4,800–6,200 feet. Field transects were completed on representative delineations of map units for the Nez Perce National Forest, and approximately 30% of the Clearwater

National Forest was ground verified. Physical and chemical soil samples were collected within the survey area and similar soils in adjacent areas. Soils were identified to the Family level of classification. Soil profiles were not compared to adjacent survey area soils for consistency. Interpretations found in surveys are not consistent with each other or the NRCS soil interpretations. Riparian soils are not mapped in either survey. Correlating and uploading the surveys to the national databases (NASIS and SSURGO) would allow the Forests to have a consistent approach moving forward with interpretations and land use planning calls. NASIS and SSURGO provide a dynamic resource of soils information for a wide range of needs with several soil interpretations that are currently not available on the Forests. The data systems consist of multiple interrelated soil applications and databases. This data system aids in the collection, storage, manipulation, and dissemination of soil information.

In addition to consistency, in order to perform analysis such as the Relative Effective Annual Precipitation (REAP) and complete modeling efforts, both surveys would need to be in NASIS and SSURGO. REAP analysis helps identify the sites most suitable for white pine and white-bark pine restoration that could be used in management area delineation. Many hydrological and erosion models use the soils layers as a critical dataset. The current layers do not provide an accurate, consistent data set for use in modeling efforts.

2.2.3.1 Research Needs:

Soil carbon effects from management activities are not well known at this time and most carbon sequestration modeling research assumes soil carbon is static. The assumption that soil carbon in soils is static has been proven untrue (Jandl et al. 2007; Lal 2005; Nave et al. 2010; Talbot and Treseder 2011). Research is ongoing.

Climate change effects on soil temperature and moisture regimes and soil biology are unknown at this time. Research into the potential changes that will likely occur would be useful.

2.2.4 *Literature Cited*

B. C. Ministry of Forestry, Canada. 2002. Forest soil conservation and rehabilitation in British Columbia. Southern Interior Forest Extension and Research. Forest Science Publication 70.

Brown, J. K., E. D. Reinhardt, and K. A. Kramer. 2003. Coarse woody debris: Managing benefits and fire hazard in the recovering forest. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Gen. Tech. Rep. RMRS-GTR-105. 16p.

Burger, J. A., and D. L. Kelting. 1999. Using soil quality indicators to assess forest stand management. Forest Ecology and Management, 122:155–166.

Campbell, J. L., and S. T. Gower. 2000. Detritus production and soil N transformations in old-growth eastern hemlock and sugar maple stands. Ecosystems, 3:185–192.

Drury, C. F., R. P. Voroney, and E. G. Beauchamp. 1991. Availability of NH_4^+-N to microorganisms and the soil internal N cycle. Soil Biology and Biochemestry, 23:165–169.

Fisher, R., and D. Binkley. 2000. Ecology and management of forest soils. 3rd edition. Wiley & Sons. New York, NY.

Graham, R. T., A. E. Harvey, M. F. Jurgensen, T. B. Jain, J. R. Tonn, and D. S. Page-Dumroese. 1994. Managing coarse woody debris in forests of the Rocky Mountains. U.S. Department of Agriculture, Forest Service, Intermountain Research Station. Research Paper. INT-RP-477.

Grigal, D. F., and E. D. Vance. 2000. Influence of soil organic matter on forest productivity. New Zealand Journal of Forestry Science, 30:169–205.

Harvey, A. E., M. J. Larsen, M. F. Jurgensen, and R. T. Graham. 1987. Decaying organic materials and soil quality in the Inland Northwest: A management opportunity. U.S. Department of Agriculture, Forest Service, Intermountain Research Station. General Technical Report INT-225.

Hassett, J. E., and D. R. Zak. 2005. Aspen harvest intensity decreases microbial biomass, extracellular enzyme activity, and soil nitrogen cycling. Soil Science Society of America Journal, 69:227–235.

Hyvonen, R., B. Olsson, H. Lundkvist, and H. Staaf. 2000. Decomposition and nutrient release from Picea abies (L.) Karst. and Pinus sylvestris L. logging residues. Forest Ecology and Management, 126:97–112.

Jandl, R., M. Lindner, L. Vesterdal, B. Bauwens, R. Baritz, F. Hagedorn, D. W. Johnson, K. Minkkinen, and K. A. Byrne. 2007. How strongly can forest management influence soil carbon sequestration? Geoderma, 137(3): 253–268.

Lal, R. 2005. Forest soils and carbon sequestration. Forest ecology and management, 220(1): 242–258.

Mälkönen, E. 1976. Effects of whole tree harvesting on soil fertility. Silva Fennica, 10:157–164.

Miller, R. E., J. D. McIver, S. W. Howes, and W. B. Gaeuman. 2010. Assessment of soil disturbance in forests of the interior Columbia River Basin: A critique. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Gen. Tech. Rep. PNW-GTR-811.

Nambiar, E. K. S. 1996. Sustained productivity of forests is a continuing challenge to soil science. Soil Science Society of America Journal, 60:1629–1642.

Nave, L. E., E. D. Vance, C. W. Swanston, and P. S. Curtis. 2010. Harvest impacts on soil carbon storage in temperate forests. Forest Ecology and Management, 259(5): 857–866.

Neary, D. G., K. C. Ryan, and L. F. DeBano, eds. 2005 (revised 2008). Wildland fire in ecosystems: Effects of fire on soils and water. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Gen. Tech. Rep. RMRS-GTR-42-Vol.4.

Page-Dumroese, D. S., M. F. Jurgensen, W. Elliot, T. Rice, J. Nesser, T. Collins, and R. Meurisse. 2000. Soil quality standards and guidelines for forest sustainability in northwestern North America. Forest Ecology and Management, 138:445–462.

Page-Dumroese, D. S., and M. F. Jurgensen. 2006. Soil carbon and nitrogen pools in mid- to late-successional forest stands of the northwestern United States: Potential impact of fire. Canadian Journal of Forest Research, 36:2270–2284.

Page-Dumroese, D. S., R. Miller, J. Mital, P. McDaniel, and D. Miller. 2007. Volcanic-ash-derived forest soils of the inland Northwest: Properties and implications for management and restoration. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-44. 220 p.

Page-Dumroese, D. S., A. Abbot, and T. Rice. 2009. National soil disturbance monitoring protocol. Volume 1 and 2: Rapid assessment, supplementary methods, statistics, data storage. U.S. Department of Agriculture, Forest Service. 95p.

Page-Dumroese, D. S., D. Neary, and C. Trettin, tech. eds. 2010. Scientific background for soil monitoring on National Forests and Rangelands: Workshop proceedings; April 29–30, 2008; Denver, CO. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Proc. RMRS-P-59. 127p.

Powers, R. F. 1990. Are we maintaining productivity of forest lands? Establishing guidelines through a network of long-term studies. Proceedings in management and productivity of Western Montana forest soils. April 10–12, 1990. Boise, ID. GTR-INT-280.

Powers, R. F., A. E. Tiaks, and J. R. Boyle. 1998. Assessing soil quality: Practicable standards for sustainable forest productivity. Soil Science Society of America, Special Publication, 53:53–80.

Powers, R. F. 2002. Effects of soil disturbance on the fundamental, sustainable productivity of managed forest. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. Gen. Tech. Rep. PSW-GTR-183:63–82.

Powers, R. F., F. G. Sanchez, D. A. Scott, and D. S. Page-Dumroese. 2004. The North American long-term soil productivity experiment: Coast-to-coast findings from the first decade. U.S. Department of Agriculture, Forest Service RMRS-P-34:191–206.

Powers, R. F., D. A. Scott, F. G. Sanchez, R. A. Voldseth, D. S. Page-Dumroese, J. D. Elioff, and D. M. Stone. 2005. The North American long-term soil productivity experiment: Findings from the first decade of research. Forest Ecology and Management, 220:31–50.

Pritchett, W. L. 1979. Properties and management of forest soils. Wiley & Sons. New York, NY. 500 p.

Qualls, R. G., B. L. Haines, and W. T. Swank. 1991. Fluxes of dissolved organic nutrients and humic substances in a deciduous forest. Ecology, 72: 254–266.

Reeves, D., D. S. Page-Dumroese, and M. Coleman. 2011. Detrimental soil disturbance associated with timber harvest systems on National Forests in the Northern Region. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Res. Pap. RMRS-RP-89. 12 p.

Schnepf, C., R. T. Graham, S. Kegley, and T. B. Jain. 2009. Managing organic debris for forest health. Moscow, ID: University of Idaho. Pacific Northwest Extension Publication. PNW 609.

Schoenholtz, S. H., H. Van Miegroet, and J. A. Burger. 2000. A review of chemical and physical properties as indicators of forest soil quality: Challenges and opportunities. Forest Ecology and Management, 138:335–356.

Talbot, J. M., and K. K. Treseder. 2011. Ecology: Dishing the dirt on carbon cycling. Nature Climate Change, 1(3), 144–146.

Trettin, C. C., D. W. Johnson, and D. E. Todd, Jr. 1999. Forest nutrient and carbon pools at Walker Branch Watershed: Changes during a 21-year period. Soil Science Society of America Journal, 63:1436–1448.

USDA Natural Resources Conservation Service. 2006. Soil survey of the Nez Perce National Forest area, Idaho. 259p.

Wilson, D., J. Coyner, and T. Thomas. 1983. Land system inventory: First review draft, Clearwater National Forest. Orofino, ID: U.S. Department of Agriculture, Forest Service, Clearwater National Forest. 399p.

2.3 Water Resources and Quality

2.3.1 *Existing Information*

The Water Quality Division of the Idaho Department of Environmental Quality (IDEQ) is responsible for ensuring that Idaho's surface, ground, and drinking water resources meet State water quality standards. A memorandum of understanding (MOU) has been established to document coordination between IDEQ and the USDA Forest Service in Idaho (13-MU-11046000-023). IDEQ's Web site[2] has numerous water quality–related reports, documents, maps, peer-reviewed literature, and brochures and links to regulations. The Idaho Department of Water Resources (IDWR) is responsible for overseeing the implementation of Idaho's Stream Channel Protection Act. An MOU has been established to document cooperation between the USDA Forest Service and the IDWR for implementation of the Act (13-MU-11046000-014).

The main surface water quality report prepared by IDEQ is the biennial Clean Water Act (CWA) 303(d)/305(b) Integrated Report, the most recent of which was prepared in 2010 (IDEQ 2011). IDEQ is reviewing the public comments on the 2012 Integrated Report. IDEQ hopes to have the report approved by EPA in 2014. Once the 2012 Integrated Report is approved, it will supersede the 2010 report (IDEQ 2011). The Forest will utilize the most recent EPA-approved Integrated Report.

For waters that have pollutant impairments, the IDEQ or its contractors prepare a subbasin assessment and total maximum daily load (TMDL) assessment. Impaired waters without a completed TMDL are assigned to Category 5 of the CWA Section 303(d) list. Waters with impairments that have approved TMDLs are listed in Category 4a of the CWA Section 303(d) list. The following assessments were prepared for watersheds on the Forests:

- Lochsa River Subbasin Assessment (Bugosh 1999)
- Upper North Fork Clearwater River Subbasin Assessment and Total Maximum Daily Load (IDEQ 2003a)
- Lower North Fork Clearwater River Subbasin Assessment and TMDL (Henderson 2002)
- South Fork Clearwater River Subbasin Assessment and Total Maximum Daily Load (Dechert and Woodruff 2003)
- Cottonwood Creek Total Maximum Daily Load (TMDL) (IDEQ et al. 2000)
- Upper Hangman Creek Subbasin Assessment and Total Maximum Daily Load (IDEQ 2007c)
- Little Salmon River TMDL (IDEQ 2006)
- Lolo Creek Tributaries SBA and TMDL (IDEQ 2011)
- Palouse River Tributaries Subbasin Assessment and TMDL (Henderson 2005)
- South Fork Palouse River Watershed Assessment and TMDLs (IDEQ 2007b)
- Potlatch River Subbasin Assessment and TMDLs (IDEQ 2008)

[2] http://www.deq.idaho.gov/water-quality.aspx

- Lower Salmon River and Hells Canyon Tributaries Assessments and TMDLs (IDEQ 2010)
- Middle Salmon River–Chamberlain Creek Subbasin Assessment and Crooked Creek Total Maximum Daily Load (Shumar 2002)
- Middle Salmon River–Panther Creek Subbasin Assessment and TMDL (IDEQ 2001h)
- Lower Selway River Subbasin Assessment (Bugosh 2000)
- Snake River–Hells Canyon Total Maximum Daily Load (TMDL) (IDEQ and ODEQ 2004)

For each of the watersheds with a developed TMDL, the IDEQ works with local landowners to develop a TMDL Implementation Plan. The following watersheds have implementation plans:

- Lower North Fork Clearwater River Subbasin TMDL Implementation Plan (CSWCD 2004)
- South Fork Clearwater River TMDL Implementation Plan (South Fork Clearwater River Watershed Advisory Group 2006)
- Little Salmon River Total Maximum Daily Load Implementation Plan for Agriculture, Forestry, and Urban/Suburban Activities (Little Salmon Advisory Group 2008)
- Potlatch River Subbasin Total Maximum Daily Load Implementation Plan for Agriculture (ISCC 2010)
- Middle Salmon River–Panther Creek Subbasin Assessment and TMDL (IDEQ 2001h)
- Snake River–Hells Canyon Total Maximum Daily Load (IDEQ and ODEQ 2004)

The following are reports on groundwater aquifers, monitoring wells, and groundwater management plans:

- Idaho’s Groundwater Quality Plan: Protecting Groundwater Quality in Idaho (Ground Water Quality Council 1996)
- Camas Prairie Nitrate Priority Area Groundwater Quality Management Plan (IDEQ and ISCC 2008)
- Conservation Strategy for Idaho Panhandle Peatlands (Lichthardt 2004)

The Forests have numerous community and public drinking water supply points of diversion. The 3 designated municipal drinking water supply watersheds are City of Elk River, Clearwater Water Association (Wall Creek), and Elk City Water District (American River). All but the City of Elk River have a municipal watershed protection plan developed with the Forests. The IDEQ has numerous drinking water assessments for drinking water facilities on the Forests or for communities that derive their drinking water from sources on the Forests:

- Big Eddy Marina, Clearwater County, Idaho PWS #2180007 Source Water Assessment Report (IDEQ 2001a)
- Dworshak Power House, Clearwater County, Idaho PWS #2180009 Source Water Assessment Report (IDEQ 2001d)
- Freeman Creek Campground, Clearwater County, Idaho PWS #2180010 Source Water Assessment Final Report (IDEQ 2001e)

- City of Elk River (PWS 2180013) Source Water Assessment Final Report (IDEQ 2005)
- Konkolville (Surface Water) PWS #2180019 Source Water Assessment Final Report (IDEQ 2001f)
- City of Orofino (Surface Water) PWS #2180024 Source Water Assessment Final Report (IDEQ 2001b)
- Riverside Independent Water District (Surface Water) PWS #2180032 Source Water Assessment Final Report (IDEQ 2001m)
- USFWS Dworshak National Fish Hatchery, Clearwater County, Idaho PWS #2180035 Source Water Assessment Final Report (IDEQ 2002p)
- USFS Canyon Work Center (PWS #2180041) Source Water Assessment Final Report (IDEQ 2001l)
- USFS Kelly Forks Work Center (PWS #2180046) Source Water Assessment Final Report (IDEQ 2001i)
- USFS Musselshell Work Center (PWS #2180047) Source Water Assessment Final Report (IDEQ 2001j)
- Clearwater Water District (Surface Water) PWS # 2250011 Source Water Assessment Report (IDEQ 2001c)
- Lochsa Lodge (PWS #2250035) Source Water Assessment Final Report (IDEQ 2001g)
- USFS Powell Campground (PWS #2250052) Source Water Assessment Final Report (IDEQ 2001n)
- USFS Lochsa Historical Visitor and Work Camp (PWS #2250074) Source Water Assessment Final Report (IDEQ 2002i)
- USFS Wendover Campground (PWS #2250081) Source Water Assessment Final Report (IDEQ 2002m)
- USFS Whitehouse Campground (PWS #2250082) Source Water Assessment Final Report (IDEQ 2002n)
- USFS Wilderness Gateway Campground (PWS #2250085) Source Water Assessment Final Report (IDEQ 2002o)
- City of Juliaetta (Surface Water) PWS #2290018 Source Water Assessment Final Report (IDEQ 2001o)
- USFS Giant White Pine Campground (PWS #2290051) Source Water Assessment Final Report (IDEQ 2002e)
- USFS Laird Park Campground (PWS #2290052) Source Water Assessment Final Report (IDEQ 2002g)
- USFS Little Boulder Creek Campground (PWS #2290053) Source Water Assessment Final Report (IDEQ 2002h)
- City of Kamiah (Surface Water) PWS #2310003 Source Water Assessment Report (IDEQ 2002a)
- City of Lewiston (Surface Water) PWS #2350014 Source Water Assessment Final Report (IDEQ 2002b)

- Elk City Water and Sewer Association (Surface Water) PWS #2250017 Source Water Assessment Final Report (IDEQ 2002c)
- USFS Fenn Ranger Station and YCC Camp (PWS 2250091) Source Water Assessment Final Report (IDEQ 2003b)
- USFS O'Hara Bar Campground (PWS #2250098) Source Water Assessment Final Report (IDEQ 2002j)
- USFS Red River Campground (PWS #2250101) Source Water Assessment Final Report (IDEQ 2002l)
- USFS Red River Ranger Station (PWS 2250102) Source Water Assessment Final Report (IDEQ 2003c)
- USFS Slate Creek Ranger Station (PWS 2250105) Source Water Assessment Final Report (IDEQ 2001k)
- USFS Pittsburg Landing Campground (PWS #2250111) Source Water Assessment Final Report (IDEQ 2002k)
- USFS Hazard Lake Campground (PWS #2250118) Source Water Assessment Final Report (IDEQ 2002f)
- USFS Castle Creek Work Center and Campgrounds (PWS #2250088) Source Water Assessment Final Report (IDEQ 2002d)

IDEQ also prepares an audit of best management practices (BMPs) designed to protect water quality on National Forest System lands where silviculture practices are implemented. The 2004 Interagency Forest Practices Water Quality Audit (IDEQ 2007a) is the most current report. The first audit report was prepared in 1985, and subsequent reports were prepared every 4 years between 1988 and 2012.

The Forest Service also maintains several streamflow gage stations, bedload sampling stations, turbidity monitoring stations, precipitation gauges, and hundreds of stream temperature monitoring stations. These data are maintained in the Natural Resources Information System (NRIS) database and by Forest Service resource specialists. Additional analyses of existing streamflow and sediment transport data were included from a regionwide report developed by the U.S. Geological Survey:

- Sediment transport in the lower Snake and Clearwater River Basins, Idaho and Washington, 2008–11 (Clark et al. 2013)
- Estimating monthly and annual streamflow statistics at ungaged sites in Idaho (Hortness and Berenbrock 2001)

2.3.2 *Informing the Assessment*

For the water resource and quality, the best available science was used to inform the assessment. The data and reports provide background information on the current and historic water quality conditions across the Forests. These reports also provide information on restoration opportunities as well as sensitive areas that require further protection.

2.3.2.1 Current Conditions

Surface Water Quantity

Three major river systems have watersheds that originate on the Nez Perce–Clearwater National Forests: the Salmon River, the Clearwater River, and the Palouse River, all of which terminate at the Snake River.

The Salmon River is an unregulated, free-flowing river that originates in mountain ranges in Idaho and western Montana and flows about 410 miles through central Idaho before joining with the Snake River in lower Hells Canyon. The Salmon River derives its streamflow from several tributaries, including the Lemhi, Pahsimeroi, Middle Fork Salmon, South Fork Salmon, and Little Salmon rivers. Peak flows in the Salmon River generally occur in May and June during snowmelt runoff. Between 1975 and 2010, the Salmon River discharged, on average[3], about 10,700 ft^3/s of water to the Snake River. The Salmon River contributes about 22% of the combined streamflow entering Lower Granite Reservoir from the Snake and Clearwater rivers (Clark et al. 2013).

About 90% of the Salmon River Basin is comprised of federal lands, including about 77% national forest, managed by the U.S. Forest Service, and 13% other land, managed by the Bureau of Land Management. Nearly 80% of the land cover is forest in the Salmon River Basin; agricultural and urban areas together account for <3% (Clark et al. 2013). Key geologic features in the Salmon River Basin are the Idaho Batholith and Challis volcanics that tend to produce coarse, sandy soils that are highly erodible when weathered (King et al. 2004, cited in Clark et al. 2013). The erodible geology, steep topography, and lack of hydrologic control structures result in high erosion and sediment production and transport from the Salmon River Basin to downstream waters. Numerous uncharacteristically large and severe forest fires that burned large areas of the basin between 1980 and 2010 have increased the susceptibility of the Salmon River Basin to erosion (Clark et al. 2013).

The Clearwater River originates in the Bitterroot Mountains at the border of Idaho and Montana and flows westward to its confluence with the Snake River at Lewiston, Idaho. Major tributaries to the Clearwater River include the Lochsa and Selway rivers, the North Fork and South Fork of the Clearwater River, and the Potlatch River. Dworshak Dam effectively traps most of the sediment transported from the North Fork Clearwater River drainage basin before the sediment reaches the mainstem Clearwater River. From 1975 through 2010, the Clearwater River contributed about 30% of the streamflow (as measured at Spalding) entering Lower Granite Reservoir. Streamflow in the Clearwater River typically peaks in May and June in response to snowmelt runoff. Highly erodible igneous rocks underlay a large part of the Clearwater River Basin (King et al. 2004, cited in Clark et al. 2013). As a result, much of the basin is highly susceptible to erosion and subsequent sediment transport. Overall, cropland and pastureland make up about 18% of the Clearwater River Basin (Tetra Tech 2006, cited in Clark et al. 2013).

The Lochsa and Selway rivers combined drain about 46% of the Clearwater River Basin,

[3] This is the average, annual, instantaneous discharge rate for all years in the period. Each yearly average is the average of all average daily flow rates for that year.

draining areas that are essentially 100% forested; the U.S Forest Service manages >95% of the land (Tetra Tech 2006, cited in Clark et al. 2013). Underlain by the Idaho Batholith, the Lochsa and Selway drainage basins are characterized by rock that weathers deeply to produce coarse, sandy soils; if disturbed, these soils have high erosion rates (King et al. 2004, cited in Clark et al. 2013).

The Potlatch River is the largest tributary (drainage basin of about 550 mi^2) to the lower Clearwater River Basin, entering the Clearwater River about 15 miles upstream of Lower Granite Reservoir. About 57% of the Potlatch River drainage basin is forested, mostly in the northern upstream areas. Primary land uses in the forested areas include timber harvest and other forest management practices. The downstream part of the drainage basin is predominantly agricultural (about 43% of the total basin area), used primarily for dryland agriculture and grazing (Latah Soil and Water Conservation District 2007, cited in Clark et al. 2013). Land use activities in the drainage basin have caused changes in the vegetative cover, increases in soil compaction, and channel modifications that have resulted in a flashy hydrograph and rapid streamflow runoff (Latah Soil and Water Conservation District 2007, cited in Clark et al. 2013).

The Palouse River drains about 3,300 mi^2 of southeastern Washington and parts of the Idaho panhandle. The headwaters of the Palouse River originate in the forested mountains of northern Idaho; the river flows westward through farmland before joining with the Snake River about 48 miles downstream of Lower Granite Dam. Major tributaries to the Palouse River are the South Fork Palouse River and Paradise, Rebel Flat, Rock, Union Flat, and Cow creeks. Activities that affect water quality in the Palouse River Basin include dryland agriculture (67% of the drainage basin), rangeland (26%), timber harvest, mining, and urban development (Washington State Department of Ecology 2006, cited in Clark et al. 2013). Forested land comprises about 6% of the drainage basin, primarily in the upland northern and eastern parts. Agricultural fields throughout the basin are highly susceptible to erosion from November through March, when high-intensity rainstorms can cause intensive runoff and erosion. These winter storms can deliver large quantities of sediment to streams throughout the Palouse River drainage basin (Ebbert and Roe 1998, cited in Clark et al. 2013).

Surface Water Quality

Disturbances, including forest fires and roads (the construction, presence, and use of) are the primary source of sediment loading in the Salmon River subbasin (Goode et al. 2011). The current strategy is to ensure that Forest management actions continue to provide water quantity and quality that support recreational uses, healthy riparian and aquatic habitats, the stability and effective functioning of stream channels, and the ability to route flood flows. Approximately 1,443 miles of stream segments within the Forests have been listed as impaired or not meeting IDEQ standards (IDEQ 2011). The Forests contain 7,704 miles of streams, and nearly one-third of this mileage has yet to be assessed for water quality (Table 2-5).

Table 2-5. Stream mileage of water quality categories on the Nez Perce–Clearwater National Forests

Idaho 2010 305(b) Category	Clearwater National Forest	Nez Perce National Forest	Total
Fully Supporting	1,567	2,118	3,685
Not Assessed	1,124	1,083	2,207
Not Supporting			
303(d) Listed	369	0	369
Approved TMDL	331	1,112	1,443
TOTAL	3,391	4,313	7,704

The IDEQ has determined that numerous lakes and stream segments within several subbasins do not meet water quality standards for their designated and beneficial uses (Table 2-6). State antidegradation policy requires that existing beneficial uses be maintained and protected on all water bodies. TMDL assessments have been completed or are under development and are used as guidance to improve impaired conditions (Table 2-6). The Forest Service, together with land managers and landowners, is responsible for completing subbasin TMDL implementation plans within each of the subbasins listed in Table 2-6. The State of Idaho is the lead agency for TMDL development and approval. Sediment load and temperature are the primary concerns for water bodies on the Nez Perce-Clearwater National Forests.

Table 2-6. Lakes and streams not meeting standards

Subbasin	Hydrologic Unit Code (4th field HUC)	Pollutants
Clearwater River, North Fork (Upper) subbasin	17060307	Temperature
Clearwater River, North Fork (Lower) subbasin	17060308	Temperature Sediment
Clearwater River, South Fork subbasin	17060305	Temperature Sediment
Hangman Creek (Upper) subbasin	17010306	Sediment Bacteria Temperature
Little Salmon River subbasin	17060210	Temperature Bacteria
Lolo Creek Tributaries subbasin	17060306	Temperature
Palouse River Tributaries subbasin	17060108	Sediment Bacteria Temperature Nutrients
Potlatch River subbasin	17060306	Sediment Bacteria Temperature Nutrients
Salmon River (Lower) and Hells Canyon subbasins	17060209 17060101	Sediment Bacteria Temperature
Salmon River (Middle)—Chamberlain Creek subbasin	17060207	Temperature
Salmon River, Middle Fork subbasin	17060205	Temperature
Salmon River, South Fork subbasin	17060208	Temperature
Snake River—Hells Canyon subbasin	17060101 17050103 17050115 17050201	Temperature Nutrients Sediment Dissolved Oxygen Pesticides

Water temperature is the most common parameter not meeting water quality standards. Streamside buffers or riparian zones have been implemented on National Forest System lands since at least the late 1980s. In the 1990s, Forest Plan amendments, commonly referred to as PACFISH/INFISH, were implemented on National Forests within the Columbia River Basin for protection of anadromous and inland native fish species. The protective measures that were adopted further restricted riparian harvest and are now broadly practiced on all National Forest System lands within the Columbia Basin of Idaho. Though these measures are in place, increasing global temperatures resulting from greenhouse gas–induced climate change appear to be increasing stream temperatures within Idaho (Rieman and Isaak 2010).

A primary contributor of total suspended sediment (TSS) in the Clearwater drainage basin, particularly the sand-size fraction, is the Selway River, which discharged about 368,000 tons of TSS during water years 2009–11 (Clark et al. 2013). The Selway River accounted for about 71% of the TSS and about 88% of the suspended sand as measured downstream in the Middle Fork Clearwater River at Kooskia. The Lochsa River contributed about 126,000 tons, or about 24% of the TSS in the Middle Fork Clearwater River at Kooskia. Of the TSS discharged from the Selway and Lochsa rivers, about 73% and 59%, respectively, was sand-size. The mean annual basin yields of suspended sediment from the Selway and Lochsa rivers were 64 and 36 (tons/mi^2)/year, respectively, during 2009–11 (Figure 2-4).

Overall, the sediment load delivered from the Selway River drainage basin was equivalent to about 32% of the TSS and about 55% of the suspended sand discharged to Lower Granite Reservoir from the Clearwater River during water years 2009–11. The TSS load from the Lochsa River drainage basin was equivalent to about 11% of the TSS and about 15% of the suspended sand discharged from the Clearwater River Basin during water years 2009–11. Of the TSS load entering Lower Granite Reservoir from both the Snake and Clearwater rivers, the Selway River accounted for only about 3.7% and 5.5% of the TSS and total suspended sand, respectively; and the Lochsa River accounted for only about 1.3% and 1.5% of the TSS and total suspended sand, respectively (Figure 2-4).

Combined, the Middle Fork Clearwater River (as measured at Kooskia, Idaho) and the South Fork Clearwater River (as measured at Stites, Idaho) discharged about 681,000 tons of suspended sediment during water years 2009–11 (Figure 2-4). Of this total, about 76%, or 515,000 tons, was from the Middle Fork Clearwater River, an amount equivalent to about 45% of the TSS and 62% of the suspended sand entering Lower Granite Reservoir from the Clearwater River. TSS discharged from the South Fork Clearwater River was equivalent to about 14% of the TSS and 16% of the suspended sand entering Lower Granite Reservoir from the Clearwater River during water years 2009–11 (Clark et al. 2013). From the confluence of the South Fork Clearwater River at Stites and the Middle Fork Clearwater River at Kooskia downstream to the station at Orofino, the Clearwater River accrued about 279,000 tons of suspended sediment during water years 2009–11 (Figure 2-4). Of this accrual, about 54% was fine-grained sediment.

The Potlatch River contributed an additional 274,000 tons of suspended sediment to the Clearwater River. About 94% of the suspended sediment discharged from the Potlatch River was fine-grained sediment. The mean annual yields of TSS (156 [tons/mi^2]/year) and of fine-grained suspended sediment (148 [tons/mi^2]/year) from the Potlatch River Basin were the largest of all the stations monitored during water years 2009–11. During water year 2011, the yields of TSS and fine-grained sediment from the Potlatch River Basin were about 362 and 343 (tons/mi^2)/year, respectively. Although the TSS load from the Potlatch River was equivalent to about 24% of the TSS load entering Lower Granite Reservoir from the Clearwater River during water years 2009–11, the fine-grained sediment discharged from the Potlatch River was equivalent to about 39% of the fine-grained load entering the reservoir from the Clearwater River. During water year 2011, the load from the Potlatch River was equivalent to about 32% of the TSS and 53% of the fine-grained suspended sediment as measured in the Clearwater River at Spalding. During water year 2011, streamflow in the Potlatch River accounted for $<1\%$ of the total combined streamflow entering Lower Granite Reservoir from the Snake and Clearwater basins. However, the TSS load and the fine-grained suspended sediment load from the Potlatch River were equivalent to about 3.5% and 6.5%, respectively, of the total transported to Lower Granite Reservoir, most of which was generated during the rain-on-snow event in mid-January 2011 (Clark et al. 2013).

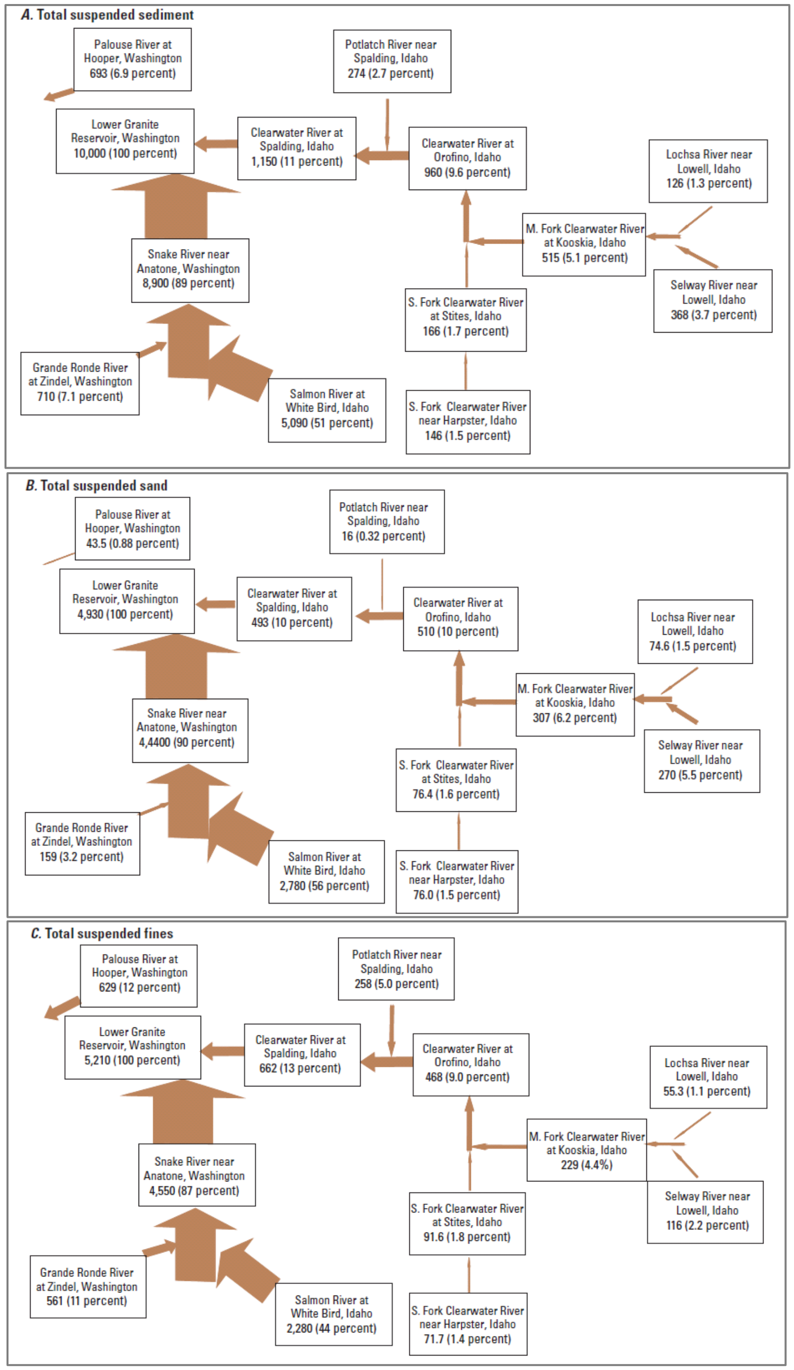

Figure 2-4. Estimated loads of (A) total suspended sediment, (B) total suspended sand, and (C) total suspended fines transported in the lower Snake and Clearwater River basins, water years 2009–11. Values are in thousands of tons and percentage of total load entering Lower Granite Reservoir during water years 2009–11. Width of each row is proportional to the estimated suspended sediment load. Source: Clark et al. 2013.

The mean annual yield of TSS in the Palouse River as measured at Hooper, Washington, was about 92 (tons/mi^2)/year during water years 2009–11. More than 90% of the sediment transported in the Palouse River was fine-grained sediment. The Palouse River discharges to the Snake River downstream of Lower Granite Reservoir, the load of suspended sediment transported in the Palouse River during water years 2009–11 was about 693,000 tons, equivalent to about 6.9% of the total discharged to Lower Granite Reservoir during water years 2009–11 (Figure 2-4). The load of fine-grained sediment transported in the Palouse River during the same period was about 629,000 tons, equivalent to about 95% of the 662,000 tons of fine-grained sediment transported from the Clearwater River to Lower Granite Reservoir (Figure 2-4).

Using continuous streamflow records and suspended sediment data collected during 1972–79, loads for suspended sand and suspended fines were estimated for the Snake River near Anatone, Washington, and for the Clearwater River at Spalding, Idaho, using the LOADEST model. The suspended sand and suspended fines from the 1970s data were analyzed separately to estimate the fractional loads during each year for 1972–79 and 2009–11. The results indicate that the TSS load entering Lower Granite Reservoir from the Snake River increased from an annual average of about 71% of the total in water years 1972–79 to 89% in water years 2009–11. Conversely, the load from the Clearwater River decreased from 29% during 1972–79 to 11% during 2009–11 (Clark et al. 2013).

As a proportion of the TSS load entering Lower Granite Reservoir from the combined Snake and Clearwater rivers, the sand fraction increased from an annual average of about 30% during 1972–79 to 48% during 2009–11. Most of the increase in the sand load was attributable to the Snake River. In the Snake River near Anatone, the sand fraction increased from an average of 28% of the TSS load during 1972–79 to an average of 48% during 2009–11 (Clark et al. 2013). Of the sediment load entering the reservoir, the Snake River accounted for about 89% of the TSS, about 90% of the suspended sand, and about 87% of the suspended fines. The Salmon River contributed about 51% of the TSS, about 56% of the suspended sand, and about 44% of the suspended fines transported to Lower Granite Reservoir (Clark et al. 2013). In the Clearwater River, data collected during this study indicated that the TSS and suspended fines concentrations during 1972–79 were not significantly different from the concentrations during 2009–11. However, the concentrations of suspended sand in the Clearwater River were significantly larger during 2009–11. The increase in the sand load in the Clearwater River may be attributable to forest fire activity in areas of the basin with highly erodible soils (Clark et al. 2013).

Applying the best-fit relation between streamflow and bedload discharge to determine the transport in the Snake River for water years 2009–11 indicates about 55,000 tons of bedload, or about 0.62% of the total amount of sediment discharged from the Snake River to Lower Granite Reservoir (Figure 2-5). These data indicate that at high streamflow, the bedload transported at Stites is about one order of magnitude larger than at Harpster, even though the South Fork Clearwater River at Stites, Idaho, is only 15 miles downstream of the Harpster, Idaho station. The particle-size distribution of the bedload at both South Fork Clearwater River stations was bimodal, with the dominant size classes being medium-sized sand and medium-sized gravel. The bedload at Harpster constituted about 3.1% of the total sediment discharge during water years 2009–11, whereas at Stites the bedload constituted about 7.9% (Figure 2-5).

The total calculated transport at Orofino was about 15,000 tons during water years 2009–11, about one-half of the combined bedload discharged from the South Fork Clearwater River and the Middle Fork Clearwater River (Figure 2-5). Downstream of Orofino, at the

Clearwater River at Spalding station, the total bedload during water years 2009–11 was about 9,500 tons, <1% of the total sediment transport at the station during that period. The reach of the Clearwater River from Orofino to Spalding probably transports less sediment (both suspended load and bedload) than it did historically, due to the construction of Dworshak Reservoir, which essentially negates sediment delivery to the mainstem Clearwater River from the North Fork Clearwater River (Clark et al. 2013). The total bedload for 2009–11 in the Clearwater River at Spalding was about 9,500 tons, about 15% of the total bedload discharged to Lower Granite Reservoir from the combined Clearwater and Snake rivers. Overall, bedload accounted for only about 0.64% of the total sediment load entering Lower Granite Reservoir during water years 2009–11 (Figure 2-5).

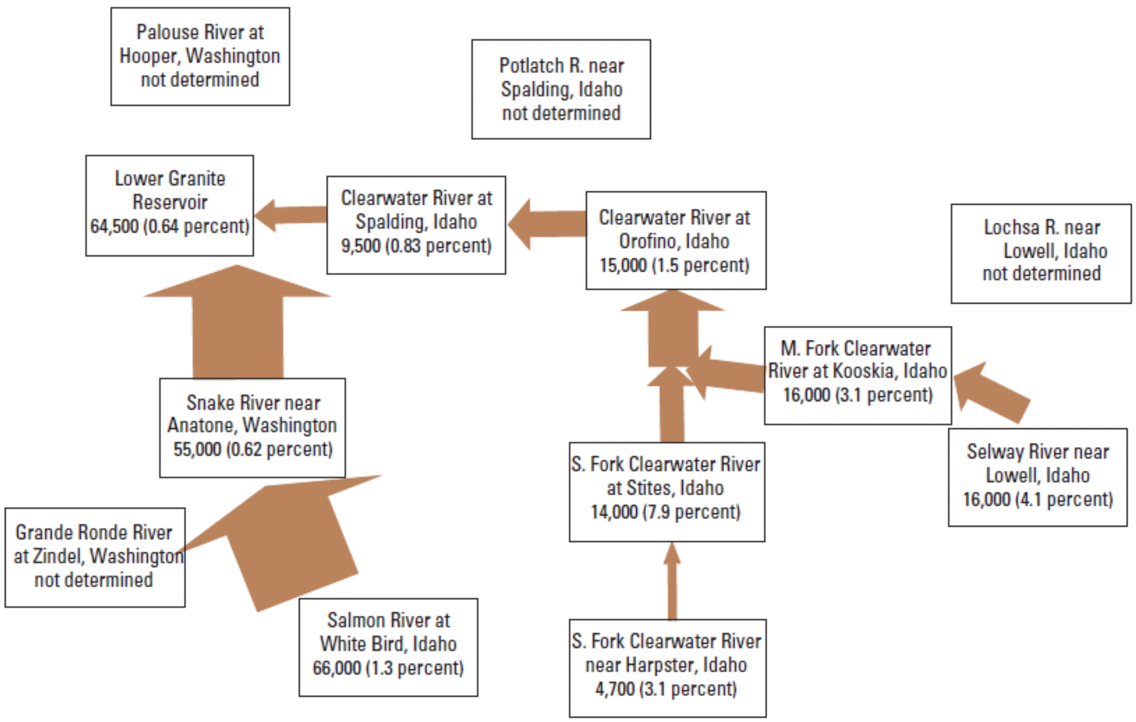

Figure 2-5. Estimated bedload transported in the lower Snake and Clearwater River basins, Washington and Idaho, water years 2009–11. Values are in tons and percentage of total sediment load (suspended and bedload) transported during water years 2009–11. Source: Clark et al. 2013.

In the Clearwater River Basin, bedload samples were collected from the Lochsa and Selway rivers 3 and 11 times, respectively. At both stations, the particle-size distribution was bimodal, with medium sand and coarse gravel being the dominant sizes (Table 10 in Clark et al. 2013). A comparison of the bedload data collected during this study from the Lochsa and Selway rivers with data collected during 1994–97 by the U.S. Forest Service at the same sampling locations (King et al. 2004, cited in Clark et al. 2013) is shown in Figure 2-6 (from Clark et al. 2013). Bedload accounted for <1% of the total sediment load entering Lower Granite Reservoir from the Snake and Clearwater rivers. The lower Snake River basin, which includes the Salmon River, had the second largest measured bedload, with a total of 55,000 tons during 2009–11, about 0.62% of the total sediment load entering Lower Granite Reservoir from the Snake River. The estimated bedload in the Clearwater River at Spalding was only about 9,500 tons, roughly 0.83% of the total sediment load transported to Lower Granite Reservoir from the Clearwater River.

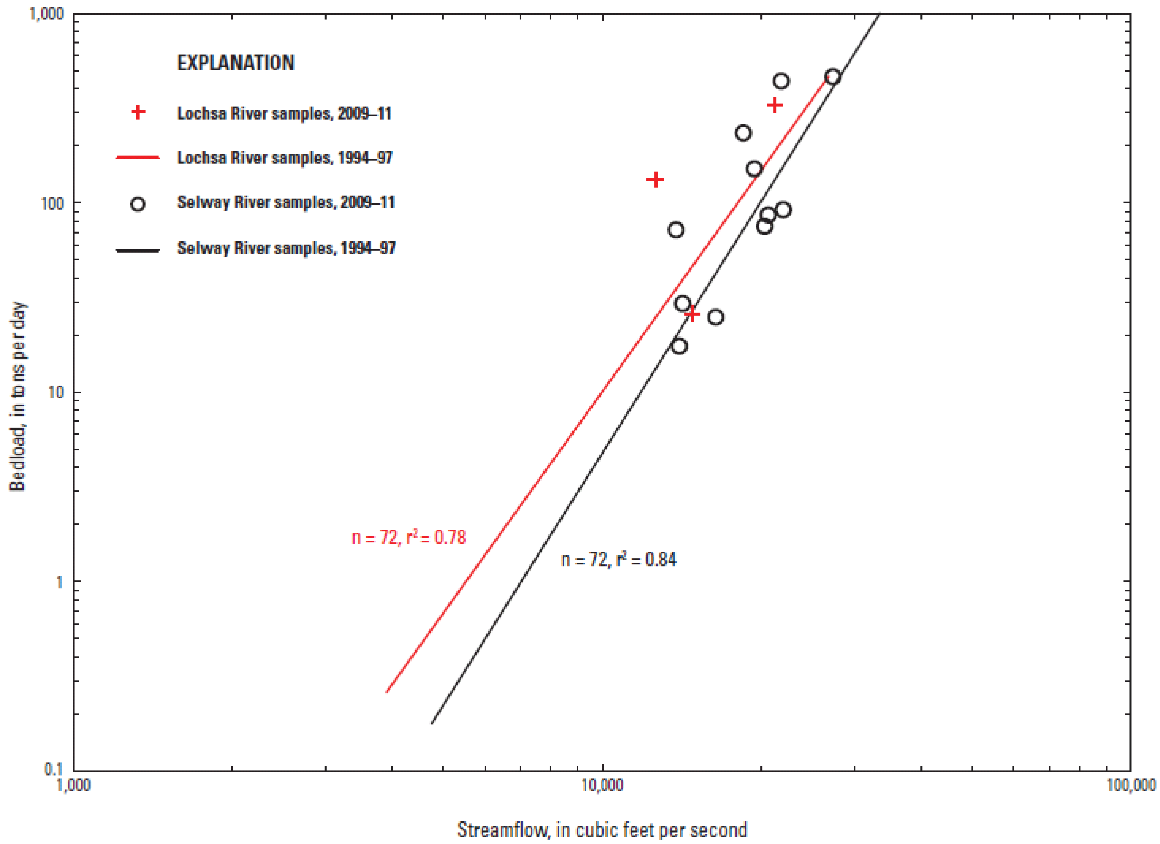

Figure 2-6. Bedload transport curves based on samples collected from the Lochsa and Selway rivers near Lowell, Idaho, during water years 2009–11, and during 1994–97 by King and others (2004). Source: Clark et al. 2013.

Although the Salmon River delivers the largest percentage of total load to the Lower Granite Dam (51%), on a unit-area, annual basis, the Potlatch River delivers a greater percentage of both total suspended sediment and total suspended fines (Table 2-7), and the Palouse River delivers a greater percentage of total suspended fines (Table 2-7).

Table 2-7. Annual unit area sediment load for stations measured in Clark et al. (2013) (upstream of Lower Granite Reservoir)

Station	Area (mi^2)	Annual Unit Area Load ($tons/mi^2$)/year			
		Total Suspended Sediment	Total Suspended Sand	Total Suspended Fines	Total Bedload
Grande Ronde River	3,940	60	13	47	n/a
Snake River at Anatone, WA	19,700	151	74	77	0.9
Potlatch River	583	157	9	148	n/a
Salmon River at White Bird, ID	13,500	126	69	56	1.6
Palouse River	2,500	92	6	84	n/a
Selway River	1,910	64	47	20	2.8
Clearwater River at Orofino, ID	5,580	57	30	28	0.9
South Fork Clearwater at Harpster, ID	865	56	29	28	1.8
Clearwater River at Spalding, ID	7,140	54	23	31	0.4
South Fork Clearwater at Stites, ID	1,150	48	22	27	4.1
Lochsa River	1,180	36	21	16	n/a
Middle Fork Clearwater at Kooskia, ID	5,490	31	19	14	1.0

Groundwater and Groundwater-dependent Ecosystems

Groundwater

Groundwater and surface water are interconnected and interdependent in almost all ecosystems. Ground water plays significant roles in sustaining the flow, chemistry, and temperature of streams, lakes, springs, wetlands, and cave systems in many settings, while surface waters provide recharge to ground water in other settings. Ground water has a major influence on rock weathering, streambank erosion, and the headward progression of stream channels. In steep terrain, groundwater governs slope stability; in flat terrain, it controls soil compaction and limits land subsidence. Slow drainage of soil moisture between saturation and field capacity is the source of a large proportion of the baseflow of forested headwaters streams, where organic matter content of forest soils tends to be high (USFS 2007). Groundwater can play an important role in slope movements because its presence in soil pores and contact zones reduces slope stability. Slope movements often occur during the wet season, or following major rainfall or snowmelt events, when soils are most likely to be saturated. Ecological resources include threatened, endangered, or sensitive fish, wildlife, plants, and habitats that that may be damaged by exposure to groundwater contaminants or groundwater depletion.

Baseflow is that part of streamflow derived from groundwater discharge and bank storage. River flow is often maintained largely by groundwater, which provides baseflow long after rainfall or snowmelt runoff ceases. The baseflow typically emerges as springs or as diffuse flow from sediments underlying the river and banks. Localized areas of ground water discharge have a largely stable temperature and provide thermal refuges for fish in both winter and summer. The ground water level in riverine aquifers is important for maintaining a hydraulic gradient toward the stream that supports the necessary discharge flux. Sufficient discharge of ground water is needed to maintain the level of flow required by the various ecosystem components. Contamination of riverine aquifers by nutrients, pesticides, or other contaminants may adversely affect dependent ecosystems in baseflow-dominated streams. The interface between saturated ground water and surface water in streams and rivers is a zone of active mixing and interchange between the two and is known as the hyporheic zone (Jones and Mulholland 2000; Stanford and Ward 1988, 1993; [all cited in USFS 2007]). In mountain streams with typical pool-and-riffle organization, ground water enters streams most readily at the upstream end of deep pools, and conversely, surface water moves into the subsurface beneath and to the sides of riffles (Harvey and Bencala 1993, cited in USFS 2007).

Lakes, both natural and human made, can have complex ground water flow systems (Fetter 2000, cited in USFS 2007). Lakes interact with ground water in 1 of 3 basic ways: 1) some receive ground water inflow throughout their entire bed; 2) some have seepage loss to ground water throughout their entire bed; and 3) others, perhaps most, receive ground water inflow through part of their bed and have seepage loss to ground water through other parts (Winter et al. 1998, cited in USFS 2007). A mixing zone similar to the hyporheic zone, called the hypolentic zone, occurs at the interface between saturated ground water and surface water in lakes and wetlands. In many lakes, the most active portion of the hypolentic zone is located in the littoral zone, in close proximity to the shoreline (Hunt et al. 2003; McBride and Pfannkuch 1975; [all cited in USFS 2007]).

Pumping of ground water can reduce river flows, lower lake (or reservoir) levels, and reduce or eliminate discharges to wetlands and springs. Pumbing also can threaten the sustainability of drinking water supplies and maintenance of critical groundwater-dependent habitats. Management activities that intentionally or unintentionally change the density, structure, and species composition of vegetation may have measurable effects on the quantity and quality of ground water (USFS 2007). Certain land uses are known to cause ground water contamination. Specific types of contaminants are associated with specific types of land uses and industries. The Office of Technology Assessment of the U.S. Congress (1984 , cited in USFS 2007) identified the following 6 categories of major sources of ground water contamination:

1. Sources designed to discharge substances—septic tanks, injection wells, land application of waste.
2. Sources designed to store, treat, or dispose of substances—landfills, surface impoundments, mine waste, storage tanks.
3. Sources designed to retain substances during transport—pipelines, material transport and transfer.
4. Sources discharging substances as a consequence of other planned activities—irrigation, pesticide and fertilizer application, road salt, urban runoff, mine drainage.

5. Sources providing a conduit for contaminated water to enter aquifers—wells, construction excavation.
6. Naturally occurring sources whose discharges are created or enhanced by human activity—ground water/surface-water interaction, natural leaching, saltwater intrusion.

Groundwater-dependent Ecosystems

In general, where groundwater intersects the ground surface, plants and animals that are supported by access to that groundwater will occur, hence the term “groundwater-dependent ecosystems.” Groundwater-dependent ecosystems are communities of plants, animals, and other organisms whose extent and life processes depend on ground water. The following are examples of some ecosystems that may depend on ground water:

- Wetlands in areas of ground water discharge or in areas with a shallow water table
- Terrestrial vegetation and fauna, in areas with a shallow water table or in riparian zones
- Aquatic ecosystems in groundwater-fed streams and lakes
- Cave and karst systems
- Aquifer systems
- Springs and seeps

In some cases, groundwater emerges at a point location, usually called a spring or seep, depending on the quantity of water available. The term “spring” will be used to include both springs and seeps. Springs are always groundwater-dependent ecosystems. Springs occur where water flowing through aquifers discharges at the ground surface through fault zones or fractures, or by flowing on top of a subsurface layer of impermeable material (USFS 2007). Springs are replenished by precipitation that percolates into aquifers by seeping into the soil and entering fractures, joints, bedding planes, or interstitial pore space. Springs can be important sources of water for streams, lakes, riparian areas, and groundwater-dependent ecosystems.

Spring ecosystems include aquatic and riparian habitats that are similar to those associated with rivers, streams, lakes, and ponds. These spring ecosystems are distinctive habitats because they provide relatively constant water temperature, depend on subterranean flow through aquifers, and on occasion provide refuge habitats that support species that occur only in springs. Ground water development can reduce spring flow, change springs from perennial to intermittent, eliminate springs altogether, or affect the chemical composition of the springwater (USFS 2007).

Shallow ground water can support terrestrial vegetation, such as forests and woodlands, either permanently or seasonally (Baird and Wilby 1999, cited in USFS 2007). Examples of such vegetation occur in riparian areas along streams (Hayashi and Rosenberry 2002, cited in USFS 2007) and in upland areas that support forested wetland environments. Phreatophytes, plants whose roots generally extend downward to the water table, are common in these areas, where the water table is high. Groundwater-dependent terrestrial plant communities provide habitat for a variety of terrestrial, aquatic, and marine animals. Some ecosystems, such as floodplains, exist along a continuum between fully aquatic communities and fully aquiferous communities.

In the case of wetlands supported by groundwater, the water does not usually flow or emerge from a single point at the surface; rather, groundwater usually emerges in a more diffuse manner, across a large area. In some wetlands, however, springs emerge within the wetland, or a complex of wetlands and springs is present across an area. In many cases, groundwater-dependent wetlands, such as fens, are simply springs covered by unconsolidated material (such as glacial deposits, pumice, and colluvium) that becomes saturated to the surface. Because an indistinct boundary exists between springs and wetlands dependent on groundwater discharge, a single field guide was developed for these systems. Groundwater emerging at the ground surface is the common thread that links springs and wetlands and their associated ecosystems (USFS 2007). Wetlands can receive inflow from ground water, recharge ground water, or do both, just as streams and lakes can. The persistence, size, and function of wetlands are controlled by hydrologic processes active at each site (Carter 1996, cited in USFS 2007). For example, the persistence of wetness for many wetlands depends on a relatively stable influx of ground water throughout seasonal and annual climatic cycles. Wetlands can be quite sensitive to the effects of ground water pumping. This pumping can affect wetlands by lowering the water table, by increasing seasonal changes in the elevation of the water table, and by exposing accumulated organic and inorganic material to oxidation.

Fens are peat-forming wetlands that receive recharge and nutrients almost exclusively from ground water. The water table is at or just below the ground surface. Water moves into fens from upslope mineral soils and flows through the fen at a low gradient. Fens are less acidic and have higher nutrient levels than other peatlands; therefore, fens are able to support a much more diverse plant and animal community. Grasses, sedges, rushes, and wildflowers often cover these systems. Over time, peat may build up and separate the fen from its ground water supply. When this happens, the fen receives fewer nutrients and may become a bog. Patterned fens are characterized by a distribution of narrow, shrub-dominated ridges separated by wet depressions. Fens provide important benefits in a watershed, including preventing or reducing the risk of floods, improving water quality, and providing habitat for unique plant and animal communities. Like most peatlands, fens have experienced a decline in acreage, mostly from mining and draining for cropland, fuel, and fertilizer. Because of the large historical loss of this ecosystem type, remaining fens are rare, but they do exist on the Forest. Mining and draining these ecosystems provide resources for people; however, the trade-off is significant, because up to 10,000 years are required to form a fen naturally (USFS 2007).

2.3.2.2 Trends and Drivers

Surface Water Quantity (Streamflow) Trends

Between 1976 and 2011, the Nez Perce–Clearwater National Forests monitored streamflow at 39 separate locations (Table 2-8). Periods of record range from 4 to 37 years, with only Fish Creek and Pete King Creek providing data that spanned the entire period (Figure 2-7).

Table 2-8. Streamflow stations monitored on the Nez Perce–Clearwater National Forests

Stream Station	Drainage Area (mi^2)	Water Years Measured
badger	5.55	1986–2000
bushy fk	81.30	1984–1991
canyon	19.70	1992–2008
cold_springs	10.70	1983–1992, 2000–2006
Crooked_abv_brushy	73.70	1985–1992
crooked_mouth	169.00	1979–1997,1999
dead_horse	4.13	1982–1984
deadman	19.80	1998, 2000–2011
deadman_lo	1.20	1989–1999
deadman_wf	4.44	1981–1989
Elk	8.29	1981–1993,1995–1997,1999–2003, 2006, 2008, 2011
Fish	88.00	1976–1995,1997–2011
fish_up	3.90	1977–1984
hemlock	33.50	1984–1989
isabella	30.80	1987–1996
Johns.Cr	113.00	1986–1992,1998–2011
Little.Slate	64.70	1986–2011
lolo_mouth	243.00	1991–1996, 2000–2001, 2003
lolo_section_6	41.00	1982–2010
Main Red River	161.00	1986–2011
meadow	4.03	1985–1989, 1997
palouse	67.20	1999–2005
palouse_abv_ls	46.20	1987–1997
papoose	20.80	1996–2004
parachute_lo	19.90	1991–1994
pete_king	27.50	1976–1997, 1999–2006, 2008–2011
Potlatch	594.00	1996–2005
quartz	43.70	1982–1988,1991–1997, 2000–2008, 2010–2011
Rapid	4.33	1986–2011
salmon_lo	4.07	1986–1996
salmon_up	3.32	1986–1991
sf_beaver	2.01	1984–1991
South.FK.Red	37.70	1986–2011
squaw	26.90	1989–1991, 1995–2002
swamp_ck	30.90	1982–1993
toboggan	21.60	1983–1989
walton	11.10	1991–1995
warm_springs	71.60	1979–1980, 1982–1984
white_sand	247.00	1979–1986, 1988–1997,1999

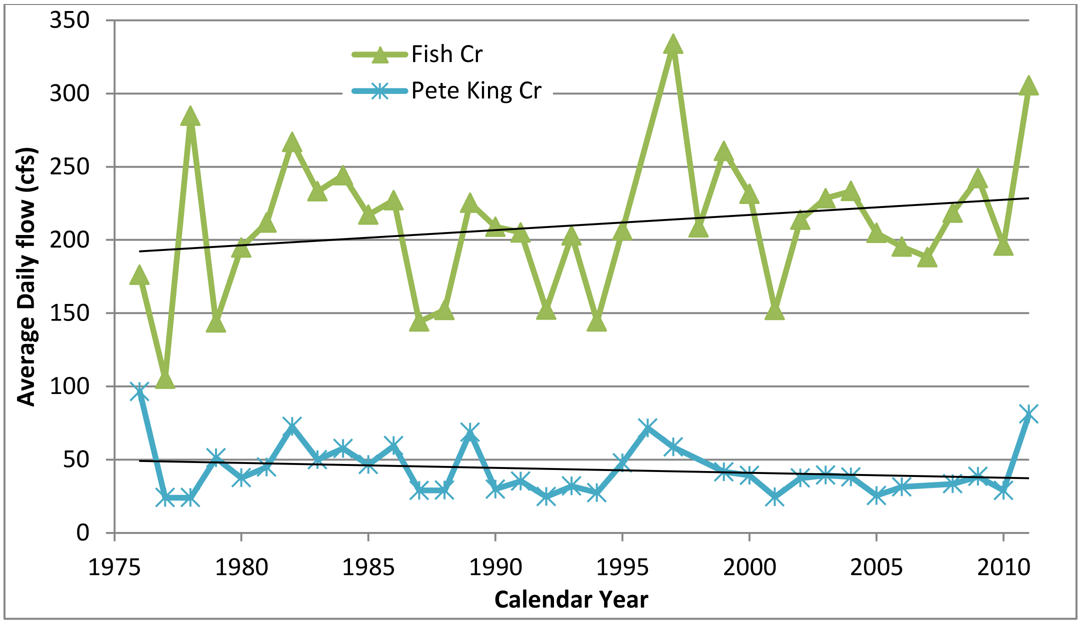

Figure 2-7. Average daily flow for Pete King and Fish creeks

To assess long-term trends of flow measured on the Forests, stations with complete records (mean flow record for every day of the year) that span >3 years were chosen for this analysis. The following 36 stations were selected for analysis: Badger, Beaver S.F., Brushy, Canyon, Cold Springs, Crooked above Brushy, Crooked (mouth), Deadman, Deadman (lo), Deadman (w.f.), Elk, Fish, Fish (up), Hemlock, Isabella, Johns Creek, Lolo (mouth), Lolo (section 6), Meadow, Palouse, Palouse (above ls), Papoose, Pete King, Potlatch, Quartz, Rapid, Main Red River, Salmon (lo), Salmon (up), South Fork Red River, Squaw, Swamp, Toboggan, Walton, Warm Springs, and White Sand. The average daily flow for each year measured was calculated from all days measured in the water year. Two stations, Main Red River and South Fork Red River, were only partial-duration stations (no flow was measured during the winter when the streams were frozen over). Average daily flow for these two stations was computed using only those days measured.

For all station data combined, a slight decreasing trend exists in average daily flow (Figure 2-8). This trend is not statistically significant and is not reflective of trends at individual stations. This trend is also strongly influenced by the fact that 3 of the stations with the highest average daily flow (White Sand, Crooked Fork (at Brushy), and Crooked Fork (mouth) were not measured after 1999. When the analyzed stations are evaluated individually (excluding the partial-duration record stations), more stations trend toward increasing annual volumetric discharge (21 stations) than decreasing annual volumetric discharge (14 stations) (Table 2-9). No conclusive trends of streamflow exist across the Forest because very few stations have complete records. As illustrated in Figure 2-7, one stream (Pete King Creek) had a slight, statistically insignificant, decreasing trend in average daily streamflow; and Fish Creek had a slight, statistically insignificant, increasing trend in the same metric. For the 8 stations that had the longest records, with measurements from at least 1986 to 2011 (Elk, Fish, Lolo (section 6), Pete King, Quartz, Main Red River, Rapid, and South Fork Red River), a slight decreasing trend in long-term average daily flow is present (Figure 2-9).

Table 2-9. Trends, by station, of annual flow volume, peak flow rate, and date of occurrence of peak flow event for stations on the Nez Perce–Clearwater National Forests

Stream Station	Trend of Flow Volume	Trend of Peak Flow Rate	Trend of Date of Occurrence of Peak Flow
badger	Decreasing	Decreasing	Earlier
bushy fk	Increasing	Decreasing	Later
canyon	Decreasing	Increasing	Earlier
cold_springs	Increasing	Increasing	Earlier
Crooked_abv_brushy	Increasing	Increasing	Earlier
crooked_mouth	Increasing	Increasing	Earlier
dead_horse	Partial	Decreasing	Later
deadman	Increasing	Increasing	Earlier
deadman_lo	Increasing	Increasing	Later
deadman_wf	Increasing	Increasing	Later
elk	Decreasing	Increasing	Earlier
fish	Increasing	Increasing	Later
fish_up	Increasing	Increasing	Later
hemlock	Increasing	Increasing	Earlier
isabella	Increasing	Increasing	Later
Johns.Cr	Increasing	Increasing	Earlier
Little.Slate	Partial	Increasing	Later
lolo_mouth	Increasing	Increasing	Earlier
lolo_section_6	Decreasing	Decreasing	Later
Main Red River	Partial	Increasing	Later
meadow	Decreasing	Decreasing	Earlier
palouse	Decreasing	Increasing	Earlier
palouse_abv_ls	Increasing	Increasing	Earlier
papoose	Decreasing	Decreasing	Later
parachute_lo	Decreasing	Decreasing	Earlier
pete_king	Decreasing	Increasing	Earlier
Potlatch	Decreasing	Decreasing	Later
quartz	Decreasing	Increasing	Later
Rapid	Decreasing	Increasing	Later
salmon_lo	Increasing	Increasing	Earlier
salmon_up	Increasing	Increasing	Later
sf_beaver	Increasing	Increasing	Earlier
South.FK.Red	Partial	Increasing	Later
squaw	Increasing	Decreasing	Earlier
swamp_ck	Decreasing	Decreasing	Earlier
toboggan	Decreasing	Decreasing	Earlier
walton	Increasing	Decreasing	Later
warm_springs	Increasing	Decreasing	Later
white_sand	Increasing	Increasing	Later

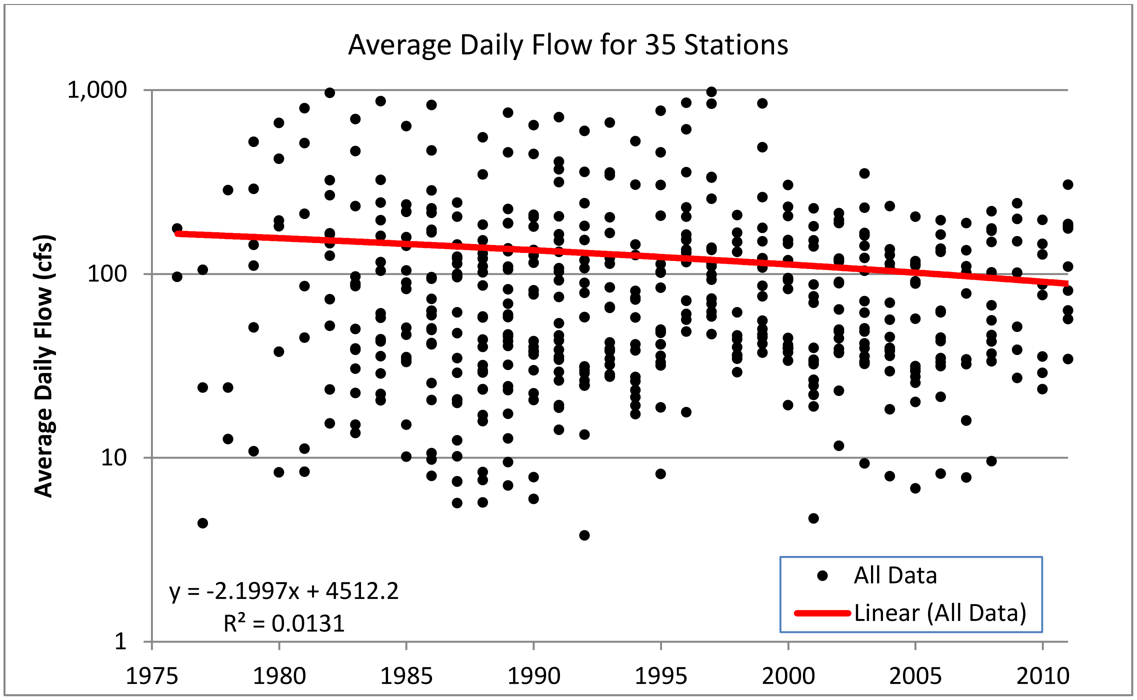

Figure 2-8. Average daily flow rate (cubic feet per second [cfs]) for the 36 streamflow stations on the Nez Perce–Clearwater National Forests between 1976 and 2011

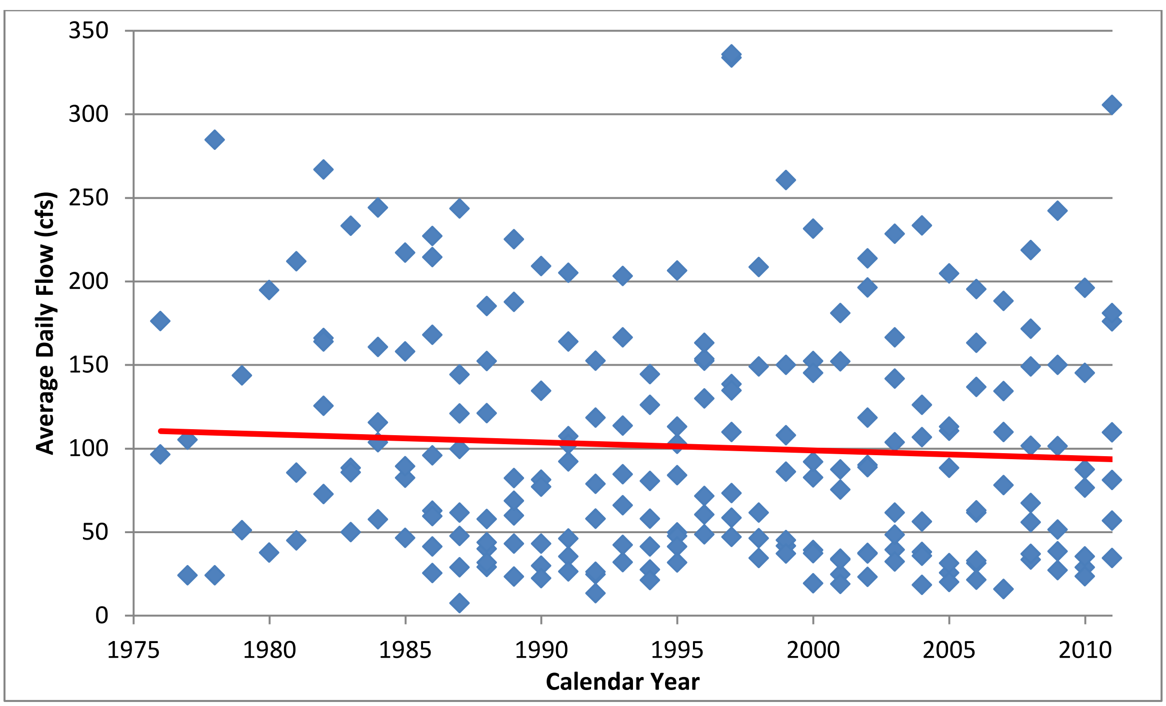

Figure 2-9. Average daily flow for the 8 long-term streams monitored by the Nez Perce–Clearwater National Forests

For the stations evaluated, annual maximum peak discharge rates appear to be slightly decreasing (Figure 2-10). This trend is not statistically significant and is not reflective of trends at individual stations. This trend is also strongly influenced by the fact that 3 of the stations with the highest average daily flow (White Sand, Crooked Fork [at Brushy], and Crooked Fork [mouth]) were not measured after 1999. When the analyzed stations are evaluated individually, more stations trend toward increasing annual volumetric discharge (26 stations) than decreasing annual volumetric discharge (13 stations) (Table 2-9). No conclusive trends of peak streamflows exist across the Forest, because very few stations have complete records. For the 9 stations that had the longest records, with measurements from at least 1986 to 2011 (Elk, Fish, Johns, Lolo, Pete King, Quartz, Main Red, Rapid, and SF Red), a slight increasing trend in annual maximum peak flow rate is present (Figure 2-11). Forest monitoring data appear to be consistent with streamflow declines across the Pacific Northwest, where approximately 73% of streams showed significant (α=0.10) declines in the 25^{th} percentile annual flow between 1948 and 2006 (Luce and Holden 2009).

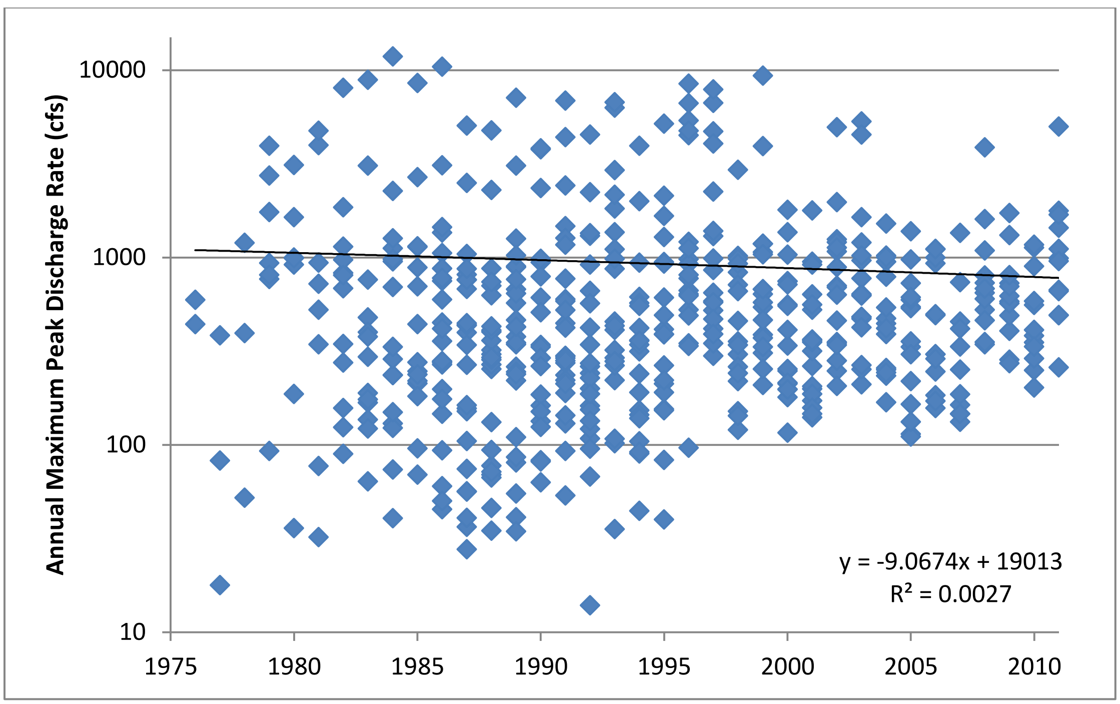

Figure 2-10. Annual maximum (peak) discharge rate for streamflow stations on the Nez Perce–Clearwater National Forests

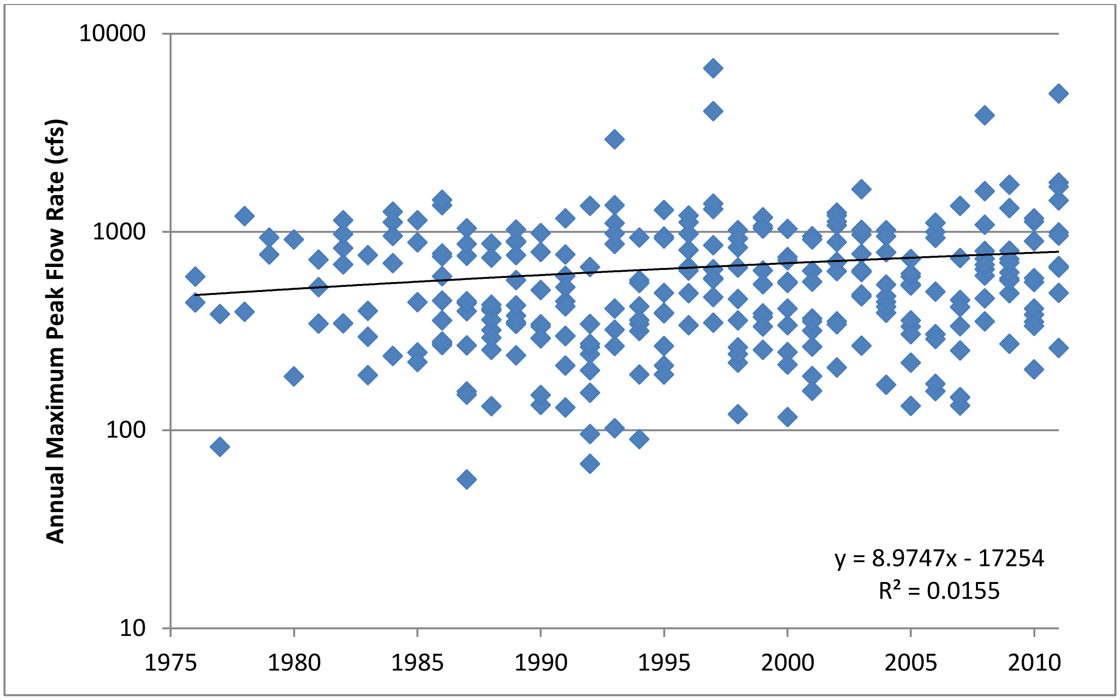

Figure 2-11. Annual maximum peak flow rates for long-term streamflow stations on the Nez Perce–Clearwater National Forests

The USGS software program, STREAMSTATS, was used to develop flood frequency relations for the following recurrence intervals: Q1.5, Q2, Q2.33, Q5, Q10, Q25, Q50, Q100, Q200, and Q500. STREAMSTATS is a GIS-based program that is designed for water resource planning and provides a variety of useful hydrology metrics based on watershed characteristics catalogued in national, standard databases. This software program is used to evaluate flood magnitudes for varying frequencies at locations without stream gauging stations. Streamstats uses published regional regression equations (e.g., Hortness and Berenbrock 2001) developed from regional stream gauging stations.

The USGS software program PeakFQ was utilized to compute the log-Pearson Type III distribution coefficients to compute peak flows for the same recurrence intervals as listed in the paragraph above. Using the methods of moments (a statistical procedure used to fit a nonlinear regression curve to a set of data) to fit the log-Pearson Type III distribution of annual flood peaks, PeakFQ uses well-established criteria to perform flood frequency analysis. On the basis of the USGS Bulletin 17B (USIACWD 1982) skew map for the United States, the area for analysis was determined to have a skew coefficient of –0.3. The drainage areas range from Meadow Creek (4.03 mi^2) to Potlatch Creek (594.15 mi^2). This method is utilized when actual streamflow measurements have been taken at one location over several years. This is the preferred method to use when sufficient data are available.

From the PeakFQ results, regional regression equations were developed for each recurrence interval, using only drainage area as the predictor variable (Table 2-10). A plotted example of these equations was developed for the mean annual flood (i.e., recurrence interval of 2.33 years) (Dunne and Leopold 1978 and Figure 2-12). Then, using only the mean annual flood, the PeakFQ results were plotted against the StreamStats results (Figure 2-13) to compare the predictions made via each method.

The predictive equations (Table 2-10) indicate generally good agreement and predictive power across the range of drainage areas, with decreasing power as recurrence interval increases. As indicated in Figure 2-13, generally good agreement exists between the 2 methods (the majority of the data are scattered around the 1:1 line with an r-squared (r^2) statistic[4] of 0.65 for the mean annual flood equation). This comparison indicates that either method produces usable results for predicting floods for varying frequencies.

Table 2-10. Annual maximum peak flood predictive equations, by recurrence interval, for stream stations on the Nez Perce–Clearwater National Forests

Recurrence Interval (years)	Equation[a]	r^2
1.5	$34.2 \times A^{0.6578}$	0.61
2	$44.8 \times A^{0.6464}$	0.62
2.33	$50.1 \times A^{0.6414}$	0.63
5	$76.3 \times A^{0.6267}$	0.63
10	$101.2 \times A^{0.6072}$	0.61
25	$137.1 \times A^{0.5909}$	0.58
50	$167.1 \times A^{0.5799}$	0.55
100	$199.8 \times A^{0.5696}$	0.52
200	$235.6 \times A^{0.5600}$	0.49
500	$288.0 \times A^{0.5479}$	0.45

[a]A = drainage area in square miles; range is 3.03–594 mi^2.

[4] The r-statistic is Pearson’s correlation coefficient (Norman and Streiner 1986). The square of this coefficient is used to describe, statistically, how well a best-fit, regression line fits to a set of data: 1.0 being a perfect fit and 0.0 having no relationship at all.

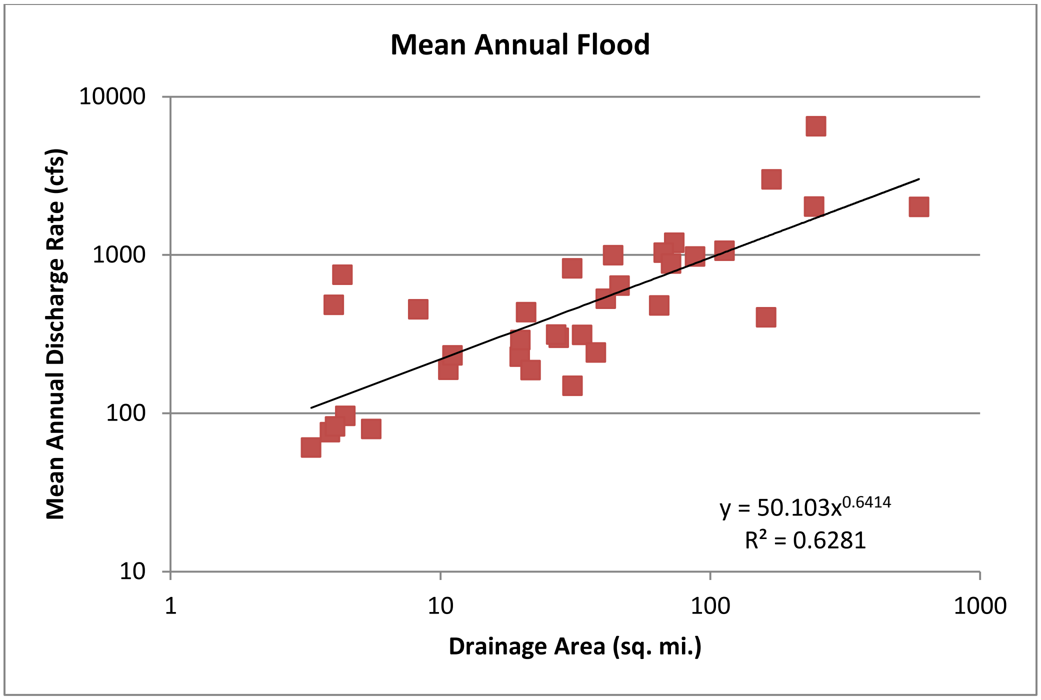

Figure 2-12. Mean annual discharge rate for basins, by drainage area, for streams on the Nez Perce–Clearwater National Forests

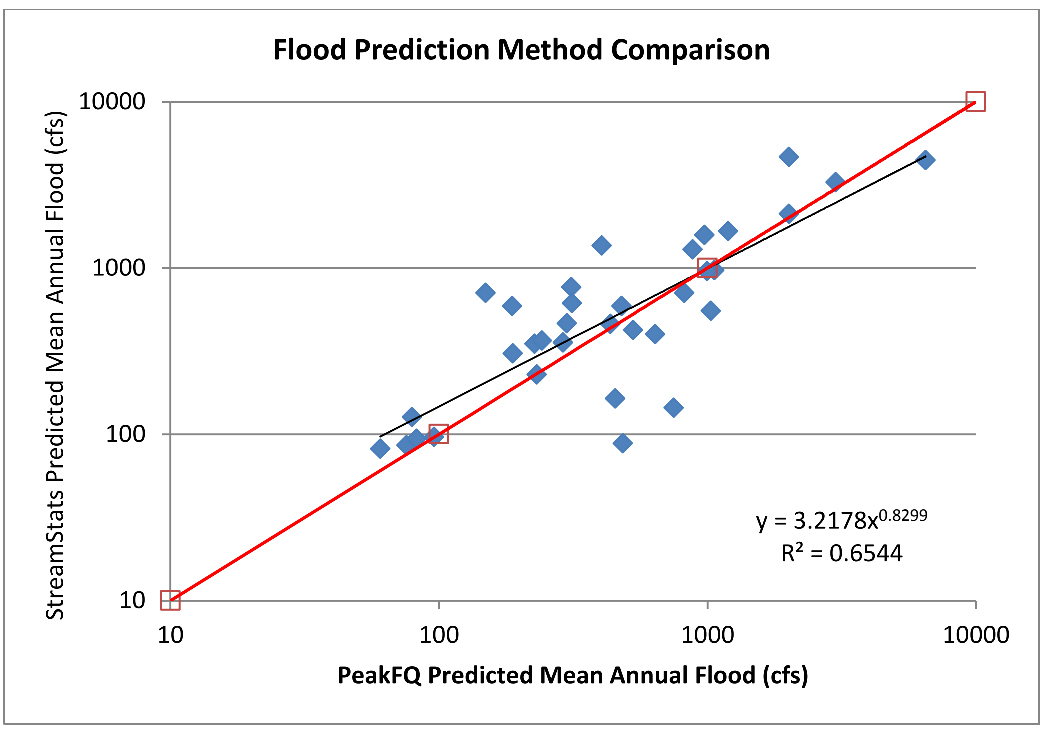

Figure 2-13. Comparison of flood prediction methods (PeakFQ and StreamStats) for streams on the Nez Perce–Clearwater National Forests; red line is 1:1 agreement line

Surface Water Quality Trends

Elevated water temperature and sediment load are the 2 most common parameters that indicate water quality impairment on streams and rivers within the Forests (Table 2-7). Water temperatures are elevated above water quality standards at numerous monitoring locations throughout these subbasins (Table 2-3). Timber harvest, roads, mining, grazing, and agricultural activities have reduced shading of surface water. After conducting temperature assessments, IDEQ concluded that many stream segments throughout these subbasins needed heat load reductions to meet water quality standards. Numerous restoration projects have been implemented to address this issue (e.g., riparian planting and increasing large woody debris in stream channels). Forest-wide BMPs were designed and implemented to reduce management-related stream temperature increases (e.g., minimizing prescribed fire and vegetation treatments within riparian habitat conservation areas).

Stream Temperature

From 1990 to 2011, the Nez Perce–Clearwater National Forests monitored stream temperatures at between 22 and 381 stream locations per year (Table 2-11); data analysis is incomplete for 2012 and 2013. For the entire period, using all stream stations lumped together, the maximum weekly average temperature (MWAT) has a slightly declining trend. This trend is not statistically significant, nor is it representative of individual stream monitoring stations (Figure 2-14).

Table 2-11. Averages of stream temperature metrics for streams monitored on the Nez Perce–Clearwater National Forests, 1990–2013

Year	Number of Streams Monitored	Average Maximum Daily Maximum Temperature (°C)	Average Maximum Weekly Maximum Temperature (°C)	Average Maximum Daily Average Temperature (°C)	Average Maximum Weekly Average Temperature (°C)
1990	22	18.3	17.4	14.9	14.4
1991	32	18.1	17.3	15.5	14.9
1992	53	21.1	19.1	17.0	16.2
1993	80	17.1	16.1	14.4	13.8
1994	149	19.3	18.5	16.6	16.0
1995	175	17.0	16.0	14.7	13.7
1996	139	18.1	16.8	15.3	14.5
1997	148	17.4	16.3	15.2	14.4
1998	247	18.5	17.6	16.1	15.5
1999	268	17.4	16.1	14.8	14.1
2000	245	18.9	18.1	16.3	15.5
2001	293	18.0	17.1	15.4	14.7
2002	309	16.9	16.2	14.8	14.2
2003	381	17.6	17.0	15.2	14.6
2004	336	17.3	16.4	15.1	14.4
2005	360	17.0	16.1	14.6	13.8
2006	357	18.0	17.1	15.5	14.7
2007	339	18.4	17.6	16.1	15.5
2008	328	15.6	14.7	13.6	12.7
2009	286	16.0	15.3	13.8	13.4
2010	295	16.6	15.6	14.3	13.5
2011	279	14.7	13.9	12.8	12.2
2012[a]	48	15.8	14.9	13.9	13.2
2013[a]	8	7.3	6.6	5.4	5.0
Annual Average	**216**	**17.3**	**16.4**	**14.9**	**14.2**

[a] Data analysis is incomplete for monitoring stations measured in 2012 and 2013.

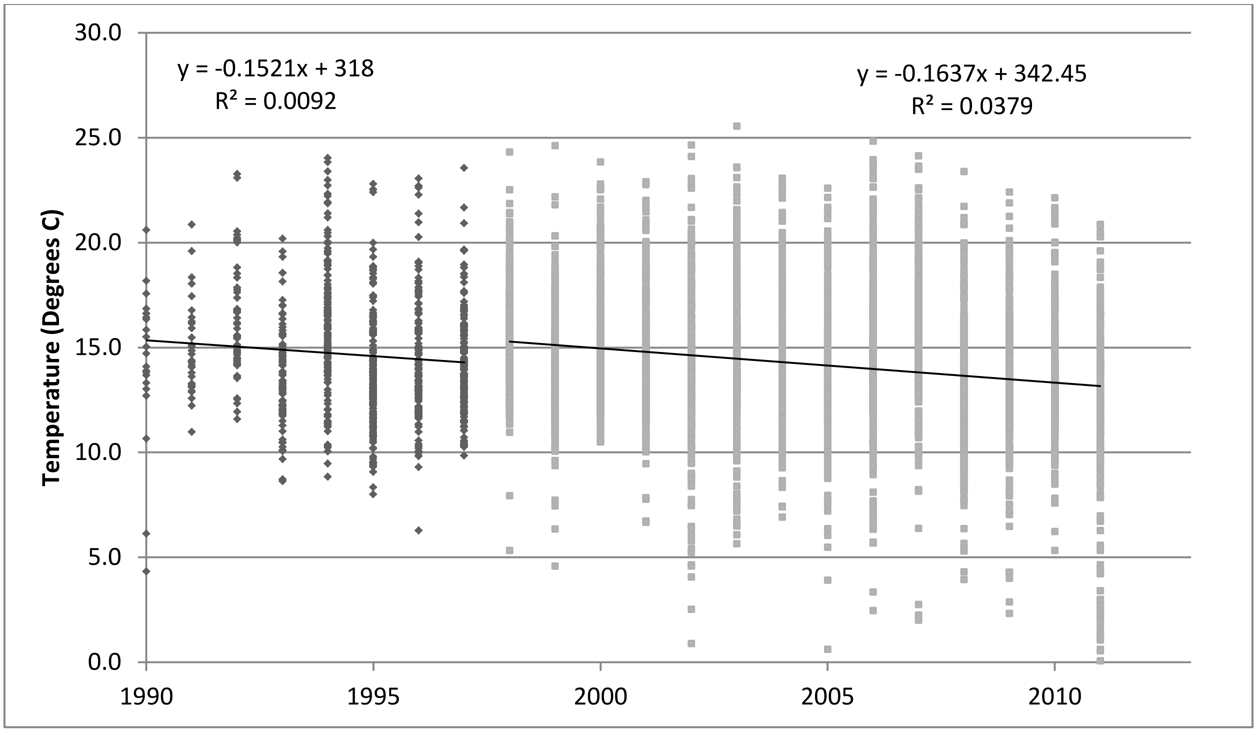

Figure 2-14. Maximum weekly average temperature for streams on the Nez Perce–Clearwater National Forests, 1990–2011

For the entire period, using all stream stations lumped together, the maximum weekly maximum temperature (MWMT) also has a slightly declining trend. This trend is not statistically significant, nor is it representative of individual stream monitoring stations (Figure 2-15). The trends observed in MWAT and MWMT are suspected to be due in part to the dramatic increase in the number of streams that were monitored at higher elevations after 1997. The same data also suggest that the number of days per year that stream temperatures are exceeding critical fish survival thresholds is declining during the period (Figure 2-16, Figure 2-17, and Table 2-12). Again, these trends are not statistically significant, nor are they representative of individual streams.

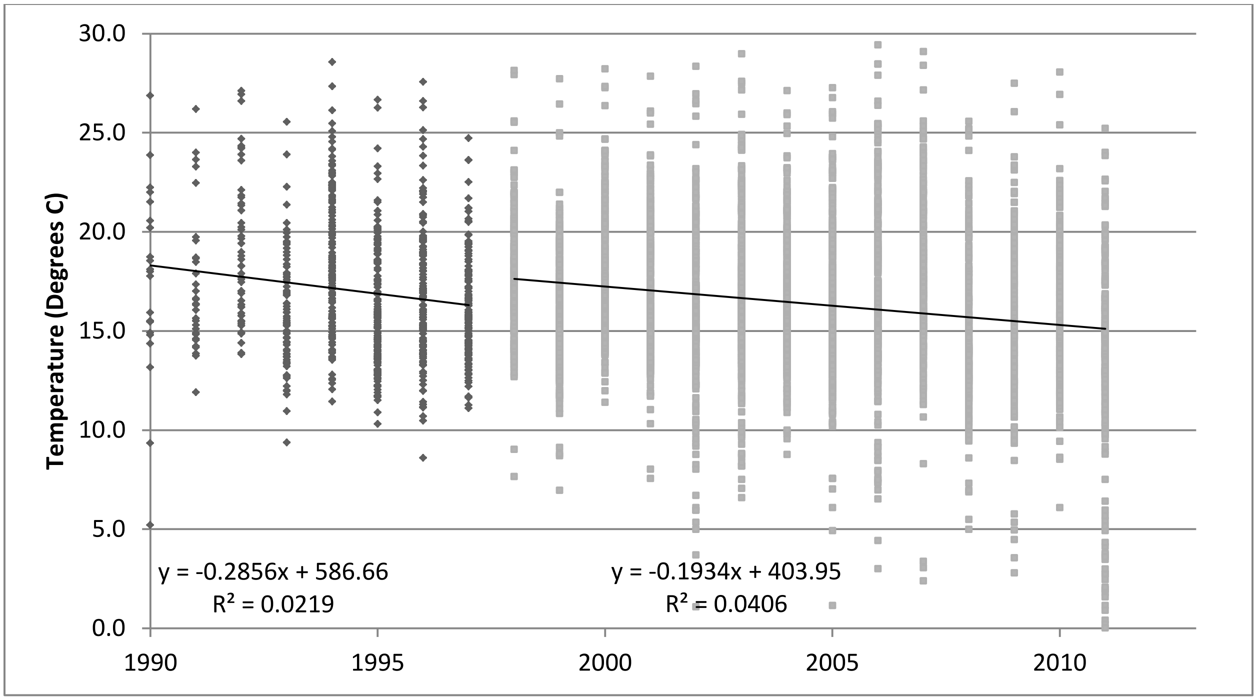

Figure 2-15. Maximum weekly maximum temperature for streams on the Nez Perce–Clearwater National Forests, 1990–2011

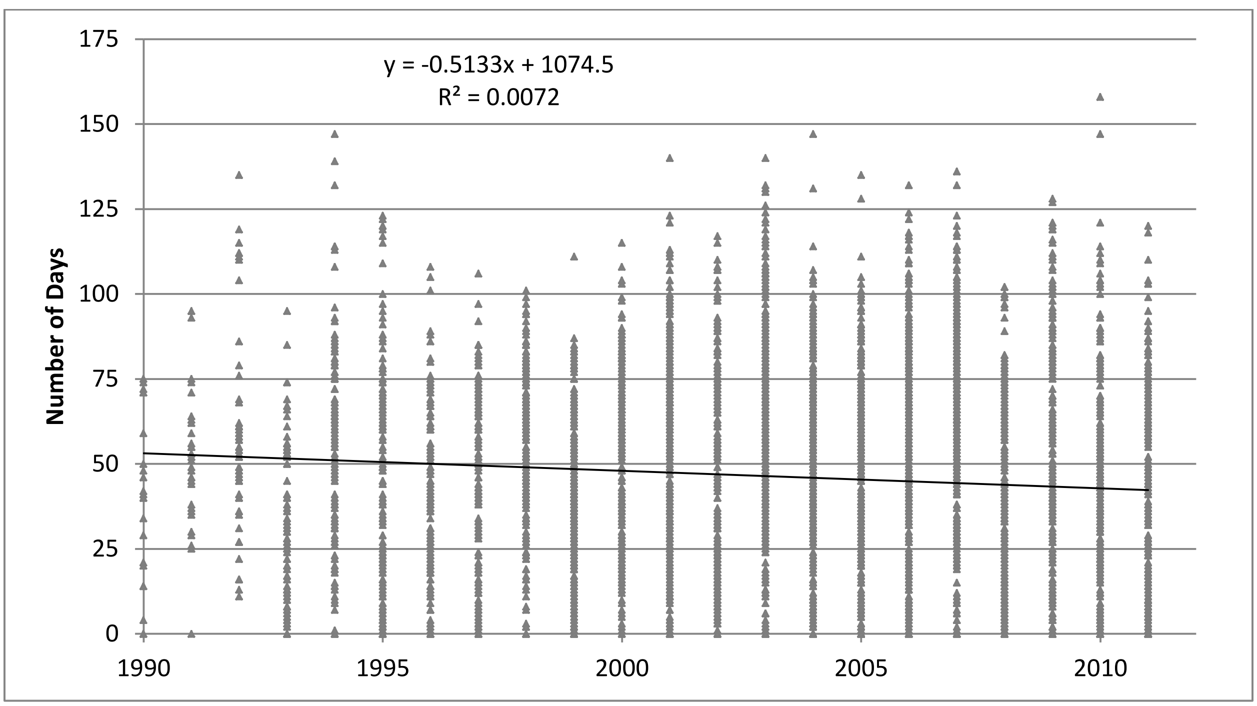

Figure 2-16. Number of days per year, per stream, when maximum daily maximum temperature exceeded 13 ºC for streams on the Nez Perce–Clearwater National Forests, 1990–2011

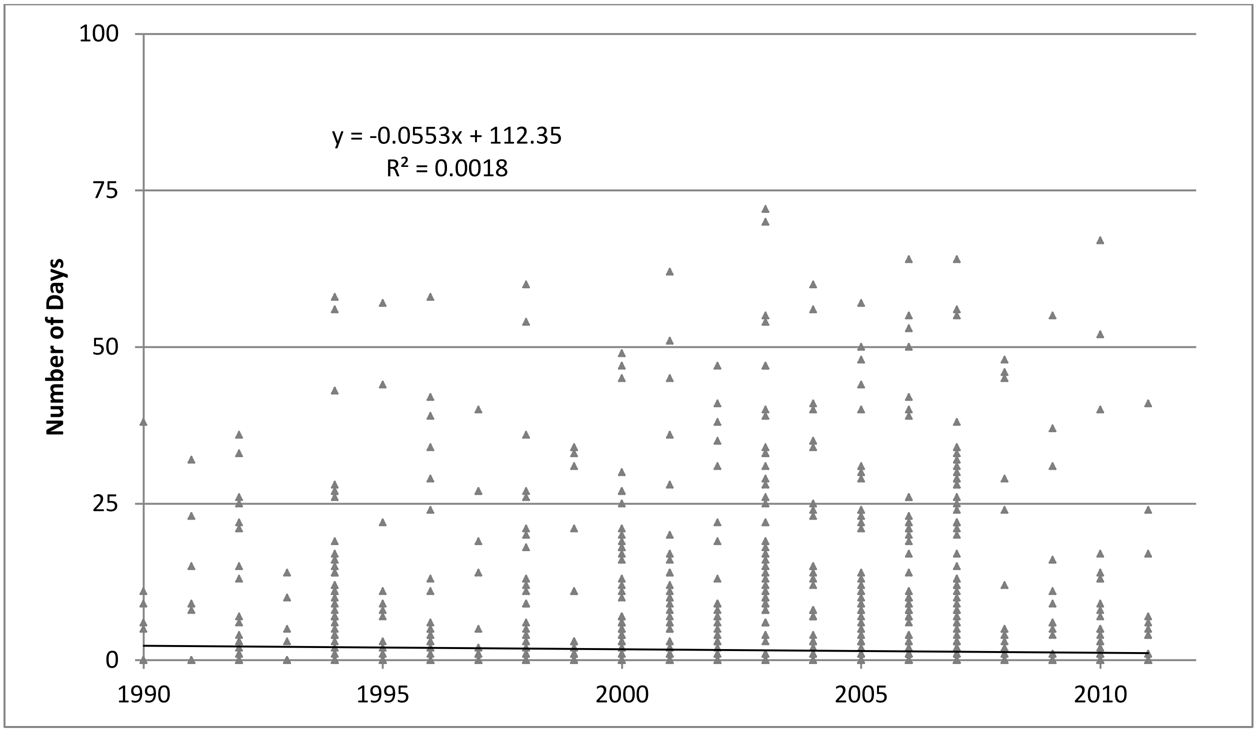

Figure 2-17. Number of days per year, per stream, when maximum daily maximum temperature exceeded 22 ºC for streams on the Nez Perce–Clearwater National Forests, 1990–2011

Table 2-12. Averages of number of days of occurrence per year of stream temperature metrics for streams monitored on the Nez Perce–Clearwater National Forests, 1990–2013

Year	Number of Streams Monitored	Average Number of Days/year Maximum Daily Maximum Temperature >13 °C	Average Number of Days/year Maximum Daily Average Temperature >9 °C	Average Number of Days/year Maximum Weekly Maximum Temperature >13 °C	Average Number of Days/year Maximum Daily Maximum Temperature >22 °C	Average Number of Days/year Maximum Daily Average Temperature >19 °C
1990	22	39	56	38	3	1
1991	32	51	71	49	3	1
1992	53	57	77	56	4	2
1993	80	33	61	31	0	0
1994	149	55	74	53	4	4
1995	175	42	71	41	1	1
1996	139	39	60	37	2	2
1997	148	44	73	43	1	1
1998	247	59	75	57	2	2
1999	268	38	61	37	1	1
2000	245	51	72	49	2	2
2001	293	57	81	56	1	2
2002	309	41	68	40	1	1
2003	381	58	85	57	3	3
2004	336	49	84	50	2	2
2005	360	46	78	46	2	2
2006	357	53	86	53	2	2
2007	339	58	88	58	3	3
2008	328	29	62	28	1	1
2009	286	44	83	44	1	1
2010	295	39	83	38	1	1
2011	279	30	60	29	0	0
2012	48	53	85	53	0	1
2013	8	0	0	0	0	0
Annual Average	**216**	**46**	**76**	**46**	**2**	**2**

Instream Sediment Load

Coarse sediment, which adversely affects salmonid spawning, has degraded water quality in many of the managed basins (e.g., South Fork Clearwater River, cited in the SFCW subbasin assessment and TMDL) (Dechert and Woodruff 2003). Nonpoint sediment sources are mainly agricultural and grazing areas (10–30 times natural background) and forested areas (2 times natural background) (Dechert and Woodruff 2003). Point sources of sediment include municipal wastewater treatment plants, suction dredge mining, and construction and industrial stormwater runoff. Numerous restoration projects have been implemented to address this issue (e.g., road decommissioning, culvert replacement). In addition, Forest-wide

BMPs were designed and implemented to reduce the management-related sediment delivery to streams (e.g., resurfacing roads, minimizing prescribed fire and vegetation treatments within riparian habitat conservation areas [RHCAs]).

Evaluating sediment transport at the larger basin scale (4th level HUC), the USGS (Clarke et al. 2013) determined that the sediment rating curves for the Clearwater River at Spalding, Idaho, indicate that the relationship between streamflow and total suspended sediment load has not changed very much (and is not statistically significantly different) between the 2 collection periods (1972–79 and 2008–11). This relationship is the same for both the sand and fine sediment loads at the same location. An increase was noted in the sand and fine sediment loads being delivered to the Lower Granite Reservoir from the Snake River (Figure 2-18 and Figure 2-19). The authors stated that,

> …*the increase in the suspended-sand load noted in the Snake River near Anatone probably is attributable to the Salmon River. A century of fire suppression and other forest-management practices resulted in an increase in the number and severity of forest fires in central Idaho during the last quarter of the 20th century (Burton, 2005* [cited in Clark, et al., 2013]*) and the first decade of the 21st century. The effect of wild fires on sediment mobility can be particularly dramatic in the Salmon River Basin and other areas of central Idaho where disturbance of steep drainage basins with highly erosive soils can mobilize large quantities of sand and gravel to streams* (King et al. 2004, cited in Clark et al. 2013).

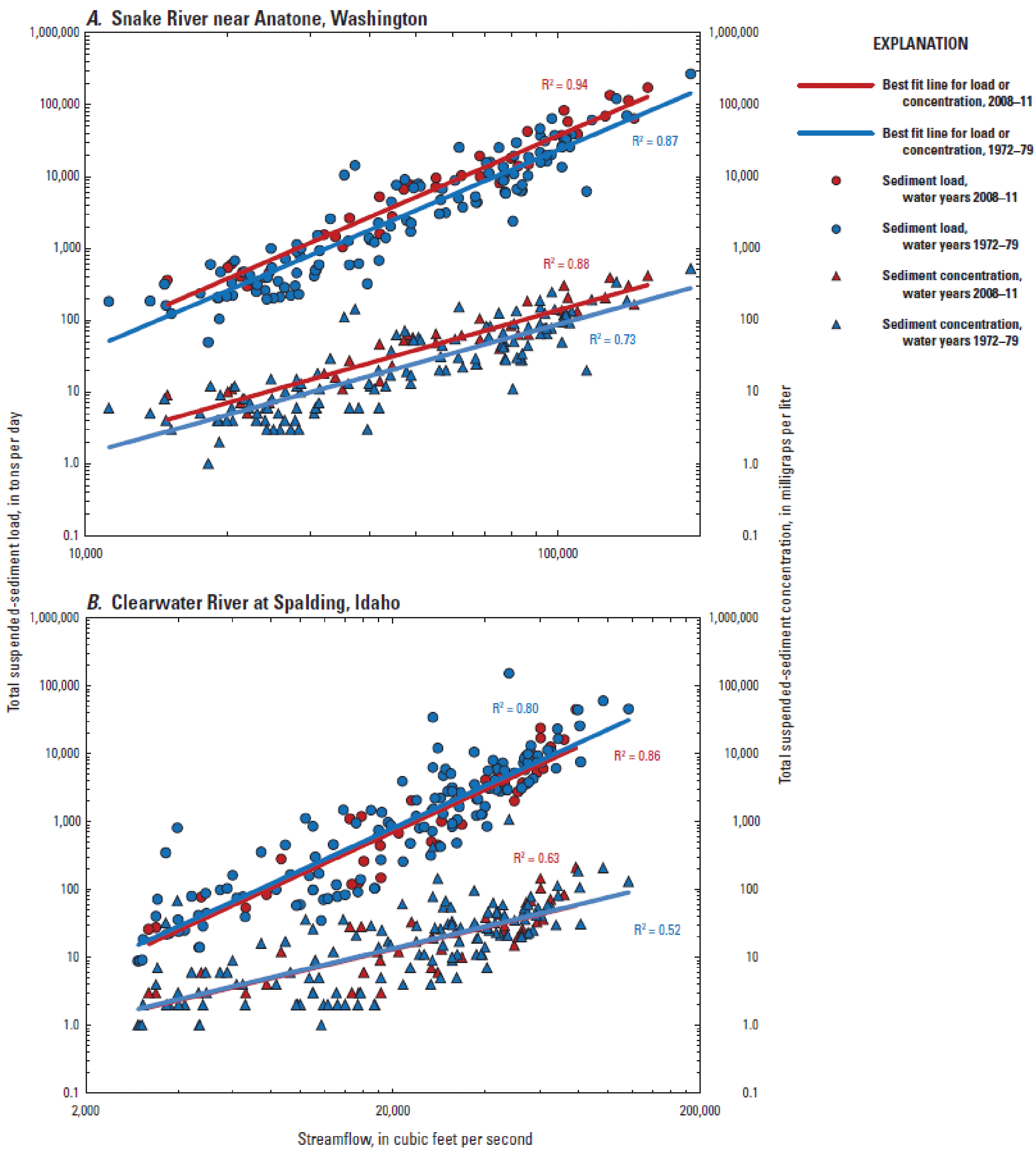

Figure 2-18. Suspended-sediment transport curves for concentrations and loads in the (A) Snake River near Anatone, Washington, and (B) Clearwater River at Spalding, Idaho, for data collected during water years 1972–79 and 2008–11. Source: Clark et al. 2013.

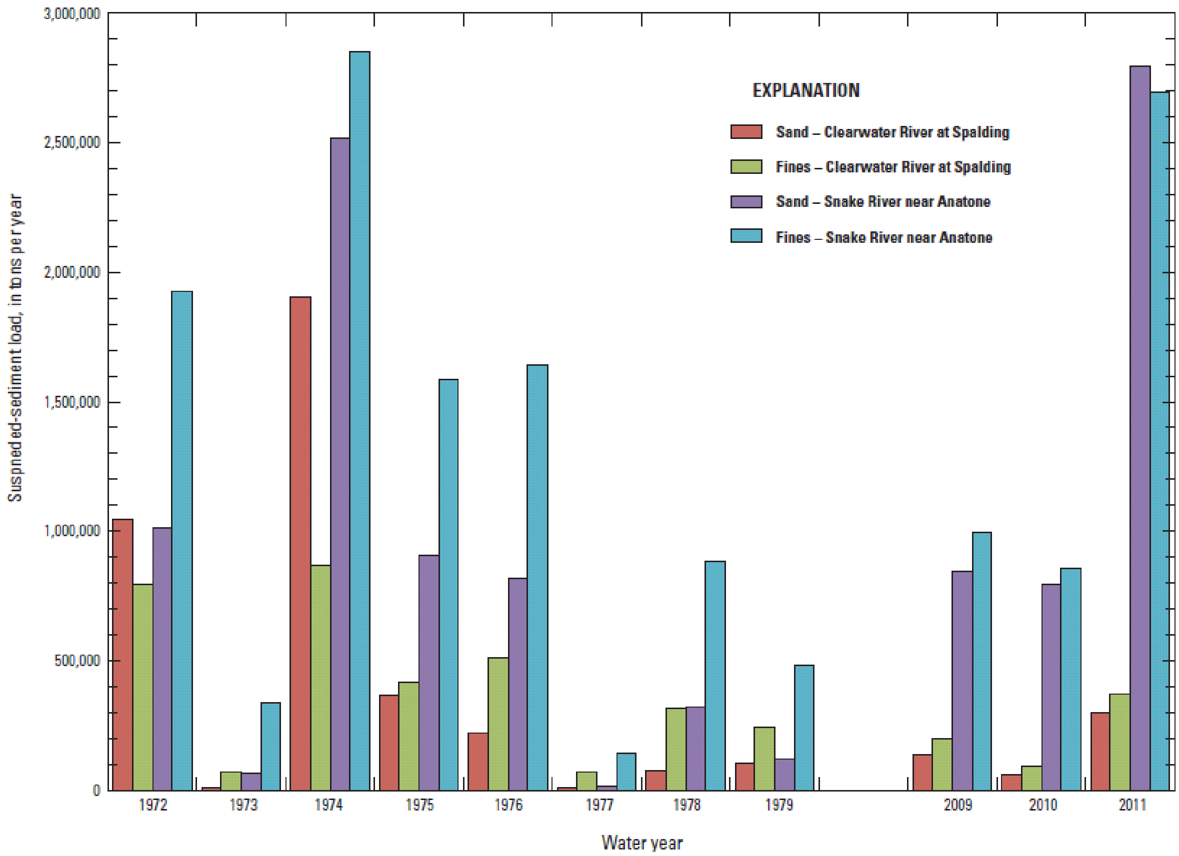

Figure 2-19. Estimated annual suspended sand and fine loads, Snake River near Anatone, Washington, and Clearwater River at Spalding, Idaho, water years 1972–79 and 2009–11. Source: Clark et al. 2013.

A comparison of data from 1972–79 and 2008–11 indicated a decrease in bedload in the Clearwater River at Spalding (Figure 2-20). The mean bedload during 1972–79, based on 78 samples collected at the Spalding station, was about 120 tons/day, ranging from <1.0 ton/day to about 3,700 tons/day. Bedload in the Clearwater River during 1972–79 was markedly larger (mean of about 2.2 times) at roughly equivalent stream discharge. Jones and Seitz (1980) [cited in Clark et al. 2013] reported that during 1972–79, bedload comprised about 4% of the total sediment load in the Clearwater River, a percentage similar to data from the Snake River. The 2008–11 data indicate that bedload was <1% of the sediment load in the Clearwater River at Spalding. The relation between streamflow and bedload was better (higher r^2) for the Clearwater River than for the Snake River, for both sampling periods (Figure 2-20).

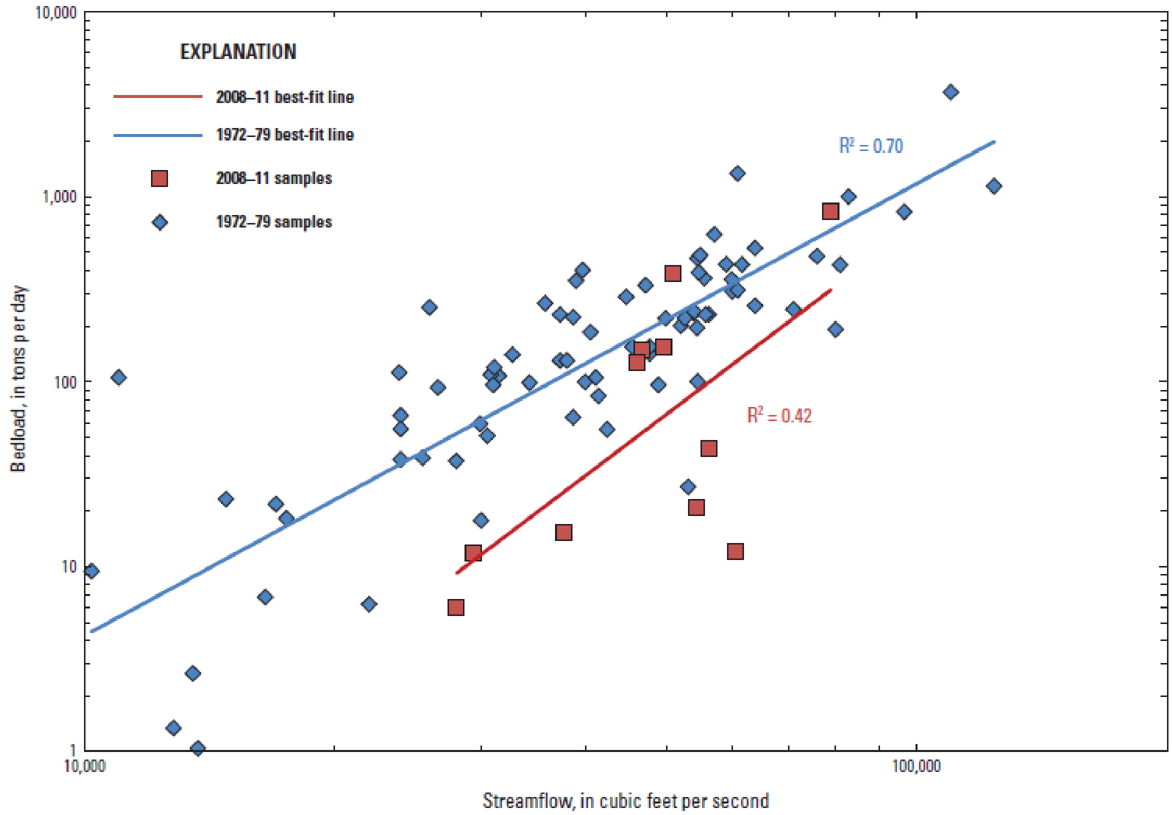

Figure 2-20. Bedload transport curves comparing data collected at the Clearwater River at Spalding, Idaho, water years 1972–79 and 2008–11. Source: Clark et al. 2013.

Data collected during this study indicated that the TSS and suspended fines concentrations in the Clearwater River during 1972–79 were not significantly different from the concentrations during 2008–11. However, the concentrations of suspended sand in the Clearwater River were significantly larger during 2008–11. The increase in the sand load in the Clearwater River may be attributable to forest fire activity in areas of the basin with highly erodible soils.

Forty stream gauging stations on the Nez Perce–Clearwater National Forests operated periodically between 1980 and 2013. To date, no analysis of trends for individual stations has been completed.

Trends of Groundwater and Groundwater-dependent Ecosystems

Very little is known about the trends of groundwater-dependent ecosystems across the Forests.

2.3.2.3 Resource-specific Information

The Forests to Faucets project uses a GIS to model and map the land areas across the United States that are most important to surface drinking water sources; the project also uses GIS to identify forested areas important to the protection of drinking water and areas where the quantity and quality of drinking water supplies might be threatened by development, insects and diseases, and wildland fire (Weidner and Todd 2011). The project is centered on 3 core objectives:

- Assess subwatersheds across the United States to identify those most important to surface drinking water.
- Identify forested areas that protect drinking water in these subwatersheds.
- Identify forested areas where future increases in housing density, insects and disease, and wildland fire may threaten surface drinking water quality and quantity in the future.

The results of the GIS modeling indicate that the Nez Perce–Clearwater National Forests have moderate importance for delivery of drinking water from surface waters originating on the Forests (Figure 2-21). Weidner and Todd (2011) also indicated that lands within the Nez Perce–Clearwater National Forests have minimal threats from development, moderate to high threats from insects and disease, and moderate to high threats from wildfire.

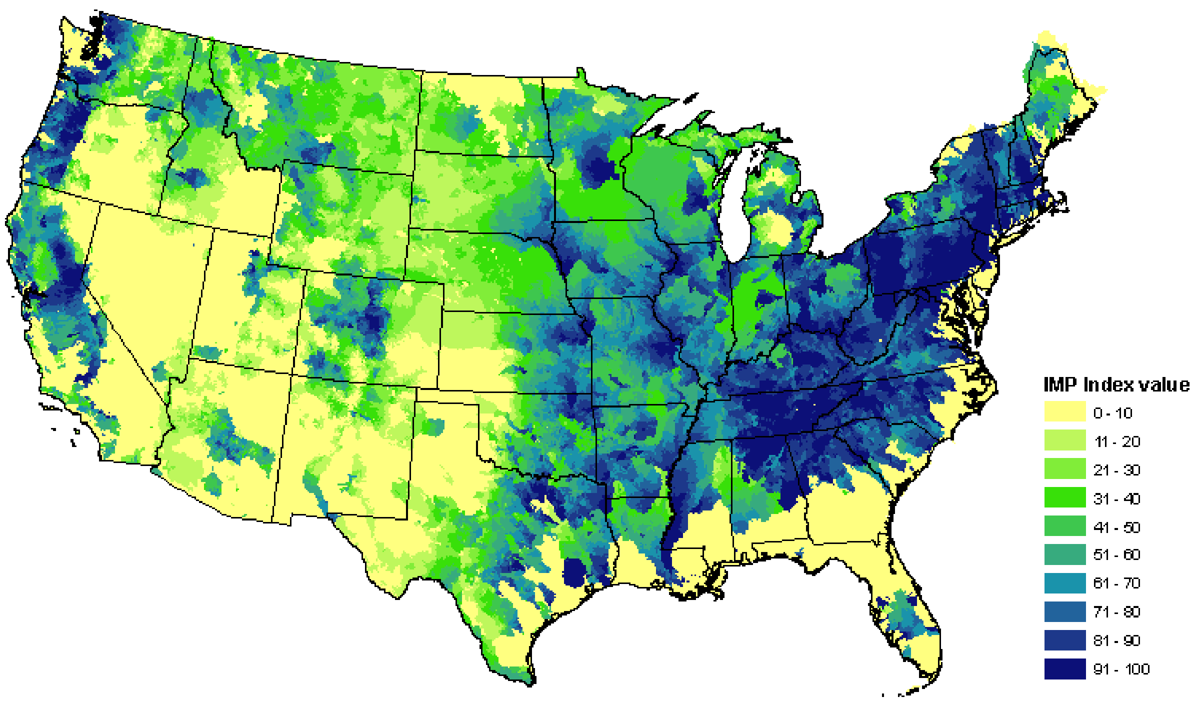

Figure 2-21. Surface drinking water importance index. Source: Figure 7 in Weidner and Todd (2011).

Municipal Watersheds

Water withdrawals on the Forests are primarily for municipal water supplies and domestic drinking water. Direction for management of National Forest System watersheds that supply municipal water is provided in 36 CFR 251.9 and Forest Service Manual 2542. The Forest

Service is directed to manage watershed lands for multiple uses while recognizing domestic supply needs. Municipalities may apply to the Forest Service if they desire protective actions or restrictive measures not specified in the Forest Plan. Formal written agreements to ensure protection of water supplies may be appropriate when multiple use management fails to meet the needs of a water user. No formal written agreements exist on either the Nez Perce National Forest or the Clearwater National Forest for protecting municipal supplies. The Forests recognize the following municipal watersheds: City of Elk River, Clearwater Water District, and Elk City Water District.

City of Elk River

In 2003, the city of Elk River, Idaho, began diverting water from Elk Creek 0.25 miles downstream from the Forests boundary. Groundwater wells were the previous source of water. The water is treated by a slow sand filter and disinfection and delivered to approximately 100 connections. The Forest Service manages 79% of the watershed above the intake. The USFS-maintained stream gage located 1/8 mile upstream of the City’s water supply intake has discharge and suspended sediment records.

Clearwater Water District

The town of Clearwater diverts water (via a concrete dam in Wall Creek on the Nez Perce National Forest) into a holding tank with a special use permit for the intake. The water is treated with a direct-pressure mixed-media filter and chlorine. This water is provided to 96 households. The Forest Service manages 100% of the watershed above the intake. The Source Water Assessment done by the IDEQ PWS#2250011 listed 2 potential contaminant sites, both related to mine prospects.

Elk City Water District

The town of Elk City diverts water from Big Elk Creek downstream from the Forests boundary. About 100 connections are provided by the Elk City Water District. The Forest Service manages the majority of the watershed above the intake. The Source Water Assessment done by the IDEQ PWS#2250017 listed several potential contaminant sources related to mine prospects and a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site.

The downstream communities of Kamiah, Orofino, Lewiston, Juliaetta, Konkolville, and Orofino Riverside also derive their domestic water supply directly from the surface water originating within the Forests. The city of Kamiah derives its drinking water from the Clearwater River and its drainage basin. The primary water quality issue currently facing the city of Kamiah is the threat of a potential contaminant spill into the Clearwater River or its tributaries, and the problems associated with managing contamination if it occurs. According to Idaho State’s Source Water Assessment database[5], the Kamiah surface water intake has not recently encountered water quality problems. However, because of the vulnerability of the shallow, poorly screened water intake, Kamiah’s drinking water system has a high risk of contamination. The prospect of contamination caused by a spill into the Clearwater River or

[5] http://www.deq.idaho.gov/water/swaOnline/

its tributaries is more pronounced due to the close proximity of U.S. Highway 12, a major route for commercial traffic, including tanker trucks.

Water Rights Withdrawals

Both consumptive and nonconsumptive water rights issues are currently being addressed with legal mechanisms. Water rights for National Forest purposes are claimed under State water law and federal reserved water rights doctrine (Table 2-13). Historic claims, consumptive and nonconsumptive, are being processed under the Snake River Basin Adjudication; once processed and approved, the water rights are decreed. Consumptive claims are mostly filed under State water law, with the exception of certain reserved claims for administrative purposes. Non-consumptive claims include reserved rights for Wild and Scenic Rivers. Non-reserved instream flow claims are being processed through the State comprehensive water planning process and the Nez Perce Tribal Settlement Agreement under the Snake River Basin Adjudication. Instream flows for resource protection are also included as conditions in special use permits.

A "statutory claim" is a statement that was filed with IDWR to make a record of an existing beneficial use right. In 1978, a statute was enacted requiring persons with beneficial use rights (other than water rights used solely for domestic purposes as defined above) to record their water rights with IDWR. The purpose of the statute was to provide some means to make records of water rights for which there were previously no records. However, these records are merely affidavits of the water users, and do not result in a license, decree, or other confirmation of the water right. “Adjudication” is a court action for the determination of existing water rights, which results in a decree that confirms and defines each water right. “Licensed” water rights are permits issued by IDWR allowing the use of water.

Table 2-13. Number of water rights and claims by type

Owner	Decreed Water Rights	Statutory Claims	Licensed Water Uses	Total
Federal Government	775	136	7	918
All Others	86	75	144	305

Drinking Water/Domestic Uses

In addition to community surface water supply, groundwater drinking water sources exist for 34 campgrounds and ranger stations within the Forests’ boundaries. More than 233 individual groundwater wells, springs, and streams in or near the Forests provide domestic water to households and ranches via wells, diversions, and spring sources. Resource management has the potential to influence drinking water quality and quantity for many users.

The State of Idaho has completed a source water assessment for each of the 35 public water systems on the Forests. These assessment reports include information on the potential contaminant threats to specific public drinking water sources, the likelihood that the water supply will become contaminated, and suggested management planning actions for communities and landowners. Community or use groups develop a written plan to document drinking water protection activities at the intakes and within the appropriate source areas.

Natural Range of Variation

A very detailed description of local climate and water resources is summarized in the following excerpt from the *Clearwater River Subbasin (ID) Climate Change Adaptation Plan* (Clark and Harris 2011):

> *Climate throughout most of the Clearwater River Subbasin is strongly influenced by warm, moist maritime air masses from the Pacific, except for the southernmost and high elevation eastern portions of the subbasin, which experience colder conditions more typical of the northern Rocky Mountains (Bugosh 1999). A general increase in precipitation occurs from west to east across the subbasin, coincident with increasing elevation (Stapp et al. 1984). Mean annual precipitation ranges from 12 inches at the confluence of the Clearwater and Snake Rivers to as high as 60 to 85 inches in the Bitterroot Mountains on the Selway-Bitterroot Divide. Due to colder average temperatures, winter precipitation above 4,000 feet falls largely as snow (McClelland et al. 1997). There is also a seasonal variability to precipitation patterns in the region, with very little precipitation occurring in the summer months. Average temperatures generally decrease as one moves from west to east in the subbasin, coinciding with increasing elevations.*
>
> *There is a large degree of variability in the hydrology [of the area], due to differences in the type of precipitation an area primarily receives (i.e., rain or snow). As noted before, precipitation generally increases from west to east through the subbasin, corresponding with increasing elevations. Peak flows generally occur in May and June, while base flows occur in the late summer months of August and September. The exact timing is quite variable, with the earliest peak flows occurring in the low elevation upland areas, and the latest peak flows occurring in the higher-elevation upland areas. Mainstem tributaries generally experience peak flows in May, however. In late winter and early spring, it is typical for rain to fall on frozen or snow covered ground under 4,000 feet elevation, often resulting in substantial peaks in the hydrograph during this period of time, while snowmelt in higher elevation regions is usually released more slowly over time.*

Flow Regimes

Flow regimes needed to sustain the biotic and abiotic integrity of aquatic ecosystems within the natural range of variation will be discussed in the aquatic section.

Future Patterns of Perturbation

A very detailed description of possible effects of climate on hydrologic processes is summarized in the following excerpt from the *Clearwater River Subbasin (ID) Climate Change Adaptation Plan* (Clark and Harris 2011):

> *Regional climate change scenarios project a significant decline in snowpack for the subbasin in the coming decades, with more winter precipitation falling as rain. This reduction in peak snow accumulation will have significant implications for regional hydrology, including more runoff in winter, earlier peak flows in spring, and reduced water availability in summer. Snowpack in higher-elevation areas could actually increase if overall precipitation increases, as is predicted. But since the area of high*

elevation is relatively small when placed in the context of the entire Clearwater River Subbasin, the total snow pack is still expected to decline.

In addition to affecting the amount of available water, climate change is also expected to reduce overall water quality, due to higher summer water temperatures and changes in the timing, intensity and duration of precipitation events. Higher temperatures can lead to reduced dissolved oxygen levels, which can have a detrimental effect on aquatic organisms. Water temperature controls the physiology, behavior, distribution, and survival of freshwater organisms, and even slight temperature changes can affect these functions (Elliot 1994). A possible increase in frequency and intensity of rainfall during fall and winter months could produce more overall pollution and sedimentation entering waterways, as well as an increased possibility of flooding in winter and early spring.

Because of their shallow water depth, wetlands are especially susceptible to the effects of higher summer temperatures, earlier runoff and lower stream flows that are predicted for this region as a result of climate change. If an increased number of wetlands dry out annually, the substantial benefits they provide to the watershed will be lost and the effects of climate change on those drainages may be compounded.

Effects of Land Use, Projects, and Activities

A large volume of scientific research discussing the effects of land management activities on hydrologic processes and water resources is available (Conroy 2005). Two primary methods exist for evaluating the effects of land management activities on hydrologic processes: direct and indirect. Direct methods are monitored for compliance, implementation, and effectiveness. Each of these components provides information on the effects that have already occurred from land management activities; comparable future activities can be assumed to have similar results. For example, monitoring data indicate the following:

- Decommissioning roads, especially those adjacent to streams, reduces sediment delivered to streams.
- Increasing culvert capacity or removing culverts from stream crossings improves free passage of water, sediment, and woody debris.
- Wildfire, timber harvest, and road building increase sediment delivery to streams.

Because the Forest Service manages such a large land base, having monitoring data for every type of project in every type of land system is very difficult. Therefore, hydrologists commonly use predictive models to evaluate the effects of land management activities. The most common parameters modeled are those that directly affect water resources after land management activities have occurred. The following parameters are commonly used by the Forests to evaluate the effects of management activities:

- Stream temperature
- Surface sediment erosion
- Sediment transport/deposition
- Rainfall/runoff and water yield
- Climate change

Numerous models are available for evaluating each of these parameters (Conroy 2005); each model has its own merits, specifications, and uses. No model or set of models can definitively determine the expected effects of land management activities.

Factors influencing changes and trends of peak streamflow rates

A tenet of watershed hydrology is that streamflow can be altered by manipulating the composition of vegetation in a watershed (Dunne and Leopold 1978). Manipulations include timber harvesting, insect/disease mortality, fire, or landslides. Two primary mechanisms for altering flows exist: reduced evapotranspiration rates following vegetation removal, and altered rates and patterns of snow accumulation and melt (Grant et al. 2008). The professional literature is rife with research on the effects of forest management activities on streamflows. The following are some generalizations about the relationship between management activities and streamflows:

- The largest peak flow increases reported were for small storms with recurrence intervals of much less than 1 year. Peak flow increases of as much as 90% over the control were reported for these small events (Grant et al. 2008, p. 30).
- Increases in peak flow diminish with increasing storm magnitude. The trend appears to be roughly an exponential decrease and was modeled as such, in both experimental watershed studies and modeling studies and from the site to large basin scale (Grant et al. 2008, p. 30).
- Peak flow increases generally approach the 10% detection limit (minimum detectable change in flow) at recurrence intervals less than 6 years (Grant et al. 2008, p. 30). The field and analytical methods represented by these studies do not provide evidence that forest harvest increases peak flows for storms with recurrence intervals longer than 6 years (Grant et al. 2008, p. 30). This interpretation is consistent with hydrologic theory that predicts diminishing effect of forest harvest with both increasing flow magnitude (Leopold 1980, cited in Grant et al. 2008) and decreasing harvest intensity (Grant et al. 2008, p. 31).
- The largest percentage increases in peak flows (with the exception of those following severe wildfire events) are expressed at 100% harvested (clearcut); this is true for all hydrologic zones (Figure 2-22). Zero percent change or no significant change in peak flow is reported from 25% to 100% harvested in both the rain and transient zones, and from 9% to 50% harvested in the snow zone. Increases in peak flow range from 0% to 40% in the rain and transient zones, and from 0% to 50% in the snow zone. In all 3 zones, averages and standard deviations of reported increases, a conservative estimate of mean percentage change in peak flow, support the general trend of smaller changes in peak flows with lower levels of harvest (Grant et al. 2008. p. 31).
- Percentage increases are greater for fall storms (Beschta et al. 2000; Jones and Grant 1996; Thomas and Megahan 1998 [all cited in Grant et al. 2008]) than for winter wet-mantle floods or spring snowmelt floods.
- The most consistent mechanism for producing peak flow changes appears to be related to reduced evapotranspiration following harvest, which results in higher soil moisture levels, hence increased runoff during early fall storms (Grant et al. 2008, p. 32).
- Percentage change in peak flow generally decreases with time after harvest (Jones 2000; Jones and Grant 1996; Thomas and Megahan 1998 [all cited in Grant et al.

2008]), likely due to rapid regrowth of vegetation (Grant et al. 2008, p. 33).

- The specific mechanisms that drive peak flow increases are likely to be sensitive to the scale of forest patches, in terms of their horizontal and vertical dimensions, and their distribution and contiguity. In particular, rain-on-snow processes at the stand level have been shown to vary with both forest stand age and patch size (Harr and Coffin 1992, cited in Grant et al. 2008).
- Strong evidence exists that patch size and orientation affect snow accumulation and melt processes in the snow zone (Storck et al. 2002; Troendle and King 1987; Winkler et al. 2005 [all cited in Grant et al. 2008]). Less evidence supports that patch age and size contribute to peak flow effects for watersheds in the rain zone (Grant et al. 2008, p. 33).
- In the rain zone, the maximum response line reaches the 10% detection limit at approximately 29% harvested (Figure 2-22). No data exist to support a resultant increase in peak flow if <29% of the watershed is harvested; in fact, the first detectable reported value occurs at 40% of the watershed area harvested (Grant et al. 2008, p. 34).
- Postfire flood events in the first few years after a fire may be 3–10+ times higher than would be expected in the same area prior to being burned (Elliot et al. 2010). In the Bitterroot Valley's Laird Creek, a convectional storm dropped 0.43 inches of rainfall in 30 minutes. This equates to a storm that can happen every 2–5 years, but the flow generated, bulked by sediment and debris, equated to a 200- to 500-year return interval (Parrett et al. 2003).
- Post wildfire annual water yield may increase if more than approximately 20% of a watershed is burned; runoff will generally occur earlier in the spring, compared to the years prior to the fire. Wetter years will have higher percentages of water yield increase than drier years (Elliot et al. 2010).
- For watersheds within the transient snow zone (TSZ), the maximum no-roads (watersheds with <2% of the area in roads) response line reaches the detection limit at approximately 15% harvested (Figure 2-23). The mean response line, which includes a few basins with roads, crosses the detection limit at a slightly higher value of 19% harvested (Grant et al. 2008, p. 34).
- The magnitude of any peak flow increase in response to forest management diminishes with increasing basin area for several reasons, including attenuation of flood peaks because of channel resistance, floodplain storage, and transmission losses, as well as effects of storm size and origin (Archer 1989; Garbrecht 1991; Shaman et al. 2004; Singh 1997 [all cited in Grant et al. 2008]). The magnitude of this effect differs from basin to basin and is affected by the location and timing of tributary inputs but can typically result in reductions in unit streamflows of 50% or greater (Woltemade and Potter 1994, cited in Grant et al. 2008).
- No hydrologic mechanism exists by which peak flow increases, when measured as a percentage change, can combine to yield a higher percentage increase in peak flows in a larger basin. As a consequence, the magnitude of peak flow increases for larger basins will necessarily be equal to or smaller than those reported for small watersheds (Grant et al. 2008, p. 37).

- To date, no field studies explicitly link peak flow increases with changes in channel morphology. Although extensive literature discusses forest harvest effects on stream channels, no known studies have demonstrated a direct correlation between peak flow changes attributed to forest harvest alone and changes to the physical structure of streams (Grant et al. 2008, p. 41). Moreover, the data suggest that peak flow effects on channels, if any, should be confined to a relatively discrete portion of the network where channel gradients are less than approximately 0.02% (Grant et al. 2008, p. 45).

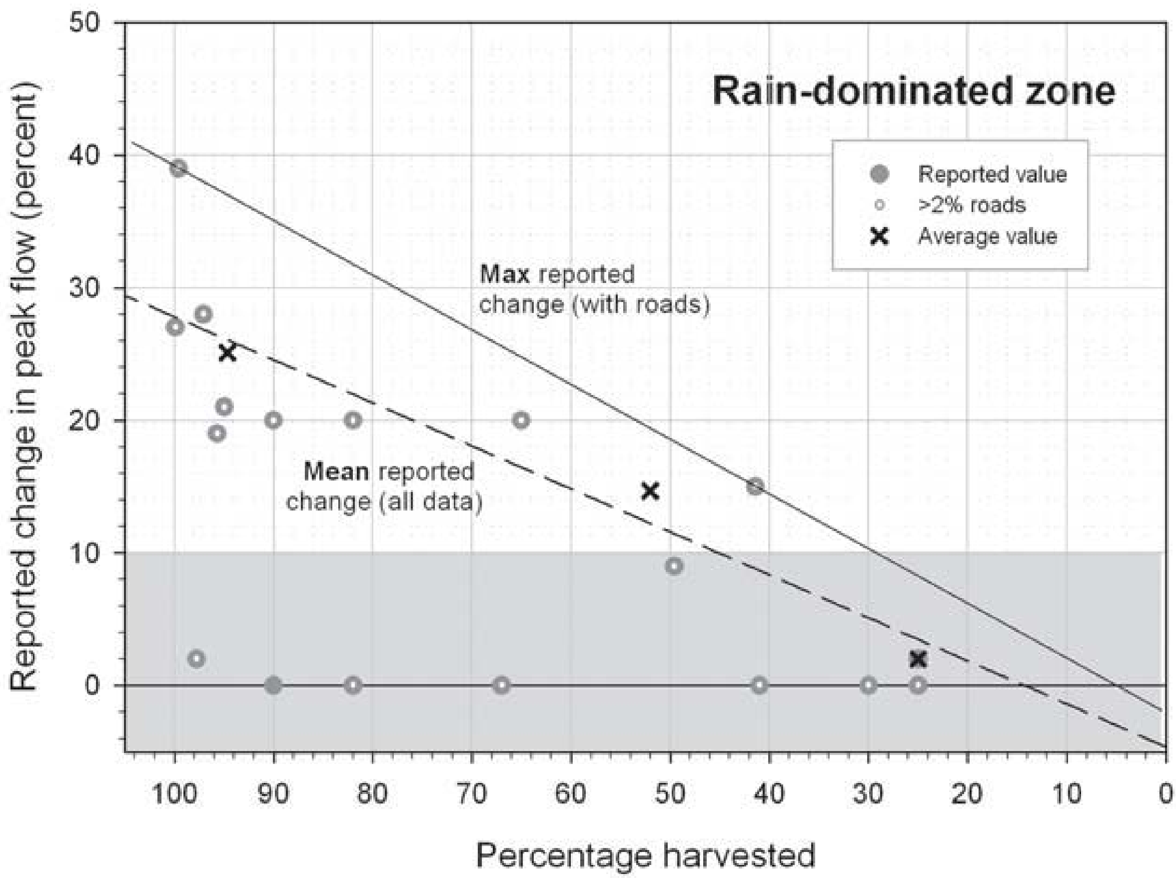

Figure 2-22. Peak flow response to harvest in the rain-dominated hydrologic zone. Solid line represents maximum values reported and includes the influence of roads. Dashed line is a linear fit through the average values from Figure 8c as cited in Grant et al. (2008, p. 29) and represents the mean reported change for all data. Gray shading around zero indicates limit of detection (±10%). Source:Figure 9 in Grant et al. (2008, p. 35).

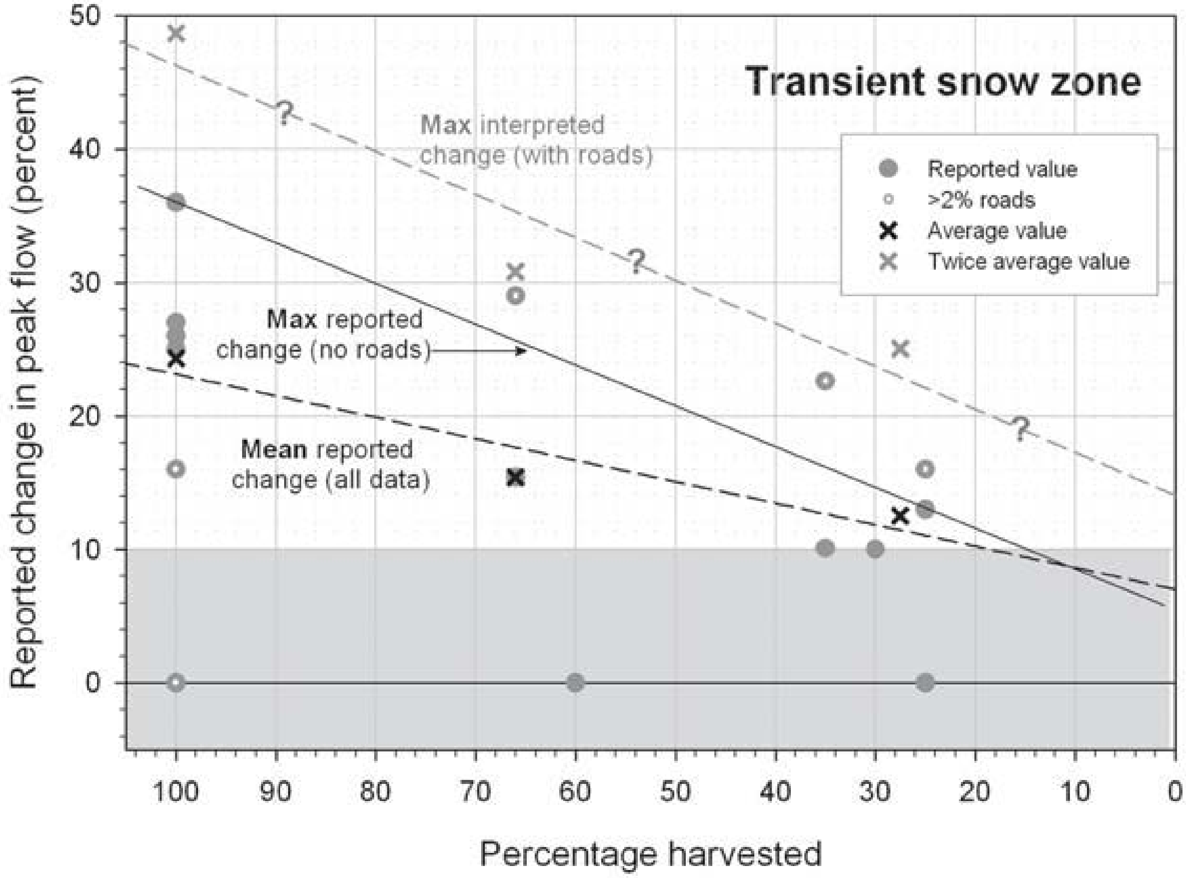

Figure 2-23. Peak flow response to harvest in the transient snow hydrologic zone. Solid line represents maximum values reported for basins without roads. Dashed black line is a linear fit through the average values from Figure 8d as cited in Grant et al. (2008, p. 29) and represents the mean reported change for all data. Dashed gray line represents interpreted change with roads and is a linear fit through a doubling of the average values. Gray shading around zero indicates limit of detection (±10%). Source: Figure 10 in Grant et al. (2008, p. 35).

2.3.3 *Information Needs*

A backlog of monitoring data needs to be entered into databases, summarized, and analyzed. Several types of monitoring data are available that would be useful for this analysis, including BMP effectiveness monitoring data, streamflow/sediment transport data, climate data, and stream temperature data.

The following GIS calculations and/or map products are needed:

- Summary of lengths of stream (by 6th field HUC) that are pollutant impaired (listed by pollutant)
- Summary of lengths of stream (by 6th field HUC) that are under existing TMDL implementation plans for restoration

Analysis needs include the following:

- Time series analysis of stream temperatures in streams with temperature TMDLs (as well as all other streams)
- Time series analysis of existing streamflow and sediment load data from FS gauge stations (correlating changes/differences with rainfall data)
- Summary of restoration projects (by 6^{th} field HUC)

2.3.4 ***Literature Cited***

Bugosh, N. 1999. Lochsa River subbasin assessment. Lewiston, ID: Idaho Division of Environmental Quality, Lewiston Regional Office.

Bugosh, N. 2000. Lower Selway River subbasin assessment. Lewiston, ID: Idaho Division of Environmental Quality, Lewiston Regional Office.

Clark, K., and J. Harris. 2011. Clearwater River subbasin (ID) climate change adaptation plan. Lapwai, ID: Nez Perce Tribe, Water Resources Division, Model Forestry Policy Program, Cumberland River Compact.

Clark, G. M., R. L. Fosness, and M. S. Wood. 2013. Sediment transport in the Lower Snake and Clearwater River Basins, Idaho and Washington, 2008–11. U.S. Geological Survey Scientific Investigations Report 2013-5083. 56 p.

Clearwater Soil and Water Conservation District (CSWCD). 2004. Lower North Fork Clearwater River subbasin TMDL implementation plan. Boise, ID: Idaho Department of Environmental Quality.

Conroy, W. J. 2005. A coupled upland-erosion, instream hydrodynamic-sediment transport model for assessing primary impacts of forest management practices on sediment yield and delivery. Doctoral Dissertation, Washington State University.

Dechert, T., and L. Woodruff. 2003. South Fork Clearwater River subbasin assessment and total maximum daily load. Lewiston, ID: IDEQ, Lewiston Regional Office; Boise, ID: U.S. Environmental Protection Agency.

Dunne, T., and L. B. Leapold. 1978. Water in environmental planning. W.H. Freeman, Inc. 818 p.

Elliot, W. J., I. S. Miller, and L. Audin, Eds. 2010. Cumulative watershed effects of fuel management in the western United States. RMRS-GTR-231.

Goode, J. R., C. H. Luce, and J. M. Buffington. 2011. Enhanced sediment delivery in a changing climate in semi-arid mountain basins. Implications for water resource management and aquatic habitat in the northern Rocky Mountains. Boise, ID: U.S. Forest Service, Rocky Mountain Research Station, Submitted for publication in *Geomorphology*.

Grant, G. E., S. L. Lewis, F. J. Swanson, J. H. Cissel, and J. J. McDonnell. 2008. Effects of forest practices on peak flows and consequent channel response: A state-of-science report for western Oregon and Washington. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Gen. Tech. Rep. PNW-GTR-760. 76 p.

Ground Water Quality Council. 1996. Idaho groundwater plan: Protecting groundwater quality in Idaho. Boise, ID: Idaho Department of Health and Welfare, Division of Environmental Quality; Department of Water resources; and Department of Agriculture.

Henderson, R. D. 2002. Lower North Fork Clearwater River subbasin assessment and total maximum daily load. Lewiston, ID: IDEQ, Lewiston Regional Office.

Henderson, R. D. 2005. Palouse River Tributaries subbasin assessment and TMDL. Lewiston, ID: IDEQ, Lewiston Regional Office.

Hortness, J. E., and C. Berenbrock. 2001. Estimating monthly and annual streamflow statistics at ungaged sites in Idaho. Water-Resources Investigations Report, 01-4093.

Idaho Department of Environmental Quality (IDEQ) and Idaho Soil Conservation Commission (ISCC). 2008. Camas Prairie nitrate priority area groundwater quality management plan. Lewiston, ID: IDEQ, Lewiston Regional Office; and ISCC, Lewis Soil Conservation District.

Idaho Department of Environmental Quality (IDEQ). 2001a. Big Eddy Marina, Clearwater County, Idaho (PWS #2180007) source water assessment report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001b. City of Orofino (surface water) (PWS #2180024) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001c. Clearwater Water District (surface water) (PWS #2250011) source water assessment report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001d. Dworshak Power House, Clearwater County, Idaho (PWS #2180009) source water assessment report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001e. Freeman Creek Campground, Clearwater County, Idaho (PWS #2180010) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001f. Konkolville (surface water) (PWS #2180019) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001g. Lochsa Lodge (PWS #2250035) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001h. Middle Salmon River–Panther Creek subbasin assessment and TMDL. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001i. USFS Kelly Forks Work Center (PWS #2180046) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001j. USFS Musselshell Work Center (PWS #2180047) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001k. USFS Slate Creek Ranger Station (PWS #2250105) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001l. USFS, Canyon Work Center (PWS #2180041) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001m. Riverside Independent Water District (surface water) (PWS #2180032) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001n. USFS Powell Campground (PWS #2250052) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2001o. City of Julietta (surface water) (PWS #2290018) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002a. City of Kamiah (surface water) (PWS #2310003) source water assessment report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002b. City of Lewiston (surface water) (PWS #2350014) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002c. Elk City Water and Sewer Association (surface water) (PWS #2250017) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002d. USFS Castle Creek Work Center and Campgrounds (PWS #2250088) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002e. USFS Giant White Pine Campground (PWS #2290051) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002f. USFS Hazard Lake Campground (PWS #2250118) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002g. USFS Laird Park Campground (PWS #2290052) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002h. USFS Little Boulder Creek Campground (PWS #2290053) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002i. USFS Lochsa Historical Visitor and Work Camp (PWS #2250074) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002j. USFS Ohara Bar Campground (PWS #2250098) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002k. USFS Pittsburg Landing Campground (PWS #2250111) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002l. USFS Red River Campground (PWS #2250101) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002m. USFS Wendover Campground (PWS #2250081) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002n. USFS Whitehouse Campground (PWS #2250082) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002o. USFS, Wilderness Gateway Campground (PWS #2250085) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2002p. USFW Dworshak National Fish Hatchery, Clearwater County, Idaho (PWS #2180035) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2003a. Upper North Fork Clearwater River subbasin assessment and total maximum daily loads. Lewiston, ID: IDEQ, Lewiston Regional Office.

Idaho Department of Environmental Quality (IDEQ). 2003b. USFS Fenn Ranger Station and YCC Camp (PWS #2250091) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2003c. USFS Red River Ranger Station (PWS #2250102) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2005. City of Elk River (PWS #2180013) source water assessment final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2006. Little Salmon River TMDL. Boise, ID: IDEQ, Boise Regional Office.

Idaho Department of Environmental Quality (IDEQ). 2007a. 2004 interagency forest practices water quality audit. Final report. Boise, ID: IDEQ.

Idaho Department of Environmental Quality (IDEQ). 2007b. South Fork Palouse River watershed assessment and TMDLs. Lewiston, ID: IDEQ, Lewiston Regional Office.

Idaho Department of Environmental Quality (IDEQ). 2007c. Upper Hangman Creek subbasin assessment and total maximum daily load. Lewiston, ID: IDEQ, Lewiston Regional Office.

Idaho Department of Environmental Quality (IDEQ). 2008. Potlatch River subbasin assessment and TMDLs. Lewiston, ID: IDEQ, Lewiston Regional Office.

Idaho Department of Environmental Quality (IDEQ). 2010. Lower Salmon River and Hells Canyon tributaries assessments and TMDLs. Lewiston, ID: IDEQ, Lewiston Regional Office.

Idaho Department of Environmental Quality (IDEQ). 2011. Idaho’s 2010 integrated report. Final. Boise, ID: IDEQ.

Idaho Division of Environmental Quality (IDEQ), Nez Perce Tribe (NPT), and Environmental Protection Agency (EPA). 2000. Cottonwood Creek total maximum daily load. Lewiston, ID: IDEQ, Lewiston Regional Office.

Idaho Department of Environmental Quality and Oregon Department of Environmental Quality (IDEQ and ODEQ). 2004. Snake River–Hells Canyon total maximum daily load. Boise, ID: IDEQ, Boise Regional Office; Pendleton, OR: Oregon Department of Environmental Quality, Pendleton Office.

Idaho Soil Conservation Commission (ISCC). 2010. Potlatch River subbasin total maximum daily load implementation plan for agriculture. Boise, ID: Idaho Department of Environmental Quality.

Lichthardt, J. 2004. Conservation strategy for Idaho Panhandle Peatlands. Idaho Conservation Data Center, Idaho Department of Fish and Game, Report prepared for the Idaho Panhandle National Forests. 50 p.

Little Salmon Water Advisory Group. 2008. Little Salmon River total maximum daily load implementation plan for agriculture, forestry, and urban/suburban activities. Boise, ID: Idaho Department of Environmental Quality.

Luce, C. H., and Z. A. Holden. 2009. Declining annual streamflow distributions in the Pacific Northwest United States, 1948–2006. Geophysical Research Letters, Vol. 36.

Parrett, C., S. Cannon, and K. L. Pierce. 2003. Wildfire-related floods and debris flows in Montana in 2000 and 2001. USGS Water-Resources Investigations Report 03-4319.

Rieman, B., and D. Isaak. 2010. Climate change, aquatic ecosystems and fisheries in the Rocky Mountain West: Implications and alternatives for management. Fort Collins, Colorado: USDA Forest Service, GTR-RMRS-250.

Shumar, M. 2002. Middle Salmon River-Chamberlain Creek subbasin assessment and Crooked Creek total maximum daily load. Boise, ID: Idaho Department of Environmental Quality, State Technical Office.

Norman, G. R., and D. L. Streiner. 1986. PDQ Statistics. B. C. Decker, Inc. Philadelphia, PA. 172 p.

South Fork Clearwater River Watershed Advisory Group. 2006. South Fork Clearwater River TMDL implementation plan. Boise, ID: Idaho Department of Environmental Quality.

United States Forest Service (USFS). 2007. Technical guide to managing ground water resources. Gen. Tech. Rep. FS-881.

U.S. Interagency Advisory Committee on Water Data (USIACWD). 1982. Guidelines for determining flood flow frequency, Bulletin 17-B of the Hydrology Subcommittee: Reston, Virginia: U.S. Geological Survey, Office of Water Data Coordination. 183 p.

Weidner, E., and A. Todd. 2011. From the forest to the faucet: Drinking water and forests in the US. Methods Paper. USDA, Forest Service, State and Private Forestry, Ecosystem Services & Markets Program Area.